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Estimates of the NAIRU Using an Extended Okun's Law

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The opinions expressed in this paper are those of the authors and should not be attributed to the Bank of Canada. The paper uses an idea suggested by Douglas Laxton, and an estimator designed by John Armstrong. Helpful comments were received from Paul Jenkins and Jean-Pierre Aubry. Christine Banham provided valuable research assistance.

Abstract

This paper reports estimates of the NAIRU derived from a model in which an Okun's Law equation is estimated simultaneously with a production function and a Phillips curve. The NAIRU is found to depend on the proportion of young workers and women in the labour force and hence has tended to rise over time. The model is estimated using both aggregate-economy and commercial-sector definitions of the labour market, and using estimation samples ending in 1981 and 1986. The preferred results indicate that the NAIRU was about 8 per cent at the end of 1987.

Résumé

La présente étude fait état des estimations du TCNA dérivées d'un modèle où la loi d'Okun, une fonction de production et la courbe de Phillips ont fait l'objet d'une estimation simultanée. D'après les résultats, le TCNA est fonction du pourcentage de la main-d'oeuvre représenté par les jeunes et les femmes et tend par conséquent à s'accroître au fil du temps. Pour estimer le modèle, on a fait appel à deux définitions du marché du travail - l'une concernant l'ensemble de l'économie, et l'autre uniquement le secteur commercial - ainsi qu'à des périodes d'estimation s'arrêtant en 1981 et 1986. Les résultats retenus indiquent que le TCNA était de 8 % environ à la fin de 1987.

1. Introduction

A contraction of aggregate demand reduces the demand for labour. Since prices and wages are sticky in the short run, the rate of unemployment rises. Okun's Law relates the degree of excess supply in the output market (the output gap, or the difference between potential and actual output) and the degree of excess supply in the labour market (the labour market gap, or the difference between the equilibrium[1] and actual unemployment rates).

This paper reports estimates of the NAIRU derived from a model in which an Okun's Law equation is estimated simultaneously with an explicit production function and a Phillips curve. This method avoids some drawbacks of more traditional implementations of Okun's Law. In particular, the output and labour market gaps are simultaneously determined. The method was devised in earlier work at the Bank by Douglas Laxton; this paper can be viewed as an update of his work.

The NAIRU is found to depend on the proportion of female and young workers in the labour force. As a result, the estimated NAIRU rises over time. The measure of Unemployment Insurance (UI) benefits proved insignificant as an explanation of the NAIRU in this work. This is surprising, since many investigators have found UI to be a significant factor in determining the NAIRU. The point estimates of the NAIRU depend on the specification of the equations and the sample period used. In brief, samples that include the 1982-85 period yield higher NAIRU estimates than

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[1] In this work we do not define "equilibrium" precisely. In particular, we make no attempt to distinguish short-term from long-term equilibrium. We use the term NAIRU (non-accelerating-inflation rate of unemployment) to mean the underlying temporary equilibrium rate of unemployment consistent with conditions in product and labour markets.

those that end in 1981. We suggest that this may be due to an underestimation of potential output during the 1981-82 recession, which could imply that the shorter-sample estimates are more accurate. According to the shorter-sample estimates, the NAIRU was about 8 per cent at the end of 1987.

2. Okun's Law and the NAIRU

Okun's Law is not the only relationship that can be used to infer the NAIRU[2], but it may be a good choice if the output gap can be measured accurately and if stable, reliable estimates of Okun's Law are obtained. The traditional implementation of Okun's Law relies on a time-trend specification of potential output. While straightforward, this approach has several disadvantages. First, there is a logical simultaneity between potential output and the NAIRU; potential output depends in part on the "full employment" level of the inputs (capital and labour). However, in many implementations of Okun's Law this is ignored and an "exogenous" measure of potential is used in the estimation of the parameters and subsequent calculations of the NAIRU. Second, the use of a regressed time trend to represent potential output tends to force the output gap (and, therefore, the labour market gap) to zero on average over the sample.[3] The labour market gap has probably not been zero on average over the relatively short samples typically used to estimate the NAIRU. Third, a time trend rules out shifts in the growth rate of potential output stemming from changes in

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[2] For example, a common approach is to estimate a Phillips curve and interpret the intercept, divided by the unemployment rate coefficient, as the NAIRU. This method uses the average unexplained (by the Phillips curve) wage growth over the sample as a means of inferring what the NAIRU must have been.

[3] This is not an essential feature of the time trend methodology. For example, the constant term in the time trend could be <u>imposed</u> to create a non-zero average output market gap over the sample, but this average gap would have to be estimated extraneously.

the growth rate of the inputs. This last point suggests the use of an explicit production function in place of the exogenous trend.

In earlier work at the Bank, Douglas Laxton addressed these problems. He estimated a three-equation system in which: potential output is determined by a production function, an Okun's Law equation is used to link the output and labour market gaps, and a Phillips curve is used to incorporate wage pressures.

