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In search of the natural rate of unemployment ☆

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Abstract

The natural rate of unemployment can be measured as the time-varying steady state of a structural vector autoregression. For post-War US data, the natural rate implied by this approach is more volatile than most previous estimates, with its movements accounting for the bulk of the variation in the unemployment rate, as well as substantial portions of the variation in aggregate output and inflation. These movements, in turn, can be related to variables associated with labor-market search theory, including unemployment benefits, labor productivity, real wages, and sectoral shifts in the labor market. There is also a strong negative relationship between inflation and the corresponding measure of cyclical unemployment, supporting the existence of a short-run Phillips curve.

JEL classification: E24; E32; J64

Keywords: Structural vector autoregression; Natural rate of unemployment; Search theory; Sectoral shifts; Phillips curve

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1. Introduction

The natural rate of unemployment is the long-run equilibrium in the labor market, and economists often appeal to it as a proxy for broader macroeconomic equilibrium. A measure of the natural rate is therefore potentially useful for assessing the contribution of equilibrium fluctuations to overall macroeconomic volatility, the structural sources of equilibrium fluctuations, and the short-run relationship between inflation and movements away from equilibrium. In this paper, we present an estimate of the natural rate that allows us to examine these issues.

The traditional approach to estimating the natural rate makes the assumption that it is a constant, with at most a few structural breaks in its level (e.g., Papell et al., 2000). Other approaches assume that the natural rate is the time-varying realization of a particular smooth time series process by using techniques such as deterministic polynomial trends (Staiger et al., 1997), calibrated unobserved-components models (Gordon, 1997), low-pass filtering (Staiger et al., 2001), and the Hodrick–Prescott filter (Ball and Mankiw, 2002). All of these approaches impose a certain degree of smoothness on the natural rate, meaning that the estimates cannot be used to assess the contribution of equilibrium fluctuations to overall macroeconomic volatility. Likewise, estimates based on an assumed set of structural factors (e.g., Salemi, 1999) cannot be used to determine which factors are relevant, while estimates based on an assumed short-run relationship between inflation and cyclical unemployment (e.g., Gordon, 1997) cannot be used to test the existence of a short-run Phillips curve.

Our approach to estimating the natural rate avoids these problems by relying on the following definition given in Phelps (1994, p. 1):

> [The 'natural rate of unemployment' is defined as] the current equilibrium steady-state rate, given the current capital stock and any other state variables. (It is the unemployment rate that, if it were the actual rate at the moment, would make the current rate of change of the associated equilibrium unemployment rate path equal zero.) In [this] theory, then, the equilibrium path of the unemployment rate is driven by a natural rate that is a variable of the system rather than a constant or a forcing function of time. The endogenous natural rate becomes the moving target that the equilibrium path constantly pursues.

Under this definition, which is closely related to Friedman's (1968) idea of the natural rate as the value "ground out by the Walrasian system," the unemployment rate is determined by a stable dynamic process and, in the absence of exogenous shocks, converges to a unique steady-state equilibrium. Importantly, this equilibrium is itself endogenous, determined by technological, institutional, and demographic factors, and is therefore not necessarily constant over time. However, identification of steady state does not require specification of all the contributing structural factors, but only requires identification of the aggregate impact of these factors.

We use a structural vector autoregression (VAR) model of aggregate output, inflation, and the unemployment rate to estimate the natural rate under Phelps's definition as the time-varying steady state of the unemployment rate. For the structural VAR model, a change in the steady-state level of the unemployment rate represents a specific type of shock that is identified to have permanent effects on the unemployment rate. Under this identification scheme, there is no arbitrary smoothness restriction on the natural rate, nor are there restrictions on which structural factors affect the natural rate. Meanwhile, the corresponding measure of cyclical unemployment allows us to test for a short-run Phillips curve, without presupposing its existence.

In contrast to many previous studies, our results suggest that the natural rate is quite volatile and support the idea that most macroeconomic activity reflects movements in long-run equilibrium, not from equilibrium. Indeed, movements in the natural rate account for over half of the variation in the post-War US unemployment rate. In addition, these movements have substantial effects on aggregate output at all frequencies and on inflation at high to moderate frequencies. To examine our estimated natural rate further, we consider whether it relates to a number of variables that economic theory suggests may be relevant. Consistent with recent search-based models of equilibrium unemployment, the most important determinants are unemployment benefits, labor productivity, real wages, and sectoral shifts in the labor market, with sectoral shifts having the largest estimated impact. Also, consistent with the short-run Phillips Curve, there is a strong negative relationship between inflation and the corresponding measure of cyclical unemployment.

