THE OUTPUT GAP: MEASUREMENT, RELATED CONCEPTS AND POLICY IMPLICATIONS

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ABSTRACT

This paper compares the various approaches to the measurement of potential output and the NAIRU, and identifies practical policy implications. The respective advantages and disadvantages of each method -- the Okun's Law approach, the trend-fitting method, the production function approach, the simultaneous equations system method and the stochastic filter methods – are discussed in detail. It is noted that the production function approach, despite obvious advantages in comparison with the trend and the Okun's Law methods, has the drawback of relying on exogenous or trend values of NAIRU to get equilibrium values of labour inputs. Some of the weakness of this approach is noted to be present even in the 'fully structural' system approach, which does not overcome the limitations of its individual component equations. In search of alternatives, the stochastic univariate and multivariate filter methods are compared to the structural methods. It is reasoned that the extended multivariate filter methods in which additional structural information replaces a priori restrictions of univariate methods may be better-equipped to produce good estimates of potential output. On the NAIRU, a recommendation of the paper is that open-economy influences should not be neglected in its estimation, so that the real exchange rate is given its due role. An implication is that in a situation where a current account surplus that leads to allows a fall in the endogeneous relative price of imports prevails, the NAIRU is lowered, allowing the possibility of beneficial policy action using such a trade-off.

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I. INTRODUCTION

It has been sometimes said that the Non-accelerating Inflation Rate of Unemployment, the NAIRU, is not carved in stone. The same holds for the concept of potential output – even independently of the way the NAIRU is conceived – which has undergone considerable reformation over the years, leading to reappraisals and revisions of the output gap which is the difference between potential and actual output. The way this gap is measured has important consequences for policymaking, especially by central bankers monitoring the relationships between monetary aggregates and inflation.

The concept of an output gap that is linked to inflationary tendencies is present in Keyne's early manuscript, "How to pay for the war", but gained currency really only in inflationary Seventies. Until then, the widely used concept of potential output had a kind of engineering intonation: it is simply the maximum capacity output with all factors of production fully employed and utilized. The peak to peak trend-fitting method embodied this concept: capacity output was assumed to be reached at the peak of each cycle, leaving open the question whether all factors were indeed employed fully, or to the same extent, at all peaks.

Still, the trend-fitting method was thought to provide estimates of potential output at least as good as the somewhat more involved method based on the Okun's Law, a basic macroeconomic relationship popularized by Artur Okum (1962) in his work for the U.S. President's council of economic advisors. This relationship between the changes in unemployment – of labour, just one of the factors of production – and output growth may be considered to be more of a theorem, rather than a rigid law, since the so-called Okun's Coefficient that quantifies this link has been subject to quite a bit of variation over the years. This variation has been mostly attributed to the non-inclusion of the other production factors, which meant for instance that the effects on capital formation of the oil shocks of the seventies were not captured. To correct for this "misspecification", the Okun's Law has sometimes been used embedded in a more general formulation that encompasses the input of other factors of production as well.

The complete production function approach for the measurement of potential output has, of course, been used independently, without any reference to the Okun's Law which has had a foothold basically only in the United States. It has been used – at least by some of the research staff – at the International Monetary Fund (IMF), and is now in vogue at the OECD's Economic Secretariat. The primary advantage of this approach lies in the fact that all the various sources of output growth are represented (though sometimes measurement is arbitrary, as is usually with total factor productivity), and it is often used as complementary input even in stochastic approaches, providing structural information.

However, the concept of potential output to which the production function approach is being applied is no longer that of maximum capacity output. That was discarded hastily after the supply shocks of the seventies brought the necessity of controlling inflation to a level of urgency. Since then, potential output has been increasingly defined as the level of output consistent with non-accelerating inflation; and, accordingly, the NAIRU used as the level of equilibrium unemployment rate that is used in the Okun's Law and production function approaches to the estimation of potential output. It may be added that the popular concept of the NAIRU need not always correspond to that of the NARU, the natural rate of unemployment that Friedman (1969) wrote about, which could have very long-run equilibrium conditions built in.

In fact, in some of the so-called "fully structural" approaches, used for instance by the IMF, the NAIRU and potential output are determined simultaneously. At the other end of the spectrum is the fully stochastic approach that relies on univariate filters. Occupying a promising fertile middle ground are the "structural-stochastic" methods, espoused particularly by the Bank of Canada, which take in considerable structural information for use in their multi-variate filters which are described in a later section.

All these diverse methods for determining potential output and the output gap have their own advantages as well as disadvantages, but a discussion of these is deferred to the end of the paper, which is structured as follows. The next short section disposes of the trend-fitting method, which does not attract much attention now. Section III discusses the Okun's Law approach, and the following section extensions of it. V describes the production function-based method in some detail, followed by an examination of the common ways of estimating the NAIRU. Section

VII takes up the "fully structural" or "system" approach, followed by sections describing the univariate and the extended multivariate filter, or the "stochastic-structural" method of the Bank of Canada, respectively. Before the final section which provides some recommendations, there is a section (X) which discusses the methods adopted by the various national and international organisations, and their respective merits and drawbacks.

II. ESTIMATING POTENTIAL OUTPUT BY THE USE OF LINEAR TRENDS

This method, which is based on a maximum capacity notion of potential output, was commonly used until the 1970s because of its simplicity, and because the other concomitant approaches did depend anyway to varying degrees on trend-fitting. Linear trends are fitted through consecutive peaks, the assumption being that capacity output is reached at all peaks – and that output grows at a constant rate between successive peaks. No consideration is given to the possibility that the employment and utilization of production factors can differ between peaks. Sometimes, as something of a compromise, trends are fitted through centre points in the cycles instead.

In none of its specifications does the method take any account of inflationary pressures, nor is any macroeconomic relation an input into the procedure. During periods of supply shocks, this pure time trend method invariably produces inflated estimates of potential output, the use of time dummies for the supply shock periods being not of much help when a continuous string of supply shocks occur. However, in many of the other estimation methods such as the production function approach, time trend-fitting is resorted to partially, due to its simplicity, providing a weak link in the method.

III. THE OKUN'S LAW AND THE OUTPUT GAP

The Okun's Law is a well-established macroeconomic relationship dating back to the formulation by Okun (1962), who advanced the proposition that a one percent rise in the unemployment rate in the United states will translate into a three percent fall in the growth rate of GNP. Thus, in the following equation, 'a', the so-called Okun's Coefficient, will have a value of around 3:

$$y - y^* = -a\,(u - u^*), \tag{1}$$

where 'y' is the log of output and 'u' the unemployment rate, the superscript * representing potential or natural rate values. These potential values are often purely exogenous in this approach, fixed at some benchmark level, or obtained from underlying variables such as the labour participation rate using time trends.

Kinwall (1996) has used this approach to estimate the GNP gap for Sweden, and compared the results with those derived from an Hodrick-Prescott (H-P) approach. He uses equation (1) in the form

$$y^* = y + a\delta u, \tag{2}$$

with 1986 as the benchmark year when actual and potential output were equal, and the actual unemployment rate equal to the natural rate NAIRU. This assumption follows the usual practice when using this approach, that of making arbitrary assumptions about 'normal years' during which actual and potential output (and unemployment) have coincided. He attributes this to the fact that with the (H–P) method, the restrained growth of actual output in the recession of the early 1990s would have even affected potential output due to the end-point problem associated with this method; however, when he adopted a higher NAIRU – quite realistically – from 1993 onwards, the estimated output gap with the Okun method came closer to that obtained with the H-P filter. Clearly, the exogenous inputs of the potential values are crucial when using the Okun relationship.

There are other difficulties associated with the Okun method; Wage and price dynamics play no role whatsoever, and this is of course the reason why the equilibrium level of unemployment has to be fed in exogenously, unless the Okun's relation is presented as part of a larger system. Also, in any 'abnormal' period, such as that of the supply shocks of the seventies, this approach falters since labour is the only production factor that is explicitly considered; so the increased scrapping rate of the capital stock, for instance, due to higher energy prices, that lowers the growth of potential output, will not be captured. Actually, the Okun's Coefficient has varied considerably in the United States, from around 3 in the sixties to between 2 and 2.5 in the seventies.

All the same, the Okun's Law continues to be regarded as an important macroeconomic relationship between unemployment and growth. And it may well be that given the fact that the determination of the equilibrium levels of output and unemployment lie outside the domain of this approach, the better option would be to forecast changes in unemployment using output growth estimated by other-say, stochastic – methods.

IV. OKUN'S LAW : EXTENSIONS AND RELATED APPROACHES

As noted already, the Okun's Law has been subject to criticism because of its focus on only one of the factors of production. This exclusion of other (factor) influences in fact means that the estimated Okun's Coefficient actually represents a *composite* effect, rather than the sole effect of unemployment changes, as Prachowny (1993) points out. He embeds the Okun's relation in a composite production function relationship:

$$y = \alpha (k + c) + \beta (n + h) + t, \qquad (3)$$

where (in logs) y = output, k = capital stock, c = utilisation rate of capital, n = no. of workers, h = no. of hours, t = total factor productivity. A similar expression holds for potential output, with stars representing potential values of the variables in equation (3) :

$$y = \alpha(k^* + c^*) + \beta(n^* + h^*) + t^*. \qquad (4)$$

Then, assuming that capital stock is at its potential, from (3) and (4),

$$y - y^* = \alpha(c + c^*) + \beta(n + n^*)\ \beta(h - h^*) + (t - t^*)$$

Or, writing in terms of labour supply 'e' and the unemployment rate 'u',

$$y - y^* = \alpha(c - c^*) + \beta(e - e^*) - \beta(u - u^*) + (t - t^*)$$

From (6), it can be seen that even when unemployment is at its potential level, output can deviate from its potential level. It follows that in the coefficient that is usually interpreted as the Okun's multiplier ('a' in equations 1 and 2) the effects of changes in factor utilisation and the total factor productivity growth are also incorporated; these do not appear formally in the Okun representation because underutilization of production factors or changes in the rate of productivity growth are not concepts encompassed within this framework. In his empirical work, Prachowny (1993) did find that the composite specification (6) provided better estimates than those using (1). The potential values in (6) needed for the estimates were obtained using trend methods.

Perry (1977) follows the Okun's Law tradition in his emphasis on the labour market in the estimation of potential output, but works at a more disaggregated level. He considers altogether ten age groups, differentiating by sex as well, and determines (weighted) total potential manhours based on the estimates of potential participation rates and potential average hours for each group. Estimates of estimates of potential output are then made from total potential manhours and trend labour productivity. A study on the natural rate of unemployment for Canada (Fortin (1989)) has a similar approach, with a stable NAIRU being estimated only for males over 25, with the aggregate NAIRU being more volatile due to labour market composition effects. A detailed description of the methods adopted for the determination of equilibrium unemployment is deferred to section VI.

Even in the extended form discussed above, the Okun's approach is lacking in wage and price dynamics that influence equilibrium unemployment levels. An early attempt at the inclusion of these influences was by Friedman and Wachter (1974), who included expectational variables in an unemployment equation, which in bare elements was an Okun's law formulation. In the system approach to be described in section VII, the Okun's relationship forms part of a system of equations that includes wage and price equations, potential output and the natural rate of unemployment being determined simultaneously. In Vector Autoregression (VAR) approaches also, for instance in Blanchard and Quah (1989), the Okun's relation is part of a whole system, just one of the relations between innovations. The VAR methodology enables a distinction to be made between supply and demand shocks, the former having long-lasting effects, but does not make use of the macroeconomic relationships that form the key inputs into the system approach, used for instance, by the IMF.

V. THE PRODUCTION FUNCTION APPROACH

In this approach, estimates of potential output are obtained from the production relation between factor inputs and output when the former are at their potential level, as are factor productivities – or total factor productivity, when technical progress is of the disembodied form. The definitions of factor inputs used in the estimate are not self-evident; for instance, there is considerable ambiguity about the definition of equilibrium labour inputs, and often it is the actual stock, rather than any estimated potential, of capital that is used. This method is exemplified by the OCED (Giorno, Richardson, Rosevare and Van den Noord (1995)) approach, which is now being used in preference over the H-P filter approach that was opted for earlier:

Business sector production is (small letters representing logs),

$$y = a + \alpha n + (1 - \alpha)\, k + t, \tag{7}$$

where n is labour input, k capital stock, α is the average labour share (in a Cobb-Douglas formulation), a is a constant and t is total factor productivity. From (7), the factor productivity series is calculated and then smoothed with the H–P filter to get the potential series, which is substituted back into the function,together with actual capital stock and potential labour input to get potential output:

$$y^* = a + \alpha n^* + (1 - \alpha)k + t^*, \tag{8}$$

stars representing potential values of variables. For obtaining the potential labour input used in (8), the equilibrium level of unemployment is pinned down first. The next section is devoted to a discussion of the concept and estimation of the equilibrium level of unemployment. Here we may just note that while the OECD has chosen to work with the concept of NAWRU, the non-accelerating wage rate of unemployment, the NAIRU is often the preferred concept: primarily because price inflation is a policy target variable, while the control of wages is not a goal in itself.

To get at the NAWRU, it is first assumed that the rate of wage inflation is proportional to the unemployment gap:

$$D^2\text{Log } W = -\, b(U - \text{NAWRU}), \tag{9}$$

where D is the difference operator, W the wage rate, and U the actual unemployment rate. For a period of stable NAWRU, the value of b is obtained from (9), and then substituted back to get a series for the NAWRU, which is then smoothened. It may be noted that the NAWRU series so obtained will tend to move with actual unemployment, in contrast to the constant NAIRU obtained in a long-run equilibrium in the absence of supply shocks with permanent effects.

The NAWRU estimates thus obtained is used in the following way to get the labour input used in (8) in the determination of potential output:

$$N^* = L(1 - \text{NAWRU}) - EG, \tag{10}$$

where L = smoothed labour force = working population * trend participation rate, and EG is government employment. Potential output for the economy as a whole is obtained by adding *actual* value added in the government sector to the business sector estimates obtained by using (10) in (8). In comparison, potential output estimates fluctuates less from year to year with the H–P filter smoothing method used earlier.

The OECD also uses a more detailed production function approach that can incorporate the effects of energy price changes. Torres and Martin (1990), in their work for the OECD, has the following nested CES specification for the business sector:

$$Q = (a(Le_f)^{\rho} + b(KE)^{\rho})^{1/\rho}, \tag{11}$$

where KE is the actual capital-energy bundle, L is actual employment, ef is the labour efficiency index and a and b are scale parameters. In the production function, the scrapping rate has been endogenized, thus supplying the vintage element; an estimated proportion of the capital stock is adjusted in each period with shifts in real energy prices. Technical progress is labour-embodied, represented by the labour efficiency index, and is assumed to follow the productivity development in the U.S for other OECD countries, a kind of "catch-up" hypothesis.

Potential output is obtained from equation (11) using the actual capital-energy bundle, potential employment and the labour efficiency index. It will be the level of output consistent with non-accelerating wage inflation, since that is the definition (NAWRU) of equilibrium unemployment adopted, leading to the estimation of potential labour input using (10). The labour force variable used there is normalised using a geometric moving average, to eliminate as far as possible the effects of cyclical variations in the participation rate. It may be mentioned that the concept of the NAIRU has also been used by the OECD elsewhere (Coe (1985)), along the lines of the discussion in the next section

The incorporation of energy as a production factor leave – or, rather, along with capital as a composite factor, to be precise – and the endogenization of the scrapping rate seems to be a necessary step to capture the effects of the energy price shocks of the seventies, and the estimates of potential output for the OECD countries studies are lower than those using time trend methods for same period. But it may be mentioned that similar effects on capacity growth for Sweden in the middle of the 1970s has been obtained by Markowski (1988), based solely on real wage costs, using a model similar to Knoester and Sinderen gap (1980).

The merits and drawbacks of the general production function approach are discussed in section X. An innovation of the OECD approach is the user of the "catch-up" hypothesis for the estimation of potential labour productivity, which avoids the common problem associated with the time trend estimation of total factor productivity.

In KOSMOS, the macroeconometric model of the national Institute of Economic Research, Stockholm, the concept of potential output is akin to that of *capacity* output, with *full* employment (actual employment + unemployment) labour input being used in the production function. In the case of industry, actual output is derived using an endogenous capacity utilization index, which is the ratio of actual to potential output, given as (see Ernsater and Markowski (1994))

$$CU = f\left(\frac{S}{y_p}\frac{RIS}{DIS}, PR\right).$$

Where S is total sales, y_p is potential output, RIS is real inventory stock, DIS is desired inventory stock and PR is profitability. As in Helliwell (1984), actual output will be decided by the level of capacity utilization. But note that in Helliwell's paper the denominator in the capacity utilization index expression is normal output, derived using actual employment: at the actual employment level, utilization varies from the normal due to demand shocks. A case can be made out for measuring potential output using equilibrium labour inputs consistent with an estimated natural rate of unemployment, rather than full employment; then the capacity utilization index will represent deviations from an equilibriumlevel of employment, rather than from a level which is never ever reached.

VI. DETERMINING THE NATURAL RATE OF UNEMPLOYMENT – CONSISTENT WITH NON-ACCELERATING INFLATION

The usual way of obtaining the NAIRU is from an augmented Philips Curve equation (Gordon (1996), Fortin (1989)). Such an estimate need not be synonymous with Friedman's (1969) natural rate of unemployment, which is the level of equilibrium unemployment ground out by a fully-specified general equilibrium equation system, unless additional long-run equilibrium conditions are imposed as will be discussed later in this section. The estimation of NAIRU as commonly done from wage and price equations is as follows in the simplest specification:

$$w_t = a_0 + a_1 p_{te} - a_2 u_t \qquad (12)$$

$$p_t = b_0 + b_1 (w - q)_t + b_2 z_t \qquad (13)$$

Lagged terms have been omitted for simplicity. Also, there will be an additional equation representing price expectations formation based on lagged prices. Equation (12) is a Philips Curve relation for wages – in logged form; w is the wage rate, u actual unemployment, and subscript e represents an expected variable. (13) is a price mark-up equation, where q is the trend productivity growth and z a vector of other relevant variables.

In the "long-run" equilibrium with stable inflation, realized expectations, and full nominal wage adjustment to expectations as well as full mark-up for wage costs, we have

$$p_{te} = p_t = p_{t-1};\ a_1 = 1,\ b_1 = 1. \qquad (14)$$

The NAIRU, the level of unemployment consistent with this non-accelerating inflation equilibrium is solved out to be independent of the price level – representing a vertical long-run Philips Curve – and depends only on the coefficients in the equations. It is, however, influenced by trend labour productivity. Also, when employer's payroll taxes are taken into account, $(w - q)$ in the price mark-up equation will be replaced by $(w + s - q)$, where s is the payroll tax rate, and the NAIRU will be seen to vary with changes in s as well. Now, substituting (13) and (14) into (12), the NAIRU can be solved out as.

$$U^* = ((a_0 + a_1 b_0 - (1 - a_1 b_1)w - a_1 b_1)w - a_1 b_1 q)/a_2.$$

With a_1 and b_1 equal to unity, the natural rate of unemployment is independent of wage inflation.

Of course, there could be other, country-specific, variables which can influence the estimated NAIRUs. These may be incorporated in a simple fashion by writing the wage equation (12) as

$$w_t = a_0 + a_1 p_{te} - a_2 u_t - a_3 u_{t-1} + a_4 x_t\ . \qquad (15)$$

Here, the presence of lagged unemployment is to capture the possibility of *hysteresis*, the possibility of cyclical changes in actual unemployment affecting the natural rate. A few reasons have been advanced in support of this possibility. Workers laid off for fairly long periods could suffer from "skill deterioration", leading to their permanent alienation from the labour market; or, after their initial discharge in a recession, "insiders" may set wages rates so high that their reentry becomes difficult even when the economy emerges from the downturn.

In (15), x represents a vector of other relevant variables. This could include variables such as the degree of unionization, profits etc., which may be justified by bargaining models of wage determination; there may be also structural variables relating to labour market composition. These structural variables could be directly tested for cointegration relationships with unemployment, as in a Bank of Canada working paper (Cote and Hostland (1996)).

The price mark-up equation (14) could be formulated in error correction terms, as in Torres and Martin (1990):

$$p_t = b_0 + b_1 c_{te} - b_2(p_{t-1} - c_{t-1}) + b_3(R - 1), \tag{16}$$

where c represents total unit cost, including capital cost (in (13), capital costs would be submerged in the constant term). R is the ratio of actual to potential output. Since the error correction term is in level terms, price will equal cost in long-run equilibrium. Also, then, actual output will equal potential, so that there is consistency between factor and product markets.

The open-economy aspects of NAIRU determination are given prominence in Joyce & Wren–Lewis (1991). Basically, they use a Layard & Nickell (1986) type model, with imperfect competition in goods and labour markets – with a bargaining model of wage determination – complemented by endogenous real exchange rate determination this studence missing determination – complemented by endogenous real exchange rate determination via current account imbalances. But, we can even extend the framework represented by equations (12)–(14) to arrive at the insights that an explicit open economy extension has to offer:

Rewrite (13) as

$$p = b_0 + b_1 (w - q) + b_2 z + b_3 p_m , \tag{17}$$

where subscript t has been dropped for convenience and "p_m" is the import price that is expected to affect the mark-up of firms. Solving as before by substituting (17) and (14) into (12), the NAIRU is obtained as

$$u* = \frac{((a_0 + a_1 b_0 - (1 - a_1 b_1)w - a_1 b_1 q + a_1 b_2 p_m))}{a_2}. \tag{18}$$

with a_1 and b_1 equal to unity, the NAIRU is independent of the wage rate, but varies with the import price. Hence, in a period of supply shocks – which have permanent effects, which is the sense in which they are usually distinguished from demand shocks even in the stochastic filter approaches – the NAIRU will not be constant. For a constant NAIRU, i.e., invariant with respect to import price changes, additional assumptions have to be made: that

$$w = p_m;\ 1 - b_1 = b_2\ . \qquad (19)$$

This may be considered to be a long-run condition, domestic and foreign inflation coinciding.

Joyce and Wren-Lewis (1991) derive the following relationship from their wage and price equations:

$$w^* + p^* = a_1 cu - a_2 u + a_3 s + a_4\,(m - p), \qquad (20)$$

where starred *w* and *p* are target real wage and target profit margin respectively (all in log form), *cu* is capacity utilization, *s* is the payroll tax rate (they have other taxes as well), m is import price, and p domestic price. In steady state when inflation is constant, the LHS of (20) will be zero, capacity utilization will be unchanging, and then the level of unemployment consistent with this scenario is the NAIRU, which is seen to depend on the real exchange rate (and the payroll tax rate).

The implications of this dependence can be easily illustrated. Suppose there is a current account surplus as there is in Sweden now; with an endogenous real exchange rate that moves to eliminate trade imbalances (as is in Joyce-Wren-Lewis's larger model), there will be a real exchange appreciation, which from equation (20) above, is seen to *reduce* the NAIRU. In other words, a current account surplus is an indication of a scenario where reductions in actual unemployment and the NAIRU are possible (of course, if the current account is *always* constrained to be balanced, as in Forslund (1995), then this possibility vanishes; but note that the definition of NAIRU does not incorporate current account balance).

Hence the NAIRU can be time-varying. There may be other structural factors which cause this variation, in addition to the supply shocks discussed above, for instance, changes in labour market composition. A study by the Bank of Canada (Cote and Hostland (1996)) found trend unemployment – which does not exactly correspond to the common definition of NAIRU – to be cointegrated with the degree of unionization in the labour market, as well as with payroll tax rates.

Gordon (1996) estimates a time-varying NAIRU in a simple fashion, complementing a Philips Curve equation with the following hystersis – type specification:

$$u_t^* = u_{t-1}^* + \varepsilon_t, \tag{21}$$

where, if the standard deviation of the error term is not zero, a varying NAIRU series is obtained, even if the Philips Curve had implied a constant one. The choice of the standard deviation is here a key step, somewhat similar to the choice of the smoothing parameter in the H–P filter method that will be discussed later.

For estimating the natural rate or structural rate of unemployment, Koskinen & Öller (1996) and Assarson & Jansson (1996) use the method of additive decomposition of the unemployment rate into two unobservable components: a natural rate or a trend component, and a cyclical component. The natural rate here is not synonymous with the NAIRU, since there is no reference to the rate of inflation. Koskinen and Oller use the "median filter" for the decomposition, while Assarson and Jansson use what is commonly known as the unobserved components model: along with the additive decomposition of the unemployment rate into the natural and cyclical components, they have a random walk specification for the cyclical rate, and a formulation where the natural rate depends on its own lagged value and the lagged cyclical rate – so that hysteresis is present. The basic idea behind the unobserved components model is that the unobservable variables – such as the natural rate – are determined from the path of observable variables. Here, for that exercise, further information is needed, and for that the authors use two relationships (in fact, one is sufficient): that between capacity utilization and cyclical unemployment, and that between world demand and domestic cyclical unemployment. The authors choose these relationships as versions of the Okun's Law, with cyclical output-related measures co-varying with cyclical unemployment. The Kalman Filter method is used to estimate the unobserved components of the aggregate Swedish unemployment rate.

Stochastic, univariate, methods of estimating potential output, similar to the approach of Koskinen & Öller (1996), are discussed in section VIII, while semi-structural methods, similar to the work of Assarson & Jansson (1996), but with a richer variety of structural information, including inputs from the wage – price sector, are taken up in section IX.

VII. THE SYSTEM APPROACH

The IMF's (Adams and Coe (1990)) methodology represents the comprehensive "system approach" for determination of potential output and the NAIRU. These are determined *jointly*, based on a system of simultaneous equations. Essentially, what is done is as follows: a number of single-equation estimates are made from wage, price, unemployment and output equations and then these equations are combined and estimated as a system, with appropriate cross-equation restrictions. The estimation is carried out for the U.S. only.

Inputs which are exogenous for the single-equation estimates are endogenized under this approach. For instance, trend output and productivity used in the individual unemployment, