

MAKING POLICY IN A CHANGING WORLD

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COWLES FOUNDATION PAPER NO. 1011



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2001

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Making Policy in a Changing World

The era that is the subject of this conference begins and ends with decades of outstanding U.S. economic performance. In both the 1960s and 1990s, the economy surpassed what seemed achievable in light of what had come before. The long expansion of the 1960s was preceded by an era of frequent recessions and, before that, the Great Depression that ended only with World War II. It ended with a rise in inflation that accompanied the Vietnam War. That inflation was exacerbated by the supply shocks of the 1970s and was finally subdued by historically high interest rates and the massive recessions that they brought on at the start of the 1980s. The subsequent recovery and expansion lasted seven years, but business capital formation and productivity growth remained slow by historical standards and estimates of attainable unemployment rates drifted higher. The expansion of the 1990s thus began with inflation under control but with disappointing prospects for how fast the economy could grow and how far unemployment could be reduced.

The widely varying performance of the economy during different periods over the the past fifty years reflects a combination of special shocks, possible changes in macroeconomic relations confronting policymakers, and differing policy reactions. However, many econometricians have char-

acterized the entire period as one in which stable parameters relate the twin policy concerns of inflation and unemployment. In this paper, we describe why conventional analysis overstates the stability of this relation and identify ways in which it has changed. We attempt to characterize those changes, examine how policymakers were reacting, and provide some general observations on making policy when key relations vary.

An Episodic Overview

The combination of growth, unemployment, and price stability achieved in the closing years of the century has been remarkable. Beginning from what was widely judged to be a mature stage of recovery from the early 1990s recession, the economy re-accelerated after mid-1995 and expanded at a 4 percent annual rate over the rest of the decade. This strong growth in output reduced unemployment to 4 percent and was accompanied by sustained low rates of core inflation. However one explains this economic performance, the willingness of the Federal Reserve, under the leadership of Alan Greenspan, to let the unemployment rate decline below 6 percent—which many observers had regarded as the lowest rate that would not lead to accelerating inflation—was critical to its achievement. The performance of the past few years has forced a reevaluation of the macroeconomic model that led to these predictions. It has required a reestimation of its parameters and has renewed doubts about the model as a description of the inflationary process.

This is hardly the first reevaluation driven by events. The unemployment rate had last gotten down to 4 percent during the 1960s, the decade that most closely rivals the 1990s for sustained economic growth and widespread prosperity. At that time, based on Arthur Okun's analysis of the postwar economy, an unemployment rate of roughly 4 percent had been estimated as the full employment target for policymakers.¹ The postwar period had been marked by frequent recessions, and avoiding them through active stabilization policy that targeted full employment was a principal goal of the incoming Kennedy administration. When, in the last years of that decade, the Vietnam War took precedence over stabilization policy, unemployment was pushed well below that target and inflation

1. See, for example, Arthur Okun's introduction to Okun (1972).

gradually rose. Furthermore, analysis of the changing demographics of the U.S. labor market showed that the full-employment unemployment rate had risen by the end of the decade and would rise further in the 1970s.²

With that amendment, the developments of the 1960s were roughly consistent with the predictions of the cyclical Phillips curve that had been estimated from postwar experience. Nonetheless, the resurgence in the classical concept of a natural unemployment rate that came from the Friedman and Phelps models and the emergence of the theory of rational expectations in the inflationary 1970s led to substantial changes in empirical modeling and in the focus of policymakers.³ Franco Modigliani and Lucas Papademos introduced the concept of the nonaccelerating inflation rate of unemployment, or NAIRU, which used adaptive expectations to modify the short-run Phillips curve in a way that gave it some features of the natural rate model.⁴ Robert Gordon and others have elaborated on this concept and provided estimates showing a relatively constant NAIRU throughout most of the postwar period.⁵

Skeptics have come from many quarters. Ray Fair and others disputed the accelerationist specification, finding the key elasticity between current and past inflation was less than one.⁶ Others questioned the validity of modeling expectations as adaptive. Many noted that the failure to observe ever-faster deflation when unemployment was persistently high cast doubt on both the theoretical natural rate models and the empirical NAIRU model, as has the evidence that wages rarely decline.⁷ And some objected to the idea of modeling inflation with a modified Phillips curve framework at all, stressing the fact that it is not a structural relationship but a relationship among endogenous variables, with a host of difficulties of identification and interpretation.

Despite these misgivings, the NAIRU model has continued to play a central role in policy discussions. Unemployment and inflation are central concerns of stabilization policy, and few deny that upward pressures on wages and prices are likely to occur as the economy approaches the limits of capacity. Policy discussions need a simple organizing framework incor-

2. See Perry (1970).

3. Friedman (1968); Phelps (1968).

4. Modigliani and Papademos (1975).

5. See, for example, Gordon (1998).

6. See, for example, Fair (2000).

7. See, for example, Akerlof, Dickens, and Perry (1996).

porating that idea, and the NAIRU model has filled that need. And until the last few years, such a model could explain U.S. experience starting with the 1970s reasonably well, once it allowed for exogenous price shocks and for some limited variation in the NAIRU.

In this paper, we examine the conduct of policy over the past four decades in light of what was known at the time about the inflation-unemployment relation and without assuming the confines of a NAIRU framework. We also provide empirical evidence of important changes in that relation and discuss how policymakers can best respond to the uncertainty inherent in such changes. Our evidence indicates that, during periods of low inflation, conventional estimates using the NAIRU framework do not provide reliable guidance for policymakers about how low an unemployment rate is sustainable.

Data and Decisionmaking

Policymakers and econometricians must always grapple with how much weight to attach to recent developments relative to historical regularities. It is our casual observation that good policymakers implicitly give more weight to recent developments than do most econometricians, though that assessment may be unduly influenced by the Federal Reserve's recent success. Statistical theory provides precise answers about confidence intervals, but only under strong assumptions about underlying processes. The believers in a model that has fit historically are likely to stick to their beliefs until the data speak clearly. Economists trained in classical statistics are accustomed to requiring odds of twenty to one against before rejecting their null hypothesis. In practice, the ruling paradigm itself becomes the null, and it is common to accept the parameters of a model as constant until a change in a parameter is statistically significant, with a *t*-statistic of two. But twenty to one are long odds for a policymaker, for whom the costs of following the model when it is wrong can be significant.

A formal Bayesian decision theoretic approach would avoid this difficulty by treating the parameters of the model as stochastic and using a loss function in the estimation process. In our analysis we do not model formal Bayesian decisionmaking, but we do explicitly allow for stochastic drift in crucial parameters. This allows us to illustrate the role that parameter uncertainty can play in both model-based and judgmental policymaking.

What We Knew and When

To illustrate the uncertainties that confront the policymaker, we examine the inflation-unemployment relation over the past forty years. Although focusing on this simple model is open to many objections, we believe it is a good framework within which to explore the central problem confronting policymakers. We want to allow for the possibility that this relation has changed over time and that policymakers have had to contend with signs of such change. We report three sets of estimates for the central parameters of price and wage equations. The first set is simply the time series of estimates from recursive least squares. While these estimates change as the sample of observations grows, by hypothesis the true parameters are constant—the same over all samples of different lengths. In practice, when the residuals become large or the coefficient estimates change markedly over a sample, it is common to test for a structural break. The implicit assumption built into this type of structural test is that change takes place at specific points in time rather than gradually. While this assumption may be appropriate for such events as changes in exchange rate regimes or dramatic monetary reforms, it seems quite implausible to us that changes in the wage and price processes and in their relationship to the labor market and unemployment shift in such a discontinuous and infrequent way. Rather, it seems more likely that changes would be spread over time and, within the framework of our model, better represented as stochastic drifts in the coefficients.