2. Structural VAR identification

Consider the vector $\mathbf{x}_t = [y_t\ p_t\ u_t]$, where y_t is log real GDP, p_t is the log of the consumer price index, and u_t is the average unemployment rate in quarter t. We assume that the reduced-form dynamics of the first differences of these series can be described by a stationary VAR model:

$$\Delta \mathbf{x}_t = \mathbf{c} + \sum_{k=1}^{K} \mathbf{F}_k \Delta \mathbf{x}_{t-k} + \mathbf{e}_t, \tag{1}$$

where $\mathbf{c}$ is a vector of constants, $\mathbf{F}_k$ is a matrix of coefficients, and $\mathbf{e}_t$ is a vector of normally distributed forecast errors with mean zero.[1] Using quarterly data from 1948:2 through 2001:1 and setting the lag order K to eight, the VAR model explains 31% of the quarterly variation in output growth, 75% of the quarterly variation of inflation, and 56% of the quarterly variation in the first differences of the unemployment rate.[2]

Given a reduced-form time-series model such as (1), the steady state of a series can always be estimated using the Beveridge-Nelson (1981) decomposition. If one views the natural rate as the time-varying steady state, this estimate is independent of the structural model underlying the VAR, provided the estimated reduced-form model is correct. However, to determine short-run effects of changes in the natural rate—on both the unemployment rate and the other variables in the system—it is necessary to make some structural assumptions. To this end, we follow Blanchard and Quah (1989) by imposing

[1]By modeling the first differences with a stationary time-series model, we are implicitly assuming that all three endogenous levels variables are nonstationary or, more specifically, integrated of order one ($I(1)$). Although the unemployment rate cannot technically follow an $I(1)$ process (because it is bounded by zero and one), Fair (2000) demonstrates that the persistence of the series makes it difficult to reject a unit root in practice. In this paper, we view a unit root in the unemployment rate as an approximation that captures the presence of frequent permanent shocks whenever the unemployment rate lies between its bounds. It should be noted that our identification scheme is predicated on the existence of permanent shocks to the unemployment rate.

[2]Because of potential noise introduced by the volatile Korean War years, we also considered the alternative sample period of 1953:2 through 2001:1, but the results were not appreciably different.

long-run identifying restrictions on the relationship between the observable data and the structural shocks.

The structural model can be represented by an infinite-order moving-average process

$$\Delta \mathbf{x}_t = \mathbf{m} + \sum_{k=0}^{\infty} \mathbf{A}_k \mathbf{v}_{t-k}, \tag{2}$$

where $\mathbf{m}$ is a vector of deterministic drifts for the level variables in $\mathbf{x}_t$, $\mathbf{A}_k$ is a matrix of shock coefficients, and $\mathbf{v}_t$ is a vector of three structural shocks. The shocks are assumed to have means of zero, variances of unity, and zero cross correlations, and the shock coefficients are assumed to satisfy the conditions for stationarity. We also impose the following identifying restrictions:

$$\sum_{k=0}^{\infty} a_{31,k} = 0, \quad \sum_{k=0}^{\infty} a_{32,k} = 0, \quad \sum_{k=0}^{\infty} a_{12,k} = 0, \tag{3}$$

where $a_{ij,\mathrm{k}}$ is the *i,j*th element of $\mathbf{A}_k$. The restrictions in (3) impose that the first structural shock has no long-run effect on the unemployment rate and that the second structural shock has no long-run effect on output and the unemployment rate. Intuitively, the third structural shock, which is completely unrestricted, may be thought of as the "natural rate" (NRU) shock, as it is the only one that is allowed to affect the unemployment rate in the long run. The first and second shocks may be thought of as "aggregate supply" (AS) and "aggregate demand" (AD) shocks, in the sense of Blanchard and Quah (1989), inasmuch as the first may have long-run effects on output while the second may not. A slightly different interpretation is that there are two types of AS shocks, both of which have permanent effects on output: those that also result in permanent changes to the unemployment rate and those that have only transitory effects on the unemployment rate.

Given the identifying restrictions in (3) and estimates for the reduced-form VAR model in (1), it is straightforward to solve for estimates of the corresponding structural VAR model and its infinite-order moving-average representation in (2), which provides impulse response functions for the structural shocks.

3. Results for the structural VAR model

Fig. 1 presents the impulse response functions and Table 1 presents the corresponding variance decompositions. Following the identification assumptions, the AS and NRU shocks both have permanent effects on output, with NRU shocks accounting for two-thirds of the long-run variation in output. Also by construction, only the NRU shock has a permanent effect on the unemployment rate. The estimated magnitude of this effect is large: a one-standard-deviation positive NRU shock leads to a long-run increase in the unemployment rate of about 0.4 percentage points. These shocks also account for the majority of the short-run variation in the unemployment rate. By contrast, AS shocks are relatively unimportant, accounting for less than 20% of the short-run variation in output and less than 30% of the short-run variation in the unemployment rate. Of course, if one views the NRU shock as a specific type of AS shock, then the two types of supply shocks have a large joint effect on both series in both the short run and long run. But when AS is decomposed into a component with permanent effects on the unemployment rate and a

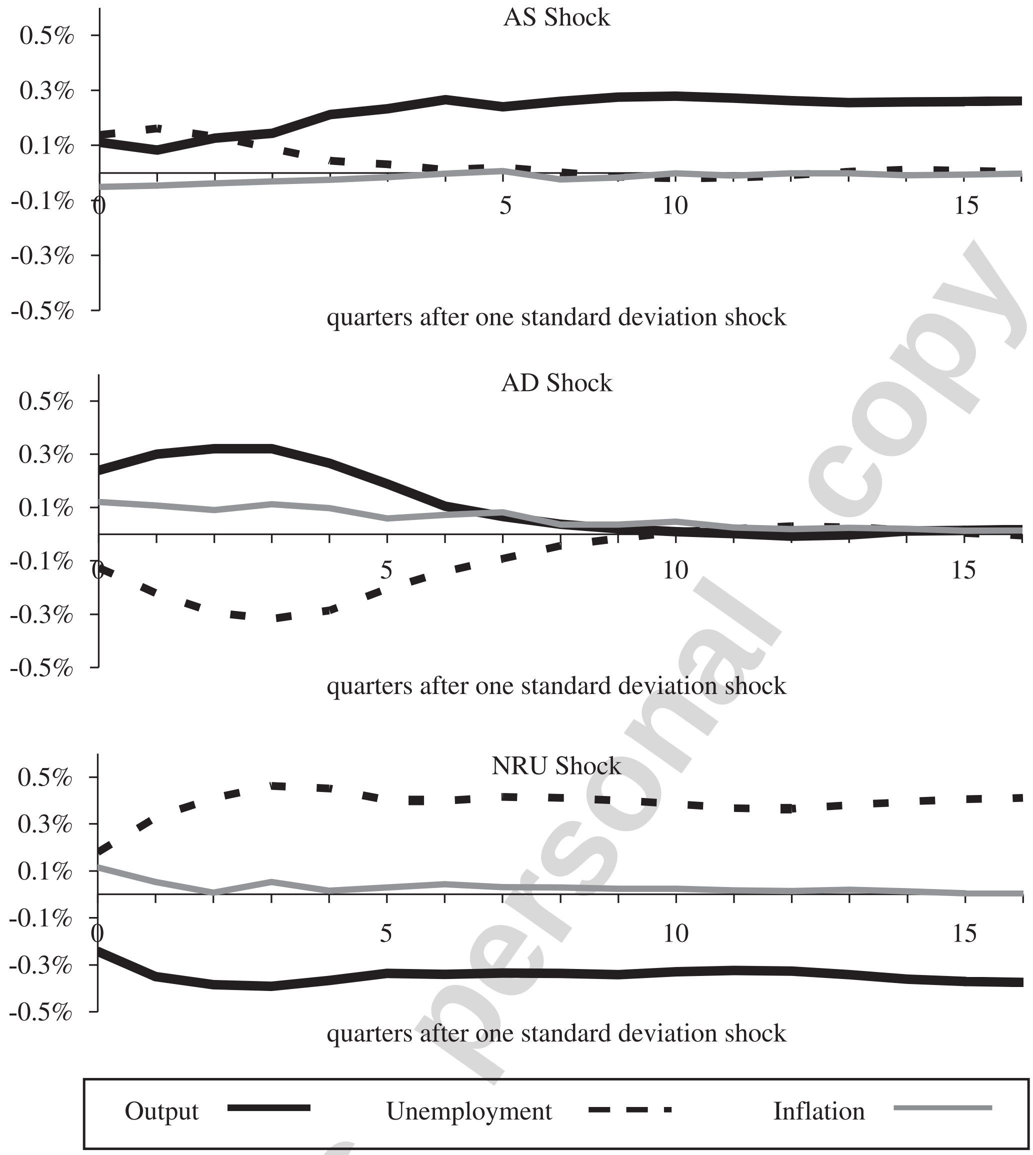

Fig. 1. Impulse response functions for structural shocks.

component with only transitory effects, the former is substantially more important than the latter.

While AD shocks dominate inflation, their short-run impacts on output and the unemployment rate are modest and largely die away within six to eight quarters. It is interesting to note that Blanchard and Quah (1989) find much stronger short-run effects of AD shocks on the real variables using the same general approach. Over the first eight quarters following a shock, they find that aggregate demand accounts for up to 86% of the variation in output and up to 89% of the variation in the unemployment rate, while we find that AD shocks account for at most 45% of the variation in output (in the quarter of the shock) and 30% of the variation in unemployment rate (at the 2-quarter horizon). The difference in results is likely driven by the fact that Blanchard and Quah implicitly assume that the natural rate of unemployment is constant (or at most follows a linear deterministic time trend) over their sample period. This assumption likely overstates the importance of transitory shocks since it imposes that all shocks to the unemployment rate, no matter how persistent, are transitory.

Table 1
Variance decompositions

	Output			Inflation			Unemployment rate		
	AS shock (%)	AD shock (%)	NRU shock (%)	AS shock (%)	AD shock (%)	NRU shock (%)	AS shock (%)	AD shock (%)	NRU shock (%)
0 (shock qtr)	9	45	46	8	48	44	29	23	48
4	9	37	54	9	68	23	6	30	64
8	18	25	56	8	69	22	4	22	74
:	:	:	:	:	:	:	:	:	:
20	28	11	61	8	69	23	2	11	87
:	:	:	:	:	:	:	:	:	:
40	31	6	63	8	69	23	1	6	93
:	:	:	:	:	:	:	:	:	:
∞	33	0	67	—	—	—	0	0	100

Notes: The table reports the relative importance of the three structural shocks in our estimated structural VAR model for variation in output, inflation, and the unemployment rate at different horizons. Because inflation is assumed to be stationary, none of the shocks has effects on inflation at the infinite horizon.

A related issue is how much the results depend on the assumption that inflation is stationary. Given its strong persistence during the sample period under consideration, it may be more appropriate to allow the structural shocks to have a long-run impact on inflation. To check the robustness of our results, we considered an alternative structural VAR in which inflation was included in first differences, rather than in levels. This change in specification produced a further decrease in the importance of AD in explaining the real variables. In particular, AD explained less than 5% of the variance of both output and the unemployment rate at all horizons, although it explained over 90% of the variation in inflation.[3]

4. The natural rate of unemployment

The innovations in the natural rate are provided by the implied long-run effects of the shocks in the structural VAR, and the level of the natural rate can be found as the accumulation of these innovations.[4] This estimate of the natural rate, which is plotted together with the actual unemployment rate in Fig. 2, confirms the conclusion hinted at by the impulse response functions: fluctuations in the natural rate explain the bulk of

[3]The overall explanatory power of this VAR was only moderately lower than the levels specification, with R^2s of 27% for output growth, 44% for the first differences of inflation, and 54% for the first differences of the unemployment rate. The robustness of the unemployment equation to the treatment of inflation is not surprising, because, as emphasized in King and Watson (1994), inflation does not appear to "Granger-cause" the unemployment rate.

[4]To compute the levels series, one needs an additional assumption about the value of the level in some period. To achieve this normalization, we assume that the deviation of the unemployment rate from the natural rate is zero on average over our sample. We also impute the small upward trend in the unemployment rate (about 0.002 percentage points per quarter) to the natural rate.

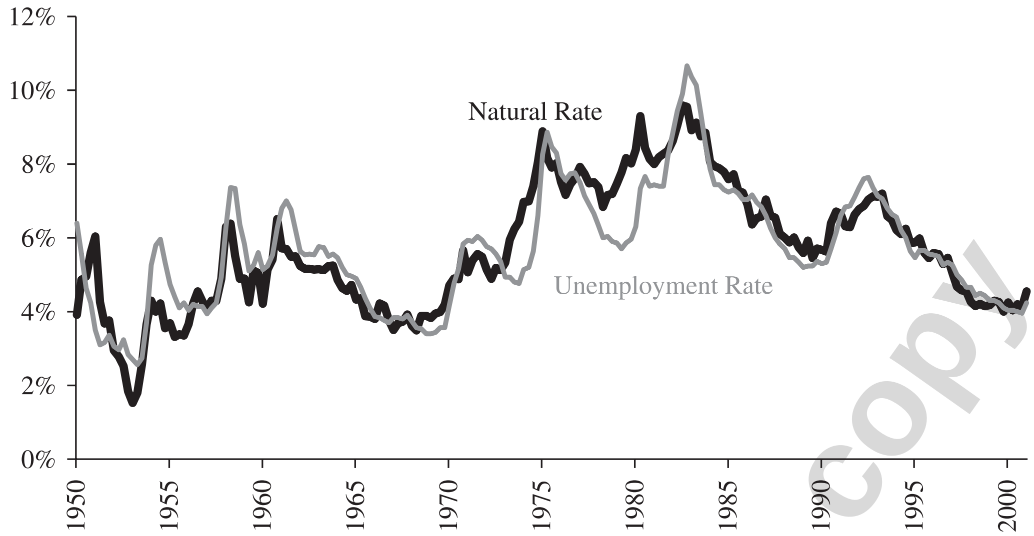

Fig. 2. The natural rate of unemployment.

fluctuations in the unemployment rate over time. The estimated natural rate is thus somewhat volatile, ranging between 1.8% and 9.5% over the post-War period.[5]

The volatility of our estimated natural rate is at odds with some previous research. Weiner's (1993) natural rate, for example, varies only between 5.1% and 7.3% between 1960 and 1993. On the other hand, estimates as volatile as ours are not entirely unprecedented, especially among studies that based on structural models, rather than arbitrary smoothing restrictions or impositions of the Phillips curve. For example, Salemi's (1999) estimate, based on a theoretical model of the labor market, ranges from about 4.0% to about 7.2% between 1948 and 1990. Phelps's (1994, p. 340) estimate also displays considerably more variation than is typical, spanning a range of about five percentage points between 1957 and 1989.

5. Determinants of the natural rate

In this section, we examine the relationship between our estimate of the natural rate and variables emphasized by previous theoretical and empirical studies, principally those concerning labor-market search theory.[6] Although several studies have tested the ability of search models to account for cyclical unemployment, little work to date has investigated their explanatory power for long-run unemployment. This analysis also serves to validate our estimate of the natural rate in the sense that, if fluctuations in this estimate could not be related to structural variables, one might be skeptical of its rather high volatility.

Four variables that are driving factors in standard search-theoretic models (see, for example, Pissarides, 2000) are reservation wages, labor productivity, real interest rates, and bargaining power. For reservation wages, we use log real unemployment benefits per unemployed person as a proxy. Higher returns to not working raise reservation wages and thus should increase the natural rate, as documented in the recent calibration study of

[5]When we estimated the natural rate under the alternative assumption that inflation is nonstationary, the results were similar, with the natural-rate series ranging from 2.1% to 9.6% and differing from the series in Fig. 2 by an average of only 0.37 percentage points. Not surprisingly, the differences are concentrated between 1972 and 1982, when the evidence for permanent shocks to inflation is strongest.