This formulation has the advantages of determining potential output and the NAIRU simultaneously, of allowing changes in the evolution of the capital stock and the labour force to influence potential output, and of bringing nominal wage information to bear on the estimation of the NAIRU via the Phillips curve. As is standard, the determinants of the NAIRU were hypothesized to include demographic variables and measures of the attractiveness and availability of Unemployment Insurance benefits.

Laxton presented several versions of his system, with different specifications of the NAIRU and different estimation periods. In general, the UI variables were not significant and the measured NAIRU depended solely on the share of women in the labour force. His estimates of the NAIRU trended upward through the sample, reaching a range of 8 to 9 per cent in 1984.

This paper reports updated estimates using Laxton's model. The principal motivation for the update was to assess the impact of more recent data and the impact of major revisions to the output data (1986 national accounts revisions), to the capital stock data (due to national accounts investment flow revisions and to revised depreciation rates from Statistics Canada), and to the trend factor productivity series.

3. The empirical model

The model equations are:

(1) $ugdp = \alpha_0 + etfp + (1-\alpha)*k_{-1} + \alpha*ls$

(2) $RNU - NAIRU = \beta_0 + \beta_1*(RNU_{-1}-NAIRU_{-1}) + \beta_2*ugdpgap$

(3) $w = p + h + \sigma_1*g + \sigma_2*(RNU-NAIRU) + \sigma_3*AIB + \sigma_4*prel$

(4) $NAIRU = \delta_0 + \delta_1*UI + \delta_2*DEM$

where:
ugdp is the log of output,
ls = log(LF * (1 - NAIRU)) is the log of the full employment labour force (LF is trend total hours worked),
k is the log of the capital stock,
etfp is the log of trend total factor productivity,
g is productivity growth (first difference of etfp),
h is the growth rate of trend average hours,
RNU is the national unemployment rate,
ugdpgap is the residual from equation (1),
w is the first difference of the log of wages,
p is inflation expectations, estimated as a second-order Almon lag of the first difference of the log of the consumer price index,
prel is a seven-quarter moving average of the first difference of the log of an output deflator over the CPI,
AIB is a dummy variable for Anti-Inflation Board wage and price control period,
UI is the maximum Unemployment Insurance wage-replacement rate times the proportion of the labour force covered, and
DEM is 1 minus the adult-male proportion of the labour force.

The first equation is the production function. The productivity term (etfp) is measured as the smoothed Solow residual from this production function using actual (not full-employment) capital

and labour use.[4] The smoothing technique assumes that growth in productivity was on average equal to the growth in this residual. The labour input is simply the trend labour force adjusted for the equilibrium rate of unemployment (i.e. NAIRU).[5] The NAIRU is defined in equation (4). Equation (4) is not stochastic; in estimation it is substituted into the other equations.[6] It is shown separately here for clarity.

The second equation is Okun's Law. The labour market gap (RNU - NAIRU) is assumed to be a function of its own lag and of the output market gap. The output market gap is defined as the residual from equation (1). It is this feature, along with the use of the same NAIRU in equations (1), (2) and (3), that ensures consistency between the output and labour market gaps.

The use of a residual from one equation as an explanatory variable in another gives rise to an identification problem. With a general variance-covariance matrix, the parameters cannot

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[4] The smoothing technique is that described by Prescott (1986), using a parameter of 1600. The etfp variable is determined prior to the final estimation of the production function in the simultaneous system. We could have taken the parameters from the production function estimated here and reapplied the Prescott method to get a revised etfp, re-estimated the system, and so on, but this was judged unnecessary. The etfp measure would not be changed noticeably, and we know from other sensitivity tests that the system results are not much affected by changes in the details of the smoothing procedures used.

[5] The trend labour force is composed of a trend participation rate (taken from RDXF, the Bank of Canada's quarterly econometric model; the RDXF variable is called PARATET), an estimate of the labour force population (provided by Statistics Canada and used in RDXF under the name NPOP), and trend average hours worked (the two methods for constructing this variable are described below).

[6] That is, (4) is substituted into the first three equations, which are then estimated together to obtain all parameters, including the δs of the NAIRU equation.

be identified. The system was estimated assuming a diagonal variance-covariance matrix, which is sufficient for identification, using the method of maximum likelihood.[7]

The third equation is the Phillips curve. Wage growth is assumed to depend on expectations of consumer price inflation (with the coefficient constrained to unity), the trend growth of labour productivity, the labour market gap, the wage and price controls that prevailed from the fourth quarter of 1975 to the third quarter of 1978, and the expected difference between the growth of the producer price[8] and that of the consumer price. This last term is meant to capture the willingness-to-pay of firms, and might represent changes in Canada's international terms of trade or cyclical productivity effects. The ratio specification, along with the unit coefficient on consumer price inflation expectations, ensures that the Phillips curve is accelerationist when both consumer and producer prices have settled on the same constant growth rate.

Equation (4) shows the determinants of the NAIRU considered in this study. The demographic variable is the share of young and female workers in the labour force. The data are taken from the Labour Force Survey (LFS), and the series is shown in Chart 1.