This leads us to estimate the wage and price relationships with a time-varying parameters model, making use of Kalman filters. Specifically we allow the intercept, the coefficient on current unemployment, and the sum of coefficients on past inflation (and, in the price equation, the coefficient on productivity) to vary over time. Each is allowed to follow a random walk, with a variance chosen to minimize forecast error in a manner described below. Allowing for time variation in this set of parameters is likely to change the estimates of other parameters in the model as well, even though these other parameters are assumed to be constant. While the assumption of a random walk cannot be literally true over long periods, we want to avoid the assumption that the parameters tend to return to some constant mean that would be implicit in assuming a stationary autoregressive process for the parameters. As will be seen, relatively small amounts of period-by-period variation in the coefficients are all that is needed to pro-

duce substantial movements in point estimates over five- or ten-year intervals.

The Kalman filter methodology provides two sets of estimates for the time-varying relationship. The first, which we call the contemporary filter estimates, are parameter estimates for each date that use only data available up to that date, just as the recursive least squares estimates do. Since we start the recursive least squares and time-varying estimates with the same initial values, these two sets of estimates are quite similar for a number of periods, diverging only after several years. By the end of the entire sample, however, they can be quite different. Recursive least squares and contemporary filter estimates are both available in real time to a policymaker.

The second set of time-varying parameter estimates, which we call backward estimates, take a historical view, using all of the data available up to the present. With the hindsight provided by the backward filter estimates, it is possible in some cases to see why the policymaker, not having the historian's advantage, may have gone wrong.

Estimating with Filters

For the reader unfamiliar with Kalman filters, it may be useful to give an informal explanation of how they work in our setting. In the contemporary estimation, the filter calculates the forecast error for the current period making use of the estimate of the coefficients from the previous period along with the current value of exogenous variables. By assumption, this forecast error is the sum of two errors: the "measurement" error in the equation relating the dependent variable—in our case, wages or prices—to the exogenous variables; and the error implied by using last period's estimates rather than the true coefficients for this period. In contemporary filter estimation, as in recursive least squares, there is estimation error in last period's estimates of last period's true coefficients. With time-varying coefficients there is an additional error arising from the innovations in the coefficients themselves. The contribution of these coefficient errors to the forecast error depends on the values of the corresponding exogenous variable. If the variable is "large," it contributes more to the forecast error than if it is small.⁸ The optimal allocation of the observed forecast error

8. This statement assumes that the covariances of coefficients across variables is zero. In general, the contribution depends on the entire variance-covariance matrix and the values of the other variables.

between measurement error and revised coefficient estimates depends on the relative variances and covariances of the coefficients, the values of the variables, and the variance of the measurement error. The filter does this optimization, updating the estimates of the coefficients and of the variances themselves. If the variances are normal, the updating is maximum likelihood. In our estimation we assume that the measurement error and innovations to the coefficients are independent.

At the end of the sample period, the contemporary estimates have utilized all of the information in the observed data, but the parameter estimates for earlier periods can be improved by utilizing the information that arrived later in the sample. The backward filter revises the contemporary estimates, starting at the end of the period and working backward. For each time period, t , the backward estimates are calculated by adjusting the contemporary estimates for t by a fraction of the difference between those estimates and the backward estimates for $t + 1$, both of which give unbiased estimates of the true parameters at time t . The weights depend on the relative variances of these two. Backward estimates are sometimes called "smoothed" estimates since, in the scalar case, fluctuations in the contemporary estimates will be dampened by this procedure.

Starting the Kaman filter requires initial estimates of the coefficients, the covariances of the coefficients, the covariances of the parameter innovations, and the measurement variance. If one is following a Bayesian approach, these are simply the priors one brings to the data. In practice, a variety of methods are used to choose these priors. In our case, we used the variance-covariance matrix from a least squares regression for the period 1948:1 to 1959:4 to provide the initial values for the coefficients' covariances. However, we used the point estimates from equations with fewer lags, setting the priors at zero for the omitted variables. Rather than specify a priori the magnitude of the variances of the innovations to the coefficients, we used a search procedure to find the magnitudes that minimized the mean squared forecast error over the entire sample, under the assumption that coefficient innovations are independent. The search procedure always started with zero values for the innovation variances, which would make the estimates the same as the recursive estimates. While choosing innovation variances by looking at the likelihood of the entire sample is appropriate for the historian, the use of these estimates in the contemporary filtering incorporates more information than would be available to a policymaker in real time.

Estimating the Productivity Trend

The trend rate of productivity change is potentially an important variable both for explaining price and wage developments and for informing policy deliberations. A faster rising productivity trend would permit faster real growth in the longer run and would make any target rate of price inflation consistent with faster wage growth. However, inferring the trend from actual productivity data is tricky. Quarterly changes in productivity are subject both to considerable measurement error and to systematic variation associated with cyclical and shorter-term fluctuations in the rate of economic expansion. Most attempts to estimate the trend in productivity from these data have fit trends across cyclical peaks, or regressed quarterly changes on cyclical variables and dummy variables to allow for changes in the trend where the data seemed to call for it. But the productivity trend is more likely to change gradually as innovations diffuse over different firms and parts of the economy.

To address this problem, we apply our time-varying methodology. We take as our estimate of the time-varying productivity trend the backward filter estimates from an equation explaining the quarterly change in the log of productivity with a time-varying constant and the change in the unemployment rate in the current and seven lagged quarters.

$$(1) \quad \Delta \ln(PR_t) = A_t + \sum a_i \Delta U_{it} + u_t,$$

where $A_t = A_{t-1} + e_t$, and u_t and e_t are i.i.d.

The productivity data are for the private nonfarm economy. For the period since the end of 1995, we adjusted these data to eliminate the part of the productivity change that came from changes in the measurement of prices.⁹

Figure 2-1 compares the changing trend from contemporary and backward filter estimates of equation 1 and the trends recently estimated by Gordon.¹⁰ The recursive trends become less meaningful in the last half of the period since, by then, the slowdown in productivity growth was widely recognized and nobody would have run a regression that assumed a constant trend. But little variation was apparent before that. In 1960, with the short postwar data period then available, Okun had treated trend productivity as a constant when he estimated Okun's law and the economy's potential growth path. A roughly constant trend was still generally

9. As in Gordon (1999).

10. Gordon (1999).

accepted through the mid-1970s. Recursive regressions, not shown in the figure, reveal that except for a few quarters, the constant trend that would have been estimated at any time between 1962 and 1977 from an ordinary least squares regression would have ranged only between 2.65 and 2.75 percent a year.

Our point here is that standard research techniques were slow to detect the change in the trend. This reflected researchers' knowledge of two things: First, a constant trend had been a good approximation for a long time, making it a natural prior that would require strong evidence to reject. Second, observed productivity varies substantially around the trend, and allowing for this makes it difficult to detect whether the trend has changed, especially around a recession.¹¹

Our backward Kalman filter (BKF) regression allows for cyclical departures of productivity from its trend but looks for drift in the trend at all times. BKF estimates in figure 2-1 show the trend ranging even more widely than Gordon's latest estimates using discrete trend breaks. More important, it shows a gradual and persistent slowdown in productivity growth between the mid-1960s and 1980. And it shows the trend during 1998, the last period in the estimation sample, rising 0.4 percentage point faster than Gordon's estimates. We make use of this productivity series in the inflation-unemployment model that we turn to next. To relate this series to currently published data, some adjustments are needed. First, adding back the effect of changes in price measurement that were introduced over the past several years would add 0.4 percentage point to 1998 trend productivity growth. Second, the revisions to the GDP accounts announced in late October 1999 add 0.5 percentage point to productivity growth during 1998, and some of this would have been added to a trend estimated with the new data. Finally, productivity growth continued to accelerate during 1999 and would lead to a higher estimate of the trend if that year were now included in estimation.