[6]Hall (2005) provides a discussion of many of the variables considered in this section.

Gomes et al. (2001). For labor-productivity growth, we use the quarterly change in log output per worker, as reported in the Bureau of Labor Statistic's establishment survey. Most theoretical models of unemployment predict that, all else equal, higher growth rates of labor-augmenting productivity growth should reduce the natural rate, because they increase the incentives for firms to fill vacancies.[7] Also, some recent empirical studies (e.g., Ball and Mankiw, 2002; Pissarides and Vallanti, 2004) have attributed variation in the natural rate to changes in labor productivity. For the (ex post) real interest rate, we use the CPI-deflated ten-yr Treasury yield. Higher real interest rates cause firms to discount the returns from hired workers more rapidly and thus should slow hiring, increasing the natural rate. For worker bargaining power, we use both the log real minimum wage and union membership as a percentage of total employment as proxies.[8] By lowering the firm's share of a job's surplus, bargaining power reduces incentives to hire, thus theoretically raising equilibrium unemployment.

Two additional variables that are typically treated as endogenous by search theories are real wages and vacancy rates. We include measures of these quantities in our regressions and run two-stage least-squares specifications to account for simultaneity. For wages, we use the log real value of employee compensation reported by the BLS. Having controlled for labor productivity, changes in the real wage should primarily reflect changes in labor supply, with higher wages representing greater costs to firms. Thus, we expect that, all else equal, higher real wages should reduce the incentive to hire and thereby increase the natural rate of unemployment (as in Pissarides, 1987). For the vacancy rate, we use the Conference Board's help-wanted index as a proxy, following Abraham (1987). Vacancies and unemployment are determined simultaneously along the Beveridge curve. However, all else equal, an exogenous, permanent increase in vacancies should lower the natural rate. Thus, again, accounting for simultaneity is important.

There are a number of other variables that are not typically addressed in search models, but may be relevant. First, we consider the growth rate of the labor force. Because new workers are likely to take some time to become employed, more people entering the workforce may increase frictional unemployment and thus the natural rate. Second, we consider demographic factors. Junh et al. (1991), Ando and Brayton (1995), and Shimer (1998), among others, have argued that demographics may be important determinants of the natural rate, especially over long time horizons. To account for this possibility, we use the percentage of male workers, the percentage of workers under the age of twenty-five, and the percentage of workers over the age of sixty. Third, exogenous shifts in sectoral composition may have long-run effects on the unemployment rate because workers must learn new skills when relative labor demand in various industries changes, a hypothesis first articulated by Lilien (1982). Although this idea seldom arises explicitly in search theory, it is closely related to search models involving worker heterogeneity, as discussed below. For sectoral shifts, we use a variable that is analogous to Lilien's and is constructed as the sum of the absolute value of the quarterly changes in percentage composition of each major employment sector—manufacturing, construction, finance, government, mining, service, transportation and utilities, retail sales, and wholesale sales.

[7]However, if productivity growth causes real interest rates to rise or skills to become obsolete, it may also work in the opposite direction, through a "creative-destruction" channel. (See Aghion and Howitt, 1994; Caballero and Hammour, 1994.)

[8]Because union participation is only reported on an annual basis, the data are interpolated to get a quarterly series.

Table 2 reports the regression results for six models of the natural rate series using the twelve variables discussed above.[9] The first model (Model I) is a simple OLS specification in levels including all of the explanatory variables and a linear time trend to control for any differing drift in the various series. Because some of the variables are likely endogenous, a two-stage least-squares model (Model II) is also considered. In this specification, unemployment benefits, labor-productivity growth, real compensation, the real interest rate, the help-wanted index, and the labor-force growth rate are allowed to be endogenous, with the exogenous variables and four quarterly lags of the endogenous variables serving as instruments.[10]

Both the OLS and 2SLS regression models fit the data well (R^2s of 0.91 and 0.88), but the Durbin–Watson statistics suggest the presence of serial correlation. One possible explanation for this result is that, because the natural rate is non-stationary and there may be no cointegrating relationship among the variables, the residuals may also be nonstationary. As a consequence, the regression results for Models I and II may be spurious (Granger and Newbold, 1974; Phillips, 1986). We therefore consider first differences of the natural rate and all of our explanatory variables using OLS (Model III) and 2SLS (Model IV) specifications. We then use a variable-selection procedure for the differenced 2SLS specification, removing insignificant variables one at a time until only significant variables remain (Model V). Finally, we re-estimate all of the models using annual, rather than quarterly, data. When all of the explanatory variables are included in the annual model, none of the coefficients is significant. However, when the variable-selection procedure is used for the differenced 2SLS specification, some variables rise above the significance threshold (Model VI).

The variable to emerge from our analysis as the most consistently significant determinant of the natural rate is the measure of sectoral shifts in the labor market. It is statistically significant at the 1% level in every case and also exhibits a high level of economic significance. According to the coefficient from Model IV, for example, an increase of 0.33 percentage points in this variable (one standard deviation) corresponds to a 0.18-percentage-point increase in the natural rate—roughly half the standard deviation of the first-difference series. Unemployment benefits have a similarly large effect. Again for Model IV, a 7.2% increase (one standard deviation) in benefits per person corresponds to a 0.15-percentage-point increase in the natural rate.