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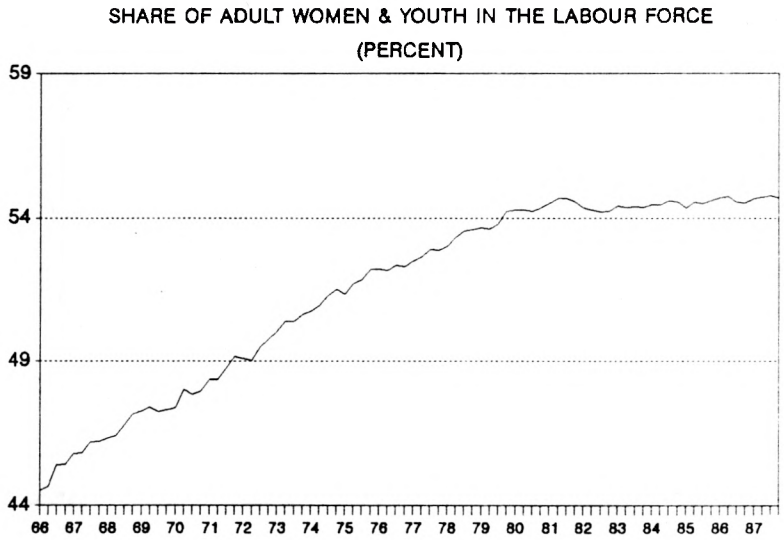
[7] See Armstrong (1985) for a description of the rationale for using a diagonal covariance matrix in the more general case, where an explanatory variable is highly correlated with the fitting error of one of the equations. In this work the problem arises in its extreme form where the fitting error from one equation appears directly elsewhere in the system. Our estimator imposes diagonality by rescaling the equations using the diagonal form of the GLS transform. The system is iterated using the Zellner method until the variance estimates converge. The result is equivalent to maximum likelihood with a diagonal covariance matrix.

[8] The producer price is measured by the GDP deflator or a commercial sector output deflator, depending on the sectoral definition used for the Phillips curve. We report results based on both definitions.

CHART 1



It is often argued that young workers have different labour market characteristics, and that these explain the relatively high unemployment rate of the group. The share of young workers in the labour force increased in the 1960s and early 1970s (the "baby-boomers"), peaking in the mid-1970s. As the baby-boomers have aged, the proportion of young workers has fallen back to its level of the early sixties. The temporary bulge of young workers could have raised the aggregate unemployment rate simply because the representation of high-unemployment individuals increased. However, a straightforward "accounting" calculation that holds labour force shares fixed shows that this effect is small. Essentially, this is because the bulge of young workers was small relative to the total work force.

A more sophisticated argument is that youths and other labour market participants are poor substitutes in production (because the young are inexperienced, for example) and the relative wage between youths and others has been slow to adjust (perhaps due to minimum wage laws). In this case, the bulge in the young working population would show up as an increase in the unemployment rate of that group. The unemployment rate of youths did rise through the 1970s, in comparison with that of the general work force. The

picture is clouded somewhat by the 1981-82 recession, because it is thought that youth unemployment is more cyclical than that of prime-aged workers (possibly because of seniority rules).

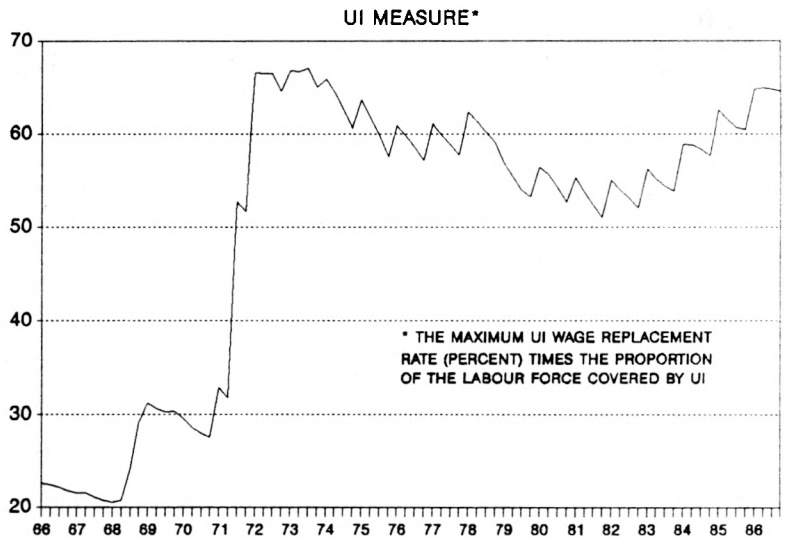
In fact, the DEM variable is dominated by the upward trend in the share of females in the labour force. It is often argued that women, too, have different labour market characteristics. However, women have not had a history of unemployment rates systematically higher than those of men. Thus, although the increase in female labour force participation has been both substantial and sustained, an "accounting" calculation (holding labour force shares fixed) does not differ much from the measured unemployment rate. Again, recourse could be made to an argument that men and women are not perfect substitutes in the production process, at least in a period of transition to much higher levels of female participation, and that the relative wage of women has not fallen enough to compensate for their higher participation. Consistent with this hypothesis, the unemployment rate for women has trended up somewhat, compared to the rate for men.