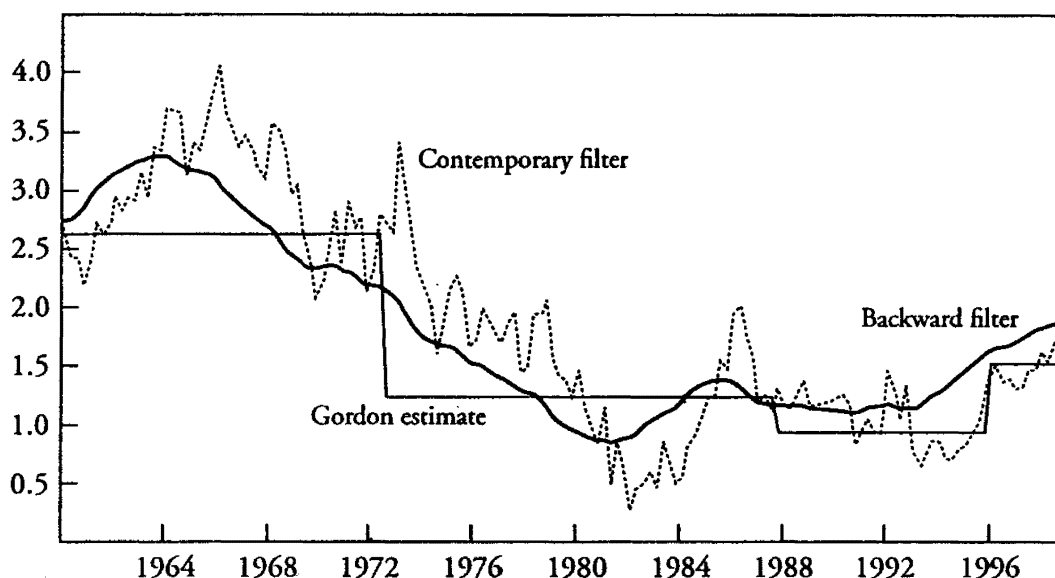
The Inflation Model and Data

We specify empirical models for wage change and price change to encompass in a parsimonious way the empirical work used by many policymak-

11. One of the present authors, writing in early 1977, found evidence of a productivity slowdown ambiguous even at that late date. If he could expunge one of his professional papers from the record, it would be this one. See Perry (1977).

Figure 2-1. *Three Estimates of the Productivity Trend, 1960–98^a*

Percent



Source: Authors' estimates as described in text and Gordon (1999).

a. The authors' two filter series use $\sigma = 0.006$.

ers and analysts since the 1960s. A highly elaborated model could fit the data somewhat better but is unlikely to affect our main points. Although current models frequently explain price rather than wage change, a wage equation would have been typical in the 1960s and we show both. Wage change can be connected to price inflation through the usual expedient of relating prices and trend unit labor costs. Our price and wage equations have the form

$$(2) \Delta \ln(X_t) = B_t + \sum b_{1it} 1/U_{it} + \sum b_{2it} \Delta \ln(P_{it}) + b_{3t} \Delta \ln(PR_t) + \text{dummies} + u_t,$$

where now the time-varying coefficients are each of the form $Z_t = Z_{t-1} + e_t$, where u_t and e_t are i.i.d, as in equation (1). X is either wages (defined below) or the consumer price index (CPI). We allow time variation in the intercept in the coefficient on current unemployment, and in the sum of coefficients in past inflation (and, in the price equations, in the coefficient on productivity). We also tried the CPI less food and fuel as a left-hand variable, but the results were much the same as with the CPI and are not shown. U is the unemployment rate for males aged 25 to 54 (to avoid effects of demographic changes); P is the CPI; and PR , which does not appear in the wage equation, is the trend in labor productivity in the non-

farm business sector. Although it has become popular to use the change in trend unit labor costs—change in wages less the productivity trend—as the left-hand variable in a wage equation, in our estimation the productivity trend as an explanatory variable was insignificant. Dummy variables are used for the period of Korean War controls, the years when wage and price guideposts were actively used in the 1960s, and the years in the 1970s when Nixon price controls were put on and taken off. The CPI term has eight lags, starting with $(t - 1)$ and the unemployment term uses the current and three lagged quarters. No continuous series for hourly wage costs is available, so we spliced three series that were: from 1980 to the present, the Employment Cost Index for wages and salaries; from 1961 to 1980, straight time hourly earnings for the private non-farm economy; and from 1948 to 1961, the hourly earnings index for manufacturing. For this early period, we do not know how similar the quarterly patterns were for manufacturing and the broader economy, but their total increases over the fourteen-year period were nearly the same: 91 percent and 89 percent, respectively.

Tables 2-1 and 2-2 summarize the parameters for the wage and price equations, in each case estimated with our three alternative techniques. The summary statistics in the tables show the considerable improvements in fit as we move across estimates. For wages, going from recursive to BKF estimation improves the root mean-squared error (RMSE) from 1.06 to 0.76, while the Durbin-Watson (DW) proxy statistic goes from 1.07 to 1.88. For the CPI, the corresponding forecast errors go from 1.53 to 1.23 and the DWs go from 1.81 to 2.12. It should be noted that these DW proxies are calculated for the forecast errors and so are not the same as usually reported for least squares regressions. Estimates for the key parameters are shown at five-year intervals starting in 1965.

Figures 2-2 and 2-3 plot the parameters continuously. The period from 1948 through 1959 was used to provide startup values for the Kalman filter regressions, and estimates for the years immediately following this period were highly volatile in both the wage and price equations, with large and offsetting variations in some parameters. Because the general story that emerges is much the same looking at either wages or prices, we will concentrate our discussion on the CPI equation.

Up until the late 1970s, the recursive and contemporary Kalman filter (CKF) estimates for all the parameters track each other pretty closely, with both sets of estimates varying markedly over time. Both estimates would have looked very different in 1975 than they had in 1965. After 1975 the

Table 2-1. *Characteristics of Wage Equations, 1965–98*

Regression type and date ^a	Coefficient			U rate for low inflation ^b
	Lagged prices	Unemployment	Intercept	
<i>Recursive</i>				
1965	0.45	10.53	0.00	2.5
1970	0.44	6.25	1.14	2.7
1975	0.53	5.74	1.19	4.0
1980	0.60	4.84	1.38	13.3
1985	0.57	5.00	1.40	6.1
1990	0.58	5.71	1.05	6.2
1995	0.59	6.64	0.63	4.0
1998	0.60	6.76	0.55	3.2
<i>Summary statistic^c</i>				
RMSE 1.057 ^d				
DW proxy 1.069 ^d				
<i>Contemporary filters</i>				
1965	0.39	10.45	0.01	2.4
1970	0.22	8.66	0.41	2.5
1975	0.51	6.41	0.88	3.7
1980	0.58	5.68	1.17	9.2
1985	0.52	5.52	1.32	5.6
1990	0.40	5.53	1.15	4.7
1995	0.29	5.69	0.99	3.0
1998	0.32	5.84	1.06	2.7
<i>Summary statistic</i>				
RMSE 0.941				
DW proxy 1.479				
<i>Backward filters</i>				
1965	0.37	5.84	1.02	1.7
1970	0.49	5.83	1.06	2.5
1975	0.54	5.84	1.10	4.0
1980	0.57	5.84	1.12	8.5
1985	0.50	5.84	1.10	4.6
1990	0.37	5.83	1.06	4.3
1995	0.29	5.83	1.04	3.2
1998	0.32	5.84	1.06	2.7
<i>Summary statistic</i>				
RMSE 0.763				
DW proxy 1.881				

Source: Equations for 1960–98 as described in text.

a. First quarter of year shown, except 1998 is fourth quarter.

b. Unemployment rate for males aged 25–54 associated with 2 percent inflation rate.

c. RMSE is the root mean-squared error. DW is the Durbin-Watson statistic.

d. For recursive regressions, these are for the 1960–98 estimation period.