The growth rate of labor productivity has a statistically significant negative effect in every case except Model II, although the size of this effect is somewhat smaller that that of sectoral shifts and unemployment benefits. For Model IV, a 0.8-percentage-point increase (one standard deviation) in productivity growth leads to a drop in the natural rate of 0.06 percentage points. Real compensation has a statistically significant positive effect that is roughly the same size as the negative effect of productivity growth in Models I–VI. However, it falls short of the 10% significance threshold for Model IV and is not selected in Model V.

[9]It should be noted that, although the natural rate series is derived from econometric estimates and is therefore likely to be subject to some amount of measurement error, it is only used as the regressand in this section. Thus, any measurement error is subsumed into the error term and generated-regressor concerns about inconsistent estimates do not apply.

[10]Although, as discussed above, only real wages and vacancies are typically treated as endogenous by search theory, it is possible that the other variables that are allowed to be endogenous are determined simultaneously with the natural rate.

Table 2
Determinants of the natural rate

Model specifications

Model I—OLS, levels	*Model IV*—2SLS, first differences
Model II—2SLS, levels	Model V—2SLS, first differences, significant variables only
Model III—OLS, first differences	Model VI—2SLS, first differences, significant variables only, annual data

	Coefficients (t statistics)					
	Model I	Model II	Model III	Model IV	Model V	Model VI
Intercept	*−83.47*	*−91.55*	*−0.09*	−0.13	0.004	*−0.75*
	(−6.46)	*(−5.57)*	*(−1.72)*	(−1.52)	(0.16)	*(−3.68)*
% Sectoral shifts	*0.80*	*1.15*	*0.49*	*0.54*	*0.55*	*0.72*
	(5.45)	*(5.5)*	*(5.67)*	*(5.22)*	*(5.92)*	*(3.76)*
Real Unemp. benefits	*0.03*	*0.03*	*0.006*	*0.02*	*0.02*	*0.02*
	(11.71)	*(7.98)*	*(1.74)*	*(3.07)*	*(4.15)*	*(4.60)*
Labor-productivity growth	*−0.15*	0.15	*−0.11*	*−0.07*	*−0.08*	*−0.15*
	(−2.62)	(0.93)	*(−4.56)*	*(−2.09)*	*(−2.45)*	*(−1.79)*
Real hourly compensation	*0.11*	*0.11*	*0.09*	0.10		*0.15*
	(9.05)	*(7.18)*	*(2.49)*	(1.61)		*(3.57)*
Real 10-year treasury yield	*0.08*	*0.15*	*−0.03*	−0.003		
	(2.71)	*(3.74)*	*(−1.73)*	(−0.07)		
% Union membership	*−0.30*	*−0.31*	0.11	−0.10		*−0.33*
	(−4.57)	*(−3.73)*	(0.65)	(−0.47)		*(−1.75)*
Real minimum wage	*0.03*	*0.04*	0.006	0.009		*0.03*
	(4.83)	*(4.35)*	(0.62)	(0.84)		*(2.23)*
% Of workforce male	*0.67*	*0.82*	0.16	0.22		*0.60*
	(4.19)	*(4.15)*	(0.87)	(0.91)		*(1.76)*
% Of workforce under 25	*0.25*	*0.28*	−0.06	−0.003		
	(6.35)	*(5.81)*	(−0.51)	(−0.02)		
% Of workforce over 60	*−0.24*	*−0.49*	0.15	0.14		
	(−1.73)	*(−2.58)*	(0.62)	(0.47)		
Help-wanted index	−0.003	−0.008	0.003	−0.001		
	(−0.77)	(−1.49)	(0.81)	(−0.24)		
Growth rate of labor force	−0.03	0.18	−0.003	0.003		
	(−1.00)	(1.50)	(−0.17)	(0.11)		
Time trend	*−0.13*	*−0.12*				
	(−12.21)	*(−9.35)*				
R^2	0.909	0.882	0.350	0.281	0.265	0.687
Adjusted R^2	0.902	0.873	0.306	0.230	0.253	0.625
Durbin–Watson	0.654	1.013	2.250	2.267	2.213	2.047
Observations	187	183	186	182	182	43

Notes: The table reports regression results with our estimate of the natural rate as the dependent variable. All real quantities are measured in 1996 dollars. Italics type denotes statistical significance at the 10% level. t-statistics are reported in parentheses.

The remaining variables do not display any consistent sign and significance patterns. The real interest rate is significant with the predicted sign in the levels specifications, but it has a counterintuitive negative sign in Model III (although the coefficient is small). Union membership appears in Model VI with a counterintuitive negative sign, although its insignificance in Models III–V suggests that this result may be spurious. The real minimum wage and the percentage of males in the workforce are also significant in Models I, II, and

VI, while the age-related demographic variables are significant in Models I and II, but none of these variables is significant in the quarterly differenced specifications. The help-wanted index and labor-force growth are not statistically significant in any of the regressions.