Finally, it has been argued that the rapid increase in the labour force during the 1970s and 1980s has increased the equilibrium unemployment rate of all groups (males, females, young and old) because the labour market has had difficulty "digesting" the influx. This argument relies on labour market rigidities of some sort, but does not depend on assumed differences between demographic groups.

A potential drawback of using the DEM variable as an explanation of the NAIRU is that it behaves essentially like a time trend. There is, in fact, an upward trend in the unemployment rate over the sample that is easily "explained" by such a trend. If the trend reflected something other than demographics it would be

difficult to rule out a spurious relationship between DEM and the unemployment rate.[9]

CHART 2



The unemployment insurance variable, shown in Chart 2, is meant to capture the increase in the NAIRU that is theoretically expected when unemployment insurance becomes more generous, in terms of payout in comparison to the wage rate, or is made available to more workers. Many researchers have found that the UI reforms of 1971, which significantly increased both the generosity and availability of benefits, raised the NAIRU in Canada.

The measure used in this paper is a statutory measure. The maximum weekly benefit is established annually and depends on a long moving average of wages. The coverage of the UI program is established by law. The advantage of a statutory measure is its independence from the business cycle. This is in contrast to measures that use actual UI payouts. The actual payout depends on the number and duration of claims, which depend in turn on the

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[9] However, as a simple test a linear time trend was included in equation (4) along with DEM. The time trend proved insignificant and DEM remained significant, with little change in the coefficient or its estimated standard error. More complicated trends, such as a quadratic, have not been examined.

business cycle. This simultaneity could lead to a confusion between unemployment stemming from a recession, which would not be an increase in the NAIRU, and unemployment due to a changed institutional environment, which would be. The disadvantage of a statutory measure is that it does not capture several important features of the UI program. For example, regionally extended and labour force extended benefits are not captured, although they have varied from time to time and they significantly change the generosity of the system.

4. Estimation

Equations (1) to (3) were estimated simultaneously. This allows the cross-equation restrictions embodied in equation (4) to be imposed. In particular, the restrictions imply that the NAIRU from the Okun's Law/production-function subsystem is the same as that in the Phillips curve. These restrictions were tested by using intercept and slope dummies in the Phillips curve, allowing it to have different δ coefficients from the production function and Okun's Law.[10]

Under the restrictions, the NAIRU series is given by the fitted values from equation (4). If the cross-equation restrictions do not hold, however, the system generates two NAIRU series, one from the Okun's Law/production-function subsystem and the other from the Phillips curve.

The UI variable was always insignificant, and only the results excluding this variable are presented. This result is contrary to the conclusions of much of the literature on the NAIRU. In particular, the UI reforms of 1971 have typically been found to have added 1 to 2 percentage points to the NAIRU. It may have

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[10] A Likelihood-Ratio test was used to test for the difference in all the coefficients in equation (4) as a group.

been, however, that it took some time for the labour market to adjust to the reforms and therefore that the UI variable used here moves too abruptly in 1971.[11] In fact the unemployment rate fell at about the same time, probably for cyclical reasons. The estimated gap measures (Charts 4 and 7) show excess demand in the early 1970s, corroborating this interpretation. Another problem is that the measure used here may be missing important aspects of the UI program.

Estimates from two different sample periods are presented. The first runs from the first quarter of 1967 to the fourth quarter of 1985. The second runs from the first quarter of 1967 to the fourth quarter of 1981. The starting point is imposed by data availability, particularly the hours data. The difference in endpoints was motivated by the presence of the large recession in the early 1980s. The Okun's Law methodology relies on being able to properly measure the extent of business cycles. The 1981-82 recession was unusual in its severity, and it is interesting to see the effects of including this period on NAIRU estimates.

Two different data sets were used, one for an economy-wide Phillips curve and the other for a commercial sector Phillips curve. Both used economy-wide data for output and factor inputs (capital and the labour force).

The first data set has an economy-wide definition of the Phillips curve. Average labour income (national accounts labour income divided by paid employment from the LFS), the GDP deflator (for the relative price variable, prel), total average hours (from the LFS) detrended using Prescott's (1986) method, and the same etfp as in the production function (in first-difference form, i.e.

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[11] Indeed, Laxton was able to find transformations of the Unemployment Insurance variable that did enter significantly. We did not pursue this point in the current research.

productivity growth) were used. The advantages of estimating this system are that data are easily obtained for the economy as a whole, and that the restriction $\sigma_1 = 1/\alpha$ can be imposed.[12]

The second data set has a commercial-sector definition of the Phillips curve. Commercial-sector definitions of weekly wages (drawn from the Survey of Employment, Payroll, and Hours and its predecessor, the ES-1), a commercial-sector output price (for the relative price variable, prel), trend hours (constructed from LFS data and smoothed using a regression), and a measure of etfp constructed from a commercial-sector production function were used.[13] It can be argued that the wage processes are different in the commercial and non-commercial sectors because the former is driven by profits and the latter is not. Most investigators have preferred to work with commercial-sector Phillips curves. A disadvantage is that data must be generated for the commercial sector, and the definition of this sector is not clear-cut.