Table 2-2. *Characteristics of Price Equations, 1965–98^a*

<i>Regression type and date^a</i>	<i>Coefficient</i>			
	<i>Lagged prices</i>	<i>Unemployment</i>	<i>Productivity</i>	<i>Intercept</i>
<i>Recursive</i>				
1965	0.52	6.77	−0.10	−1.04
1970	0.55	5.71	−0.32	−0.24
1975	0.75	4.12	−0.54	0.57
1980	0.77	3.12	−1.22	2.60
1985	0.72	3.94	−1.11	2.17
1990	0.75	4.17	−0.96	1.63
1995	0.77	4.39	−0.84	1.18
1998	0.79	4.31	−0.79	1.00
<i>Summary statistic^b</i>				
RMSE 1.526 ^c				
DW proxy 1.808 ^c				
<i>Contemporary filters</i>				
1965	0.48	6.89	−0.05	−1.22
1970	0.56	5.93	−0.25	−0.46
1975	0.73	4.76	−0.42	0.32
1980	0.94	4.26	−0.71	1.34
1985	0.60	4.29	−0.94	2.05
1990	0.55	4.34	−1.01	2.19
1995	0.46	4.50	−1.02	2.10
1998	0.41	4.26	−1.11	2.16
<i>Summary statistic</i>				
RMSE 1.470				
DW proxy 2.060				
<i>Backward filters</i>				
1965	0.58	4.28	−1.05	2.20
1970	0.67	4.27	−1.08	2.19
1975	0.71	4.27	−1.07	2.20
1980	0.80	4.28	−1.03	2.23
1985	0.55	4.28	−1.05	2.21
1990	0.52	4.27	−1.06	2.20
1995	0.44	4.27	−1.09	2.18
1998	0.41	4.26	−1.11	2.16
<i>Summary statistic</i>				
RMSE 1.228				
DW proxy 2.115				

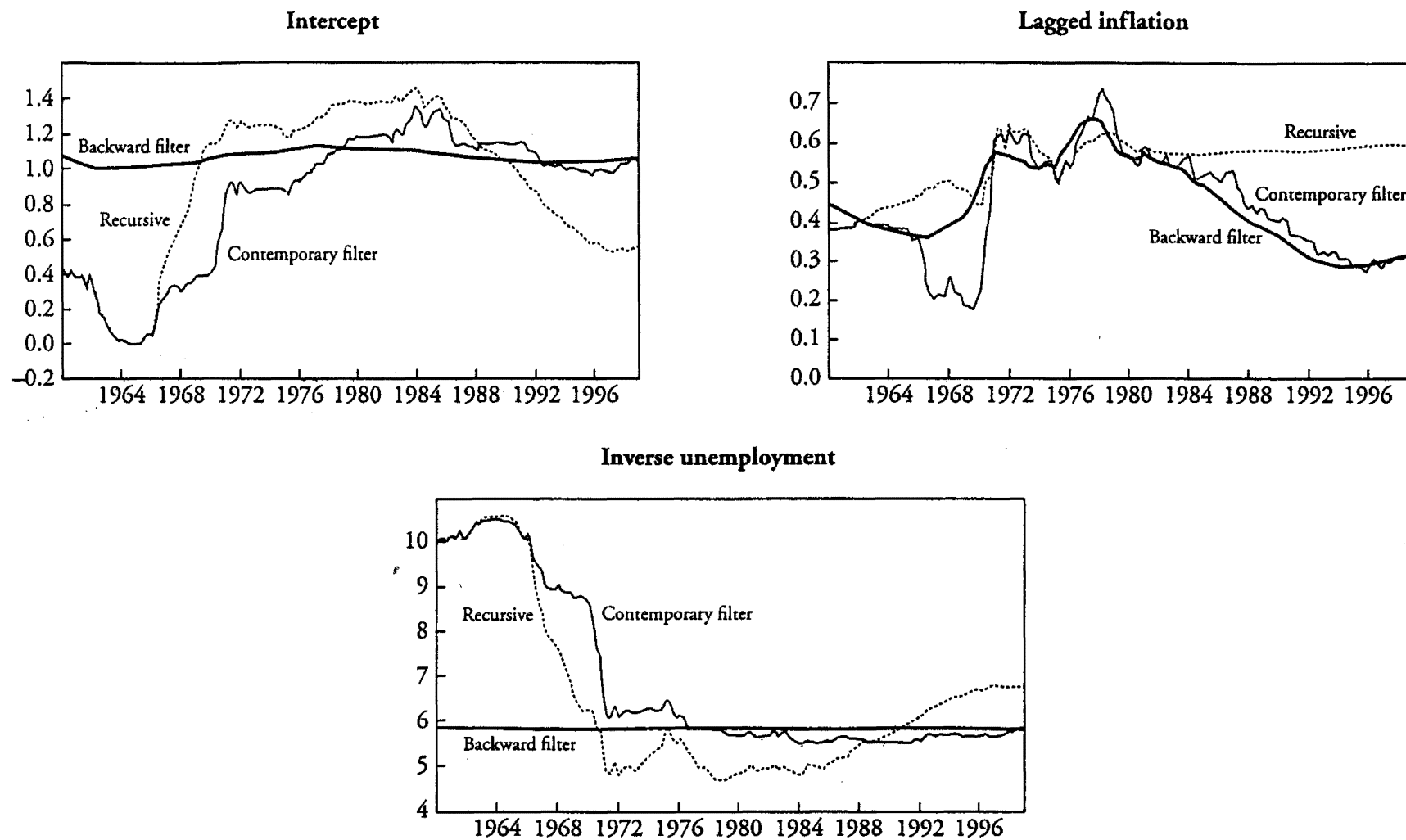
Source: Equations for 1960–98 as described in text.

a. First quarter of year shown, except 1998 is fourth quarter.

b. RMSE is the root mean-squared error. DW is the Durbin-Watson statistic.