In summary, our estimate of the natural rate of unemployment is consistent with the predictions of search theory in the sense that it is significantly related to unemployment benefits, productivity, and wages in the expected ways. However, the greatest explanatory power is associated with changes in sectoral composition. Although explicit sectoral differentiation is not common in search theory, the emphasis on cross-sectional heterogeneity, rather than just aggregate conditions, is shared by recent models involving match-specific productivity (e.g., Mortensen and Pissarides, 1994; Den Hann et al., 2000). In particular, allowing for productivity differences across jobs is important for modeling job-separation rates as endogenous. Because separation rates are responsible for most of the permanent fluctuations in the unemployment rate (see Shimer, 2005), we might expect this heterogeneity to have large effects on the natural rate.

6. The Phillips curve and deviations from the natural rate

In this section, we consider the estimation of a short-run Phillips curve. In doing so, we remain agnostic about various theories concerning the Phillips curve's underlying mechanics—worker misperception, cost–push inflation, Lucas supply curve stories, and so on. Instead, the question is whether a relationship between inflation and cyclical unemployment exists. Again, it is important to emphasize that our identification assumptions in no way presuppose this existence.

Fig. 3 displays a scatter plot of inflation against the contemporaneous value for cyclical unemployment estimated by our structural VAR. The correlation between these two variables is −0.72, and the regression line shown—a simple representation of the short-run Phillips curve—has the corresponding R^2 of 0.52. The slope of this line is −2.54, implying a large contemporaneous tradeoff between unemployment and inflation, holding the natural rate constant.

As a more sophisticated test, we estimate a Phillips Curve relation using the derived natural-rate series and the specification in Gordon (1997). Inflation is regressed on eight quarterly lags of inflation, the contemporaneous value and four quarterly lags of cyclical unemployment, and the AS shocks from the structural VAR. The results are presented in Table 3. After taking dynamics into account and controlling for the supply shocks, the magnitude of the estimated effect of cyclical unemployment on inflation is smaller, with a one-percentage-point increase in cyclical unemployment corresponding to a cumulative 0.31-percentage-point decrease in inflation after four quarters. However, this estimate is statistically significant and provides strong support for the existence of the short-run Phillips curve. (In direct comparison to Fig. 3, the coefficient on contemporaneous cyclical unemployment is −1.27 instead of −2.54.) Specifications of this regression using different lag structures generated similar estimates.[11]

[11] Also, the results were robust to the assumption that inflation is nonstationary. In particular, using the alternative measure of the natural rate and the corresponding alternative set of AS shocks, we found that a one-percentage-point increase in cyclical unemployment corresponded to a cumulative 0.70-percentage-point decrease in inflation after four quarters, again supporting the existence of the short-run Phillips curve.

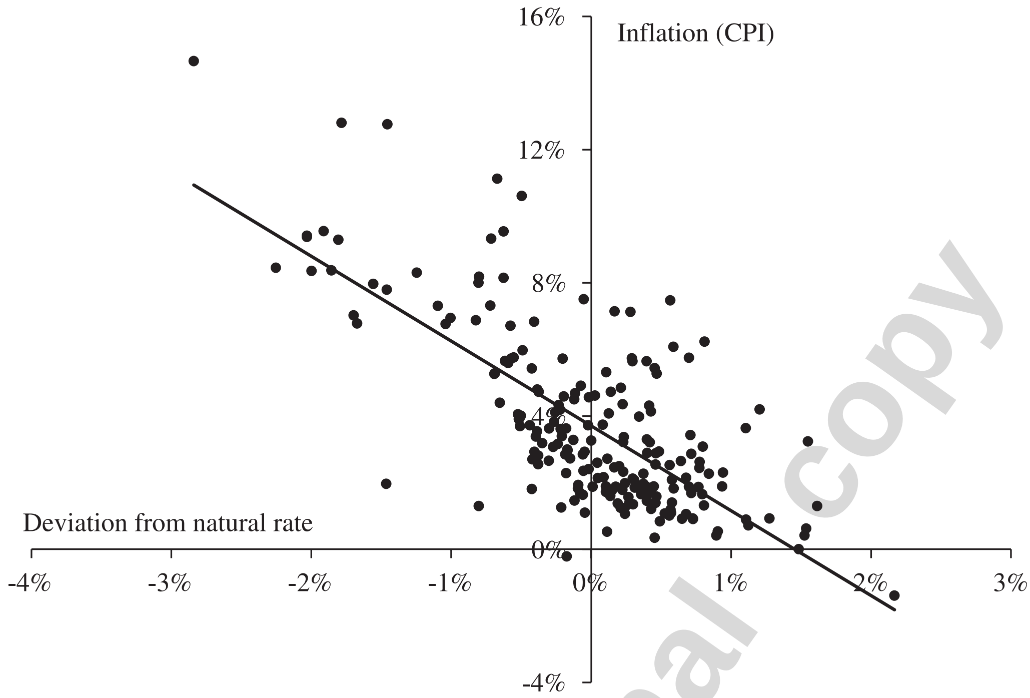

Fig. 3. Inflation versus cyclical unemployment.