4a. Estimates using the aggregate economy Phillips curve

The results are summarized in Table 1. The Phillips curve coefficients for the NAIRU variables were never significantly different from the Okun's Law/production function coefficients, and only the constrained estimates are presented. The estimated

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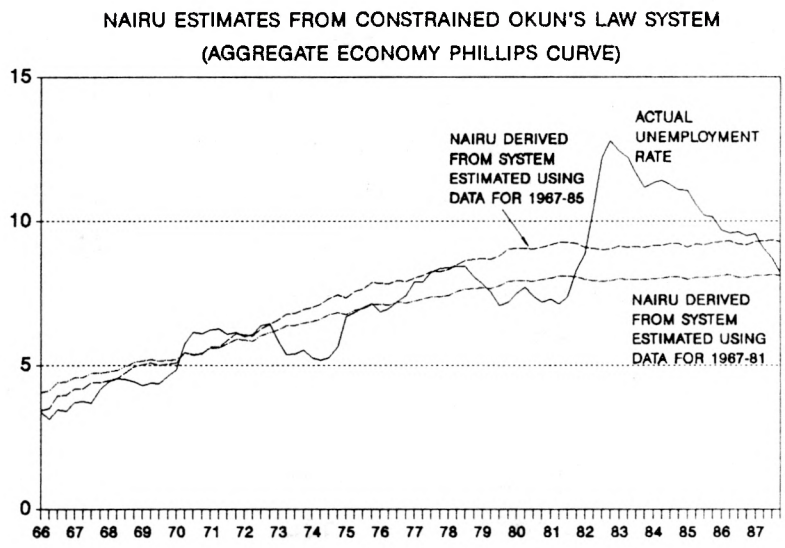
[12] This restriction follows from the assumption that labour ultimately receives the income from technical progress. This is the case in standard economic growth models and would also be the case in a small open economy whose return to capital is determined by world markets.

[13] These correspond to the variables WNIC, PGPP, HAWCT and ETFP in RDXF, the Bank of Canada's quarterly forecasting model. Note that, for this data set, etfp and average hours in the production function are not the same series as etfp and average hours in the Phillips curve. They are conceptually the same, but the Phillips curve measures are for the commercial sector, whereas the production function is for the economy as a whole.

NAIRUs, calculated from equation (4) which is the last box in the table, run from 3.4 per cent in the first quarter of 1966 to 9.3 per cent in the fourth quarter of 1987, using an estimation sample from the first quarter of 1967 to the fourth quarter of 1985. Using the shorter sample, which ends in the fourth quarter of 1981, the NAIRU runs from 4 per cent to 8.1 per cent. The NAIRU estimates are shown on Chart 3.

CHART 3



The systematically higher estimates of the NAIRU for the 1970s and 1980s from the longer sample reflect the fact that the system cannot explain the higher unemployment in the 1980s in any other way. As a result, the estimator gives a higher coefficient to the trending DEM variable and raises the level of estimates of the NAIRU through most of the sample. It may be correct that the NAIRU rose in the 1980s, but for other reasons (i.e. there are variables missing from the system). Perhaps the UI program became more generous in a way not captured by the variable used here (e.g. enhanced regional UI benefits). Another possible explanation is that the collapse of world commodity prices in the early 1980s reduced labour demand in resource-related industries, which tend to be geographically concentrated in the Atlantic region and western Canada. Sticky wages combined with labour immobility (across both industries and regions) would raise the

NAIRU, at least until commodity markets recovered or workers finally migrated. In support of this hypothesis, central Canada, which has probably been less affected by commodity markets, has recovered more rapidly and more fully from the recession than have other regions of the country. Laxton tried a measure of regional/industrial employment dispersion in an attempt to capture this. Although his measure is similar to those used successfully by Lilien (1982) for the United States and Samson (1985) for Canada, it was not significant in his model.[14] It would be worthwhile to explore alternative variables in this context. Two obvious possibilities are the terms of trade and commodity prices (especially energy prices).

Another possible interpretation of the results is that the longer sample has produced upwardly biased estimates of the NAIRU because equations (1) and (2) together underestimate potential output when the recession years are in the sample. Since there is a linear relationship between the output market and labour market gaps (given by equation (2)), this would be reflected as an underestimate of the latter; that is, in a higher estimate of the NAIRU. In general, a possible serious problem with the Okun's Law approach (or any approach that regresses the actual unemployment rate on other variables) is that an unbiased measure of the demand-induced component of the business cycle must be available (or represented in the model structure) if the residual identification of the NAIRU is to be accurate.