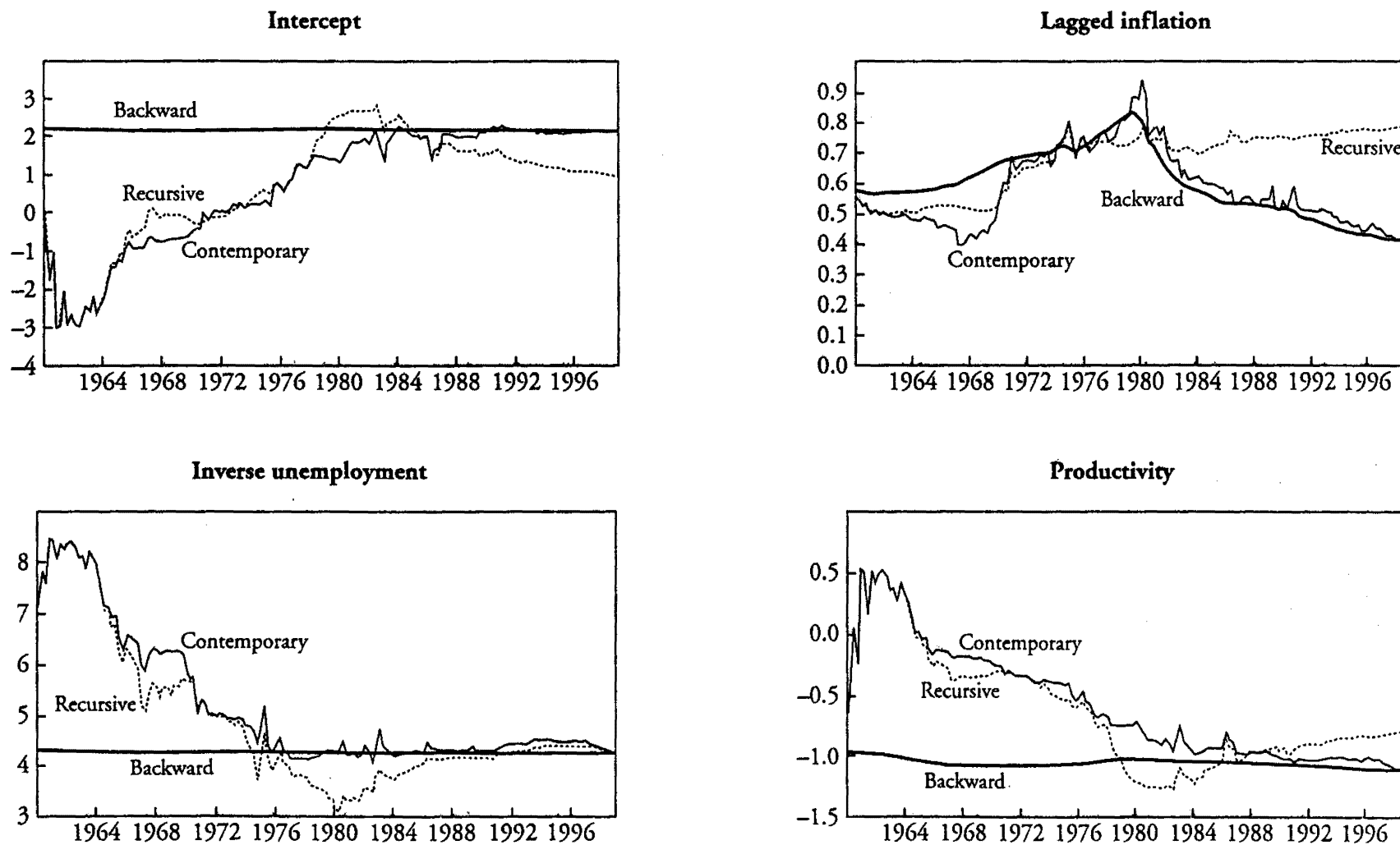
c. For recursive regressions, these are for the 1960–98 estimation period.

Figure 2-2. *Wage Equation Parameters from Recursive and Time-varying Filter Estimates, 1960–98*



Source: Authors' calculations from regressions in table 2-1.

Figure 2-3. *CPI Equation Parameters from Recursive and Time-varying Filter Estimates, 1960–98*



Source: Authors' calculations from regressions in table 2-2.

two estimators diverge noticeably, particularly in estimating the effect of lagged inflation. Recursive estimates of lagged price effects rise slowly right up to the present, while CKF estimates peak in the late 1970s and then decline to near their lowest level at present. Only the recursive estimates come close to satisfying the NAIRU assumption of this key parameter, and those estimates seem to be dominated in the data by the high inflation years of the 1970s.

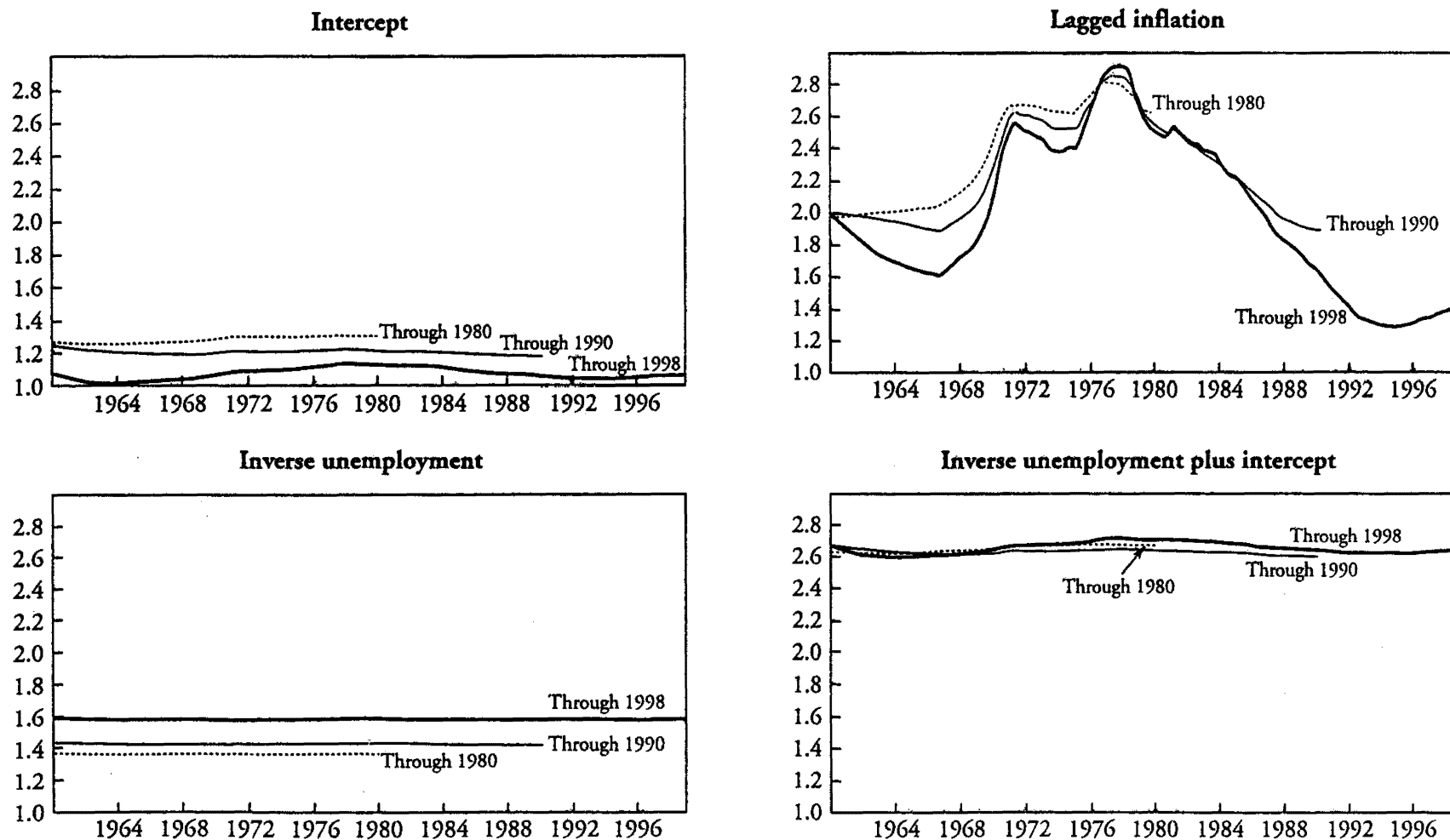
The BKF regressions provide our best estimates of the relation at all past dates from the vantage point of 1999, and the results are striking. Almost no time variation is allocated to coefficients other than lagged inflation. The estimates for the parameters other than lagged inflation are, perhaps surprisingly, stable throughout the past forty years. By contrast, the effect of lagged inflation is moderate at the start, rises even above the OLS estimate by 1980, and then declines to its lowest level at present. According to these estimates, there is little inflation persistence today, and there was only moderate persistence in the early 1960s. But there was great inflation persistence by the end of the high inflation decade of the 1970s. At that time, the relation was nearly accelerationist, approximating the NAIRU model.

The characterization of parameter changes in the early part of the sample is broadly the same if we stop the analysis a decade or two sooner. Figure 2-4 compares the BKF estimates from the wage regression, which ran through 1998, with estimates running through 1990 and 1980. The parameters are multiplied by the respective variable means to make their impact on inflation comparable. The great variability in the role of lagged inflation and the relative constancy of the other three parameters is apparent in all three.

What Does it Mean?

The BKF results support both the strategy of focusing on the unemployment-inflation relation and the importance of parameter instability. The near constant estimates for the unemployment and productivity parameters and the intercept suggest that labor market tightness or ease and the notion of a full employment range are useful concepts, reasonably proxied by a broad measure of unemployment clean of demographic distortions. A nonlinear relation between unemployment and cyclical inflation identifies a region of resource utilization where additional tightening

Figure 2-4. *Backward Filter Estimates of Wage Equation Parameters, Alternative Estimation Endpoints, Calibrated for Impact on Wage Inflation, 1960–98^a*



Source: Authors' calculations as described in text.

a. Calibrated by multiplying variable means by their time-varying parameter from backward filter estimates.

is accompanied by increases in inflation rates. In both the beginning and the end of the period, when inflation rates were low, the feedback of past inflation on wages and prices seems far from complete. This much resembles the macroeconomic modeling of the 1960s.

The full dynamic of the inflationary process is not so well established. As characterized by the sum of the coefficients on lagged inflation, it has varied markedly during the four decades we analyze. It appears that as experienced inflation rose in the late 1960s and then continued high, so did the impact of past inflation on present inflation. This is consistent with the view that expectations and institutions adapt to the actual inflation experienced. It is plausible that with sustained high rates of inflation the feedback of inflation to wages would be complete and the estimated sum of coefficients would equal one. It is also plausible that in a regime of low inflation, even if it were sustained, the feedback would not be complete. Such a pattern could be an endogenous response of wage and price setters to inflation itself that would be consistent with Alan Greenspan's identification of low inflation as a period in which people do not think about inflation.¹² However, there is only one episode on which to observe this parameter shifting and so little basis to confirm any particular mechanisms at work. Furthermore, as Thomas Sargent has emphasized, rational expectations does not imply that the sum of estimated coefficients on lagged inflation need be one.¹³ For example, in rational expectations models, if agents expect the Federal Reserve to reduce inflation, the sum would be less than 1.0, and if they expect inflation to accelerate, it would exceed 1.0. In a forthcoming paper, George Akerlof, William Dickens, and George Perry examine the kind of endogenous response of price and wage setting we have sketched out here and address the Sargent critique by using data on price expectations to complement their results with lagged inflation.¹⁴

Our estimates approximate a NAIRU specification only during the most inflationary part of the four-decade period we examined. However, the unemployment rates associated with maintaining low inflation can be calculated for any point in time. These are shown in the last column of table 1. (We provide these estimates only for the wage equation since the

12. In his statement of January 24, 1989, before the House Committee on Banking, Finance, and Urban Affairs, Greenspan stated that the Fed's strategy was to reach "price levels sufficiently stable so that expectations of change do not become major factors in key economic decisions." See Greenspan (1989, p. 141).

13. Sargent (1971).

14. See Akerlof, Dickens, and Perry (forthcoming).

point estimates from the price equation were extremely high and volatile in the 1970s.) These estimates do not describe what would have happened if outcomes had differed from the historical ones because we suspect that parameter changes reflect in some complicated way experienced inflation. Nor do they describe what unemployment rates would have been required indefinitely to maintain low inflation, since the parameters would have been expected to change under those circumstances—as, in fact, they did. The estimates are a simple way to characterize the changing situation that policymakers confronted—a situation that is not easily inferred from individual parameters. For both wage and price regressions they show the much greater sensitivity to inflation that developed in the 1970s. Figure 2-5 plots the continuous estimates of the low inflation unemployment rate from the backward filter along with actual unemployment rates. The figure uses the familiar total unemployment rate by converting the estimates based on the 25- to 54-year-old male rate that were used in the regressions. For comparison, the figure also plots the NAIRUs estimated by the Congressional Budget Office (CBO), which correspond closely to estimates by Gordon and others.¹⁵

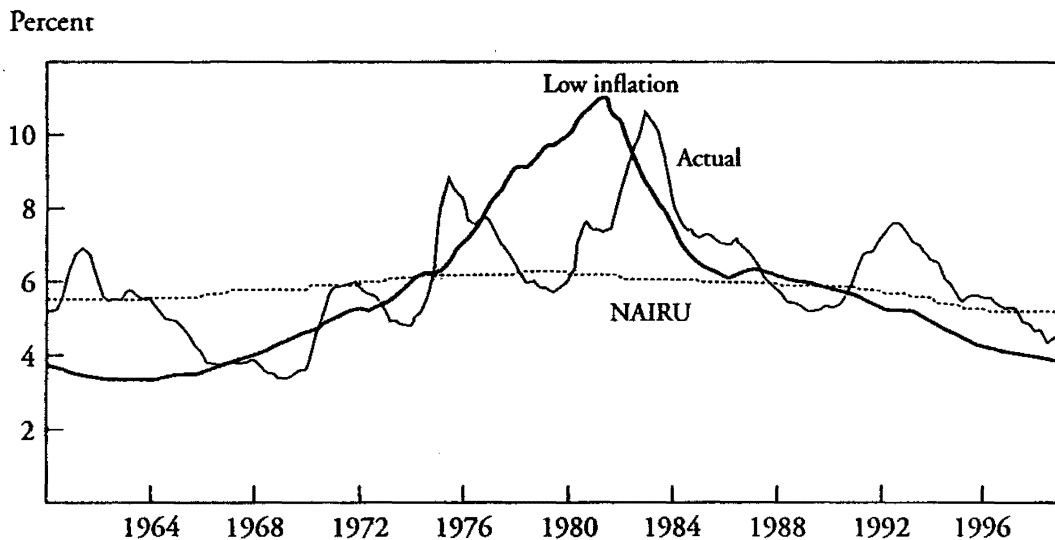
Armed with these estimates and insights from the time-varying regressions, we now take a closer look at economic performance over the past forty years and assess how the challenges to policymaking were met.

The 1960s

During the first fifteen years following World War II, the U.S. economy suffered four recessions, starting in 1949, 1953, 1957, and 1960. The incoming Kennedy economic team emphasized the need to avoid the frequent recessions of the past, to sustain the nascent recovery of 1961, and to encourage investment for long-run growth. Though these goals could have been the homilies of any new administration, in this instance they were supported by original diagnoses by the Council of Economic Advisers and accompanied by important policy initiatives. Inflation was seen as a problem confounding stabilization goals because it picked up moderately before full employment had been achieved. Okun's estimates of full employment and potential growth were translated into estimates of the full employment budget surplus as an indicator of the thrust of fiscal policy.

15. See Congressional Budget Office (2000).

Figure 2-5. *Actual and Low Inflation Total Unemployment Rates and the NAIRU, 1960–98^a*



Source: Authors' calculations from coefficients in BKF wage regressions and trend productivity, Congressional Budget Office (2000), and data from the Bureau of Labor Statistics.

a. The male unemployment rates calculated from the wage regressions were converted to corresponding total unemployment rates in each quarter using a regression of $\log(\text{total } U \text{ rate})$ on $\log(\text{male } 25\text{--}54 \text{ } U \text{ rate})$ and t , t^2 , and t^3 (where t = time). The NAIRU is CBO's estimate.

With that indicator, the most recent recession was attributed to an unwarranted tightening of fiscal policy by about 2 percent of GDP in FY1960.

On the policy front, the Kennedy administration pursued a more expansionary budget, initially through higher defense spending and before long through tax reductions. Depreciation rules were made more generous, business equipment spending received a tax credit, and income tax rates were reduced, with the top marginal rate cut from 91 percent to 70 percent. By 1965, the structural surplus had been reduced by about 0.7 percent of GDP from its level five years earlier. In response to the idea that inflation quickened before full employment was reached, the 1962 *Economic Report of the President* first introduced the idea of guideposts for wages and prices. While never having the force of law, these guideposts became a conspicuous and active initiative of administration policy, especially in 1964–65 under Lyndon Johnson, and they cast a shadow that extended throughout the 1970s when the Council on Wage and Price Stability operated in the executive branch.

Though the guideposts policy was always controversial, the view of inflation that motivated it had ample empirical support. The Phillips curve had emerged as a characterization of the cyclical behavior of the macro-

economy, although both what microeconomic behavior generated it and how the cyclical behavior might play out in the longer run were unsettled questions. In their paper to the December 1959 meeting of the American Economic Association, Paul Samuelson and Robert Solow display their awareness of the range of possible answers to these questions, many of which have reemerged in the years since. In particular, they anticipate the idea that the short-run Phillips curve may change under experienced inflation, but are open about how far such a change will go:

[A] period of high demand and rising prices molds attitudes, expectations, even institutions in such a way as to bias the future in favor of further inflation. Unlike some other economists, we do not draw the firm conclusion that unless a firm stop is put, the rate of price increase must accelerate. We leave it as an open question: It may be that creeping inflation leads only to creeping inflation.¹⁶

In interpreting the period, we should emphasize that this and other informed discussions of the time had nothing to do with desiring inflation as a way to promote employment, or with tolerance for the inflationary consequences of pushing unemployment below the full employment range. Keeping inflation low was a goal of policy then as now, and full employment and potential output were concepts of what was achievable with existing resources and under normal circumstances. One key contrast to the NAIRU models that emerged in subsequent decades was that a modest cyclical rise in inflation was not considered a sign that employment had exceeded sustainable levels.

For the years through 1970, our recursive estimates are not far from a least squares regression fit at the start of the 1960s. Forecasts from this regression are quite good for the rest of the decade. The econometrician who kept extending the sample would have found little reason to suspect instability in the relation in 1965 or even in 1970. By the late 1960s, he would have concluded that the economy had passed beyond the full employment region, that aggregate demand was excessive, and that the rise in inflation that was observed was about what was expected.

It is well documented that policymakers had been concerned about excess demand in the economy ever since the mid-1960s when the original full employment goal was reached and the Vietnam War began raising

16. Samuelson and Solow (1960, p. 185).

defense spending. The contemporary Kalman filter results would have added little additional information, but none was needed. Nonetheless, little was done to slow the expansion. Monetary policy was not then the aggressive instrument of policy that it later became, and Lyndon Johnson believed his social agenda would be sidetracked if he called for a tax increase to finance the war. In the three years after FY 1965, the structural surplus declined by 2.9 percent of GDP, leaving it in large deficit. The investment credit for business equipment was temporarily suspended in late 1966. But the temporary suspension had such a sharp effect that it threatened to cause a recession and the credit was reinstated only months later. An income tax increase was finally passed, effective in 1969, by which time unemployment was down to 3.5 percent and inflation had risen to 5.4 percent.

The paralysis of fiscal policy as a stabilization tool in this period was a problem recognized at the time as well as today. Why monetary policy did not react more forcefully is a question we cannot answer convincingly here. But recall that the Fed had been constrained by Treasury's financing needs during World War II, freeing itself only in the early 1950s. It is easy to imagine that the legendary persuasive powers of Lyndon Johnson and the pressure to cooperate with the nation again at war would have made it difficult for any Fed chairman to tighten decisively. In any event, as figure 2-6 shows, the real federal funds rate was lower in early 1969 than it had been four years earlier.

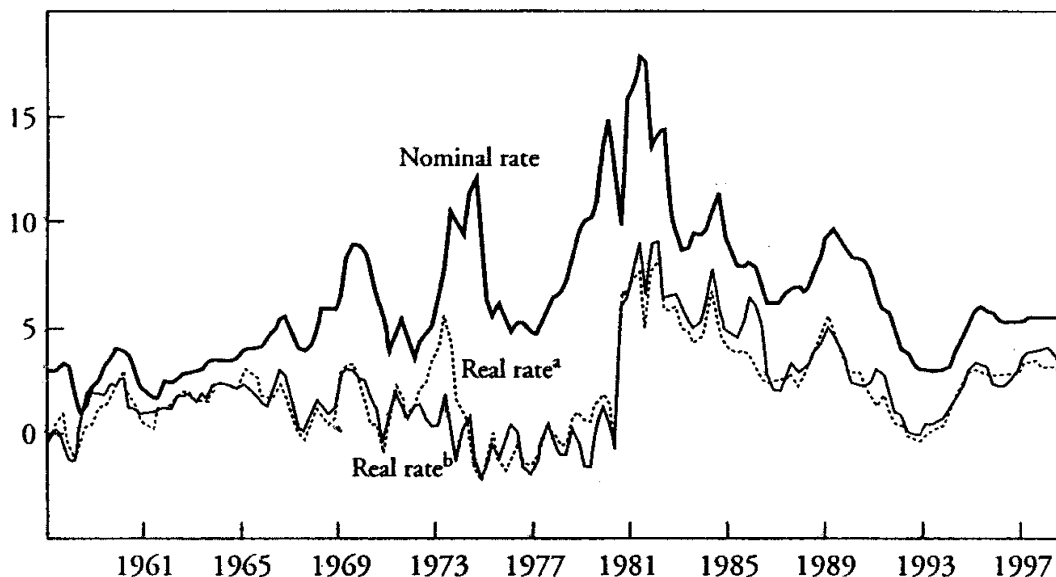
What policy reactions would have been implied by present day NAIRU models? According to the Congressional Budget Office, the economy was at its NAIRU of 5.5 percent as early as 1962 and had clearly shot past it in 1965. These models would have led policymakers to reject the initial fiscal stimulus of the early 1960s, including the tax cuts that were passed, and to call for tighter monetary policy to slow the expansion that ensued in those years. Yet the years between 1962 and 1966 were the best of the decade and widely applauded by contemporary accounts. In contrast to NAIRU models, the BKF model summarized in figure 2-5 gives a picture consistent with the contemporary account. It shows a considerable excess of unemployment in 1962–64 and would have supported the Kennedy fiscal stimulus and monetary policies of that period.

The OPEC Years

The turbulent 1970s challenged policymakers at the time and have challenged econometricians ever since. While widely remembered as the decade

Figure 2-6. *Real and Nominal Federal Funds Rates, 1957–98*

Percent



Source: Authors' calculations using data from *International Financial Statistics CD-ROM*, 1999.

a. Federal funds rate minus the three-quarter centered average of the one-quarter change in the logarithm of CPI-U (a.r.).

b. Federal funds rate minus the three-quarter centered average of the one-quarter change in the logarithm of CPI-U less food and energy (a.r.).

of two explosions in world oil prices, other shocks were just as important and as difficult to model with confidence. At the start of the decade, wages in the then-important union sector, most of which were negotiated on a three-year cycle, accelerated in the midst of recession, masking the slow-down that occurred in other wages. In mid-1971, the Nixon administration imposed wage and price controls. During 1973, a major run-up in consumer food prices, which had been decontrolled, added 5 percentage points to the PPI and 3 percentage points to the CPI for the year. The first OPEC price shock hit at the end of 1973, and soon thereafter all wage and price controls were lifted in this environment of already rapid inflation. Finally, recall from figure 2-1 that the productivity trend slowed sharply over the course of the decade.

Except for the productivity slowdown, the special nature of these shocks was recognized both by policymakers at the time and by most econometricians since then. But then as now, there was no way to model their ultimate impact on the economy with confidence. Did controls simply store up wage and price increases? The data seem to say yes, but this can

hardly be a prediction good for all times and circumstances. The controls during the Korean War abruptly slowed inflation, but their removal produced no inflationary surge like that in 1974. Did the wage accelerations that accompanied the price shocks demonstrate the NAIRU assumption that the price-to-wage elasticity is one? The recursive regressions in tables 2-1 and 2-2 show how the observations from the early 1970s dominate least squares estimates of lagged price effects from then on. However, our filter estimates indicate that the least squares results are misleading. They reveal that the relatively high estimates for the 1970s are outliers relative to the estimates for periods both before and after.

Both the CKF and recursive regressions show a more inflationary relation emerging in the 1970s. However, it would have been hard to detect in the presence of the shocks in that period and, as we noted earlier, the productivity slowdown was not detected until late in the decade. Following the deep and prolonged recession that followed the first oil price shock, it was appropriate for policy to be expansionary. But by 1978, policymakers had ample warning that inflation was quickening and might have detected that the relation itself was worsening. NAIRU estimates for those years would not have flashed a warning, showing unemployment well above the NAIRU in 1977 and about at the NAIRU in 1978. However, our time-varying estimates show the low inflation unemployment rate was rising sharply. In any case, monetary policy remained expansionary. The real federal funds rate, shown in figure 2-6, remained negative throughout most of this period.

The Volcker Era

When the second OPEC shock added to an already troublesome inflation, President Carter appointed Paul Volcker to head the Federal Reserve. With a clear mandate to control inflation, the Volcker Fed produced the massive recessions of 1980 and 1981–82. The federal funds rate averaged 16.4 percent in 1981, double the rate of three years earlier. The unemployment rate rose to over 10 percent in 1982, easily the highest rate since the Great Depression. And as figure 2-4 shows, the parameters shifted dramatically in a less inflationary direction following these policies and the unemployment they produced.

Then as now there was disagreement about whether a more gradual disinflation back then would have been less costly, and it is difficult to imagine tests that would answer that question objectively. The credibility of monetary policy was being modeled as a key determinant of policy effectiveness and the Fed's Draconian monetary policy should be viewed in that context. But in 1984, five years after the Volcker tightening began, inflation had been down to 4 percent for two years, yet the yield on 30-year government bonds was still over 12 percent. We can infer either that credibility about fighting inflation was still not established or that financial markets expected that historically high real interest rates would persist for a very long time. The latter view received support from the fiscal policies of the time. Under the Reagan combination of tax cuts and defense buildup, the structural surplus declined by 3 percent of GDP between 1980 and 1986, reaching a deficit of 5 percent of GDP in FY1986. By then the pure fiscal explanation for high long-term rates works less well since the long bond rate fell below 8 percent that year.

The 1990s

We have already described the remarkable performance of the economy in the last half of this decade. And it is in this period that our estimates provide the most dramatically different view of policy choices from those suggested by traditional analysis. Figure 2-5 again summarizes the changing relation that policymakers confronted. By the mid-1990s, when NAIRU models were warning that unemployment should not decline further, our estimates show the relation between inflation and the unemployment rate improving steadily. If we associate good policymaking with the judgmental equivalent of being alert to changing parameter values, the willingness of the Greenspan Fed to allow rapid expansion to continue after 1995 gets very high marks. The civilian unemployment rate averaged 5.6 percent in 1995, already below contemporary estimates of NAIRU, and is today near 4 percent. The economy's potential growth rate was estimated to be around 2.5 percent in 1995. Yet real GDP has risen by 4 percent a year since then. Policymakers could not have fully anticipated this performance of the economy in this period. But by 1995, the contemporary filter estimates summarized in table 2-1 would already have alerted them that a substantially lower unemployment rate was consistent with low inflation.

Some Lessons for the Conduct of Policy

Our simplified price and wage equations are not much different than the equations used by a variety of authors to examine optimal policy. If we combined our equations relating unemployment and output with a relation to monetary policy and specified a loss function in inflation and output or employment, we could formally investigate how the performance of various policy rules would be affected by allowing for time variation in parameters. Such an analysis is beyond the scope of this paper. However, we venture a few thoughts about the lessons that would likely emerge.

If structural change is important and continuous, conventional estimation procedures can be misleading. Sticking with prior estimates, unless recent observations fall outside of conventional confidence intervals, will be a mistake. Compared with conventional policy analysis, policymaking that is alert to parameter drift will respond less to the prescription from conventional econometric estimates and more to recent shocks. The policymaking episodes that we discussed earlier demonstrate the potency of this problem. The failure in the 1970s to detect the change to a more inflationary relation was a costly mistake, and the Fed's reluctance in recent years to observe the prescription of NAIRU models permitted the lower unemployment and faster growth that the U.S. economy has enjoyed.

On a related issue, we know that uncertainty about the response to policy actions calls for deviation from certainty-equivalent behavior.¹⁷ Several authors, finding small standard errors in their estimates of response, have suggested that uncertainty is small so that the appropriate behavior is approximately certainty-equivalent. However, their confidence is misplaced if parameters in fact time vary. If they do, allowing for time variation not only will improve the estimate of the parameter at any point in time, but may also enlarge estimated standard errors. Moreover, in light of the uncertainties of specification and the profession's collective mining of available data, we believe the true uncertainty about policy response is greater than even our time-varying model reveals. For all these reasons, certainty-equivalent behavior is likely to be far from optimal.

Our results indicate that a full employment range is reasonably well defined and that concern over rising inflation is well placed. They also cast doubt on NAIRU models as adequate descriptions of the economy's behavior. Although we did not formally test a NAIRU form of the inflation

17. See Brainard (1967).

equations, the unconstrained estimates provided no support for the NAIRU formulation. Our results also indicate that conventional estimates from a NAIRU model do not identify the full employment range with a degree of accuracy that is useful to policymaking.

Finally, our findings on time-varying parameters bring some new evidence to bear on the choice between simple policy rules and policy discretion. Rules have been framed in terms of departures of actual performance from fixed target values for unemployment and inflation rates. Such rules would lead to policy mistakes with the kind of time-varying parameters that we estimate. Other simple rules, such as fixing the nominal growth rate of the economy, will be inappropriate if the productivity trend is time-varying, as it has been over the postwar period. Our general conclusion that policy should be framed with continuing attention to changing parameters strengthens the argument that policymakers need to be constantly alert to unexpected developments, both shocks and changes to the economic structure.