Table 3
Phillips curve regression results

	Full sample	1948–1989	1990–2001
Inflation (1–8 lags)	*0.977*	*0.957*	*1.072*
	(2,719.88)	(2,135.15)	(562.42)
Cyclical unemployment (0–4 lags)	*−0.313*	*−0.308*	*−0.752*
	(4.91)	(3.39)	(8.02)
Supply shocks (0–4 lags)	−0.087	−0.101	0.299
	(0.25)	(0.21)	(1.82)
R^2	0.956	0.960	0.961
Adjusted R^2	0.951	0.954	0.934
Observations	197	152	45

Notes: The table reports regression results with inflation as the dependent variable. The specification follows Gordon (1997). Italics type denotes statistical significance at the 10% level. χ^2 statistics for the sums of the coefficient blocks, computed using heteroskedasticity-robust standard errors, are reported in parentheses. R^2s are calculated under the restriction that the intercept is identically zero.

The results for the Phillips curve regression match up closely with the structural VAR results in Section 3. First, the AS shocks account for little of the variation in inflation, which is consistent with the variance decomposition results in Table 1. Also, the estimated negative relationship between inflation and cyclical unemployment is consistent with the impulse response functions in Fig. 1, which suggest that inflation and cyclical unemployment move in opposite directions for all three structural shocks.[12] For a direct comparison to the estimate of −0.31 in Table 3, we calculate the ratio of the 0–4 quarter responses of inflation and cyclical unemployment for each structural shock. The estimates are −0.42 for the AD shock, −0.34 for the AS shock, and −0.90 for the NRU shock.

The results are also robust to recent claims by Atkeson and Ohanian (2001) that the Phillips curve weakened or disappeared during the 1990s. Indeed, when the regression is estimated on subsamples split in 1990, as displayed in the last two columns of Table 3, the estimated magnitude of the slope coefficient is actually larger in the later period, although it is not statistically different than before 1990 (the Chow F-statistic is 0.25, with a p-value of 0.94). This finding is consistent with the conclusions of Staiger et al. (2001), who argue that the slope of the Phillips Curve has been relatively stable over time but that the level of the unemployment rate that is consistent with stable inflation has shifted.

It is worth noting that when we regressed changes in inflation on contemporaneous changes in our measure of the natural rate, the estimated coefficient was actually positive (1.43 with a t-statistic of 5.27). This result is striking because, if some of what we have labeled as changes in the natural rate were actually part of cyclical unemployment, we would expect this coefficient to be negative in the presence of a Phillips Curve relationship. The fact that the estimated coefficient is positive argues against such mislabeling and might reflect policymakers initially confusing changes in the natural rate with cyclical unemployment (Orphanides, 2002). Given a Phillips Curve relationship, if policymakers pursue counter-cyclical policy, an unnoticed or misdiagnosed increase in the natural rate should generate higher inflation.[13] An alternative explanation is that policymakers correctly distinguish between cyclical and natural unemployment, but time inconsistency causes inflation (both expected and actual) to rise following exogenous increases in the natural rate, as argued by Barro and Gordon (1983). Ireland (1999) provides additional empirical support for this hypothesis by treating inflation as nonstationary and arguing that it is cointegrated with unemployment rate.

7. Conclusion

In this paper, the natural rate of unemployment is defined as the steady state of the labor market. The results that arise from the application of a structural vector autoregression under this definition provide further support to the already large body of literature validating the existence of the short-run Phillips Curve. In particular, the estimated natural rate implies a strong negative correlation between cyclical unemployment and the level of inflation, despite the absence of any modeling assumptions that dictated it would do so. However, the results also clearly suggest that any tradeoff between cyclical unemployment and inflation is an issue of secondary importance when compared to the effects of movements in the natural rate itself. If one views unemployment at the natural rate as

[12]For the AS and AD shocks, the implicit response of cyclical unemployment is the same as that of the unemployment rate. For the NRU shock, the implicit response of cyclical unemployment is given by the difference between the response of the unemployment rate and its long-run response. Also, given that the long-run response of inflation is always zero due to the assumption that it is stationary, it is clear that our structural VAR does not identify a long-run Phillips curve.

[13]When considering the shorter sample period of 1980:2–2001:1, which does not include the 1970s period in which many such policy mistakes are often thought to have occurred, the estimated coefficient on changes in the natural rate was much smaller (0.15 with a t-statistic of 0.45).

evidence of a market-clearing outcome, it must be inferred that shifts in labor-market equilibrium constitute the bulk of the variation in the unemployment rate. Thus, while movements away from the steady state are governed by a strong Phillips Curve relationship, a sizeable proportion of macroeconomic activity is governed by changes in the steady state, even over short horizons. To the extent that achievement of equilibrium in the labor market proxies for broader macroeconomic efficiency, this finding suggests that business cycles primarily reflect market-clearing adjustments to exogenously changing conditions.

With regard to macroeconomic policy, if the goal is to maintain the economy at full employment, the results in this paper yield a frustrating conclusion: the natural rate is a quickly moving target. If the economy responds slowly and uncertainly to monetary shocks, policymakers will have a hard time predicting the effects of policy. In order to do so accurately, one needs not only a model describing the response of economic variables to monetary changes, but also a model describing the behavior of the natural rate over time. From the analysis in this paper, relevant variables for such a model include changes in sectoral composition, unemployment benefits, and, to a lesser extent, productivity growth and real wages. Again, these findings are broadly consistent with recent search-based theories of equilibrium unemployment.

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