Chart 4 shows the estimated output market gaps for the long- and short-sample estimates. Our discussion here focusses on the results from the short-sample estimates. The equations indicate

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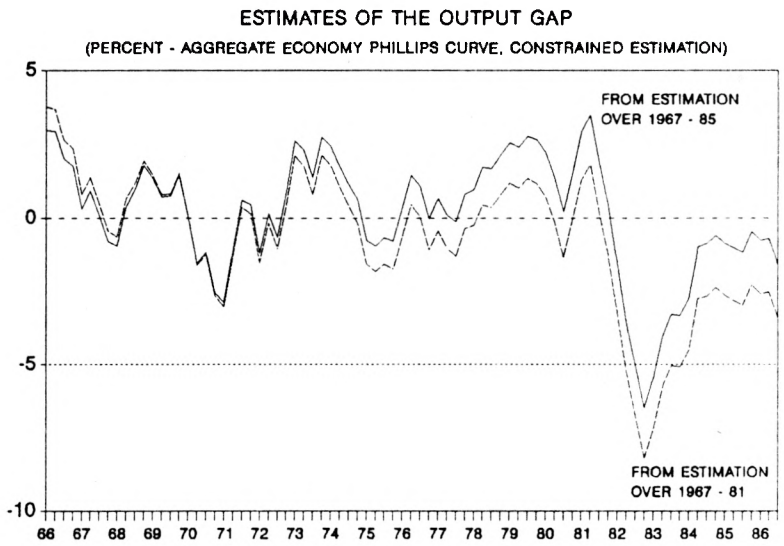
[14] However, Lilien and Samson used a different technique to capture the business cycle than did Laxton. The Lilien method has been criticized by Abraham and Katz (1986), among others, for inadequately accounting for the business cycle.

CHART 4



that output exceeded its potential on average over the estimation sample, consistent with the observation of increasing inflation rates during that time. The Okun's Law equation implies that a one-percent increase in the output market gap is associated with an increase in the labour market gap of 0.168 percentage points on impact. Since the labour market gap is specified as a function of its own past, the long-run increase will be 0.168/(1-0.77) or 0.73 percentage points.

The point estimate of the DEM coefficient indicates that a one percentage point increase in the female/youth labour force share has increased the NAIRU by 0.39 percentage points. This is far larger than would have been expected from the accounting calculations discussed in Section 3.

4b. Estimates using the commercial sector Phillips curve

The details are shown in Tables 2 and 3. The cross-equation constraints on the NAIRU variables were rejected at the 5 per cent level in the long sample and at the 10 per cent level in the

short sample.[15] Therefore, two sets of estimates are reported. Table 2 has the estimates with the restrictions imposed. The corresponding estimates of the NAIRU are shown in Chart 5. The constrained short-sample estimates are not credible; the DEM coefficient has the wrong sign, yielding a NAIRU that falls over time. The problem is that the constrained commercial sector Phillips curve does not estimate well over this period, as indicated by the statistical insignificance of many of its estimated coefficients.

CHART 5

NAIRU ESTIMATES FROM CONSTRAINED OKUN'S LAW SYSTEM
(COMMERCIAL-SECTOR PHILLIPS CURVE)

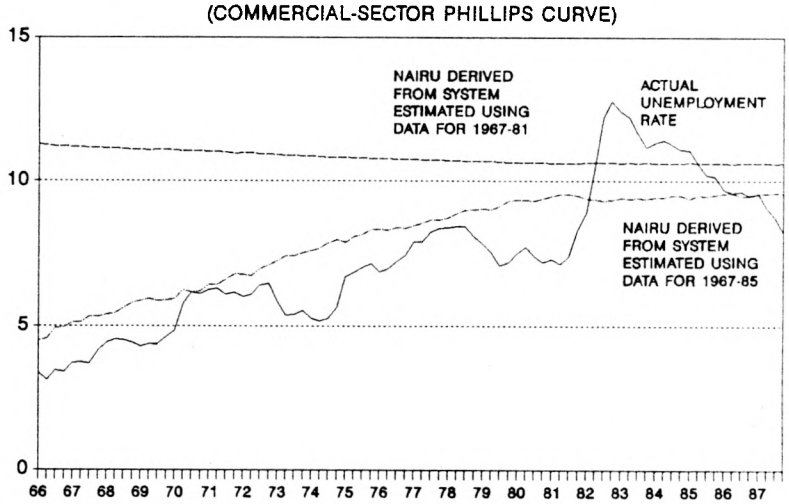


Table 3 shows the estimates from the unconstrained system. The $(\delta_0+\delta_{00})$ and $(\delta_2+\delta_{22})$ coefficients in the Phillips curve box are the unconstrained coefficients. No standard errors are shown because those generated by the program are not for the total coefficient, but only for the increment beyond the Okun's Law/production function coefficient.[16] These standard errors are not reliable as tests of the constraints, although the log likelihoods, discussed above, are.

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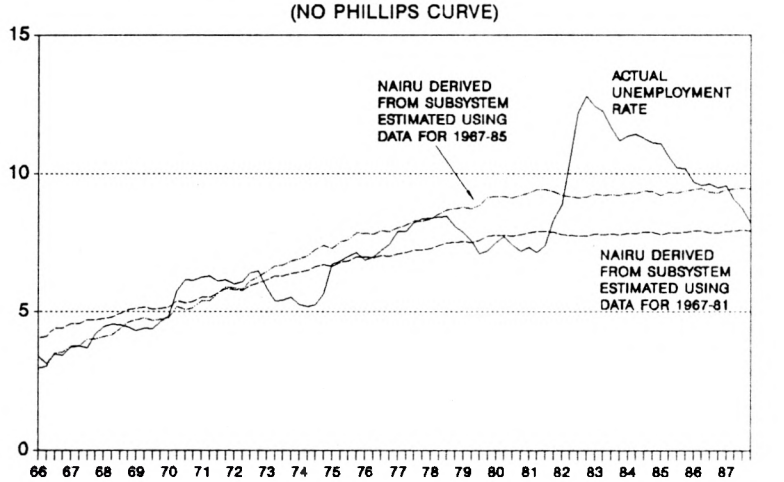
[15] The log of the likelihood ratio in the short sample is 5.33. For the long sample it is 8.4.

[16] That is, $(\delta_0 + \delta_{00}) + (\delta_2 + \delta_{22})$*DEM appeared in the Phillips Curve. The constraint was implemented by imposing $\delta_{00}=\delta_{22}=0$.

Chart 6 shows the NAIRU estimates from the Okun's Law/production-function subsystem, derived from both estimation samples, when the constraints are relaxed. Again, the shorter sample period yields a lower NAIRU at the end of 1987: 7.9 versus 9.4 for the long sample. The unconstrained Phillips curve yields a NAIRU of about 30 per cent for both samples.

CHART 6

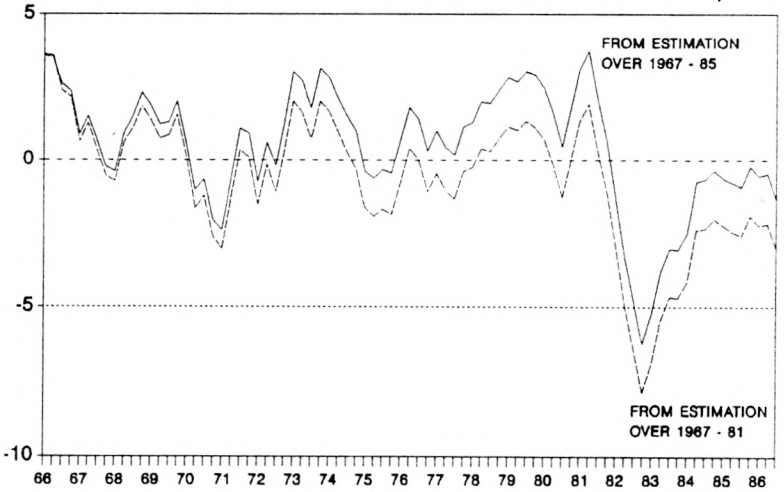
NAIRU ESTIMATES FROM THE OKUN'S LAW/PRODUCTION-FUNCTION SUBSYSTEM
(NO PHILLIPS CURVE)



This incredible number arises because the NAIRU coefficients, although significantly different from the Okun's Law estimates, are relatively large, poorly determined, and unstable.

CHART 7

ESTIMATES OF THE OUTPUT GAP
(PERCENT - COMMERCIAL-SECTOR PHILLIPS CURVE, CONSTRAINED ESTIMATION)



Both the constrained and the unconstrained systems yield output gaps that are on average positive (excess demand) over the short sample, but

approximately zero when the recession is taken into account. Chart 7 shows the measured output gaps from the constrained system. The gap estimates are very similar to those from the system using the economy-wide Phillips curve (Chart 4).

The unconstrained estimates in Table 3 are virtually identical to the constrained estimates of Table 1, except for the Phillips curves. This suggests that the Okun's Law/production-function subsystem is dominating the estimation. Experimentation with different specifications also suggests that the Phillips curve estimates are much less stable than the Okun's Law estimates.

5. Conclusions

The estimates of the NAIRU generated from the methodology used in this paper vary according to the estimation period and level of sectoral aggregation chosen. Of the estimates reported here, the ones we prefer are those from the shorter sample, using the economy-wide Phillips curve or just the Okun's Law/production-function subsystem. These results are not affected directly by the difficulty of measuring the depth of the 1981-82 recession and the inconsistencies arising from the commercial sector Phillips curve. Accordingly, our best estimate of the NAIRU at the end of 1987 is about 8 per cent. However, two areas stand out as requiring further attention.

First, the only variable "explaining" the NAIRU is the labour force share of females and youth. Moreover, the estimated effect of this variable is much too large to be explained by pure compositional changes. Thus, recourse must be made to less well-grounded arguments based on production non-substitutability or to labour market "digestion" problems.[17] More research needs to be

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[17] Conversely, the estimated coefficients could be interpreted as evidence of the existence of such effects.

done into the effects of other observable variables on the NAIRU. In particular, it is surprising that the UI variable performs so poorly, and it would be worthwhile trying other UI measures (or transforms of the one used here) that allow gradual response to changes. Other possible determinants of the NAIRU include minimum wages, income tax rates, non-wage benefits, regional variables (to capture regional dispersion of employment opportunities and the cost to workers of moving), and energy or other commodity prices (to capture the effects of real shocks, the adjustment to which may be gradual).

Second, use of Okun's Law depends on a reliable measure of the output market gap. It has already been argued that this measure may be problematic for the 1981-82 recession. Although the output gaps shown on Charts 4 and 7 are not implausible, it is worth noting that the short-sample estimates imply that a significant output gap remained at the end of 1987, whereas the labour market gap is quite small. The output gap in this paper is generated from a very simple Cobb-Douglas production function and an (economically) arbitrary detrending of the Solow residual. It would therefore be interesting to consider the implications of other production assumptions for the pattern of total factor productivity.[18]

Finally, it must be noted that the Phillips curve and Okun's Law are empirical relationships with imprecise theoretical foundations. Hence, the coefficients are difficult to interpret in terms of the demand and supply relationships that underlie the labour market dynamics described by equations (1) to (4). In contrast, the NAIRU calculations treat the estimated parameters as if they were structural (i.e. true constants that are unaffected by changed assumptions about economic conditions) by

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[18] Attempts were made to use time trends to capture technical change in the production function, but with little success.

imposing a zero output gap and computing the corresponding unemployment rate. Estimation of a structural model of the labour market would alleviate these concerns, albeit with added difficulties of specification and estimation.

TABLE 1

Aggregate Economy Phillips Curve
Constrained Estimates

Sample for estimation	67Q1-85Q4	67Q1-81Q4
Production Function	R^2=0.99	R^2=.996
Intercept (α_0)	-0.62 (0.064)	-0.75 (0.07)
Labour input (α)	0.45 (0.019)	0.40 (0.02)
Okun's Law	R^2=0.98	R^2=0.97
Lagged labour gap (β_1)	0.71 (0.068)	0.77 (0.07)
Output gap (β_2)	-22.2 (4.5)	-16.8 (4.0)
Phillips Curve	R^2=0.40	R^2=0.32
Technical change (σ_1)	2.2 (constr)	2.5 (constr)
Labour gap (σ_2)	-0.42 (0.18)	-0.61 (0.37)
AIB (σ_3)	-0.07 (0.60)	0.50 (0.66)
Relative price (σ_4)	0.57 (0.72)	0.15 (0.83)
NAIRU		
Intercept (δ_0)	-22.3 (5.2)	-13.2 (4.4)
Demographics (δ_2)	57.7 (10.1)	38.9 (8.7)

Standard errors are in parentheses.

TABLE 2

Commercial Sector Phillips Curve
Constrained Estimates

Sample for estimation	67Q1-85Q4	67Q1-81Q4
Production Function	R^2=0.99	R^2=0.996
Intercept (α_0)	-0.62 (0.07)	-0.53 (0.21)
Labour input (α)	0.45 (0.02)	0.46 (0.05)
Okun's Law	R^2=0.98	R^2=0.96
Lagged labour gap (β_1)	0.75 (0.07)	0.97 (0.03)
Output gap (β_2)	-20.7 (4.6)	-12.3 (4.5)
Phillips Curve	R^2=0.56	R^2=0.47
Technical change (σ_1)	1.6 (constr)	1.6 (constr)
Labour gap (σ_2)	-0.24 (0.10)	-0.09 (0.09)
AIB (σ_3)	-0.19 (0.33)	-0.15 (0.37)
Relative price (σ_4)	0.39 (0.27)	0.55 (0.32)
NAIRU		
Intercept (δ_0)	-17.6 (5.6)	12.0 (18.0)
Demographics (δ_2)	49.7 (10.8)	-3.8 (30.5)

Standard errors are in parentheses.

TABLE 3

Commercial Sector Phillips Curve
Unconstrained Estimates

Sample for estimation	67Q1-85Q4		67Q1-81Q4	
Production Function	R^2=0.99		R^2=0.996	
Intercept (α_0)	-0.60	(0.07)	-0.74	(0.6)
Labour input (α)	0.45	(0.021)	0.41	(0.02)
Okun's Law	R^2=0.98		R^2=0.97	
Lagged labour gap (β_1)	0.7	(0.065)	0.77	(0.09)
Output gap (β_2)	-22.5	(4.4)	-16.7	(4.8)
Phillips Curve	R^2=0.61		R^2=0.48	
Technical change (σ_1)	1.6	(constr)	1.6	(constr)
Labour gap (σ_2)	-0.15	(0.10)	-0.05	(0.19)
AIB (σ_3)	-0.23	(0.32)	-0.28	(0.37)
Relative price (σ_4)	0.46	(0.27)	0.56	(0.31)
NAIRU ($\delta_0+\delta_{00}$)	-6.21		9.8	
NAIRU ($\delta_2+\delta_{22}$)	29.8		7.8	
NAIRU				
Intercept (δ_0)	-24.9	(6.7)	-12.7	(5.7)
Demographics (δ_2)	62.8	(12.8)	37.8	(11.0)

(1)Standard errors are in parentheses.
(2)The NAIRU box shows estimates from the Okun's Law/production-function subsystem.
(3)Standard errors for ($\delta_0+\delta_{00}$) and ($\delta_2+\delta_{22}$) were not calculated.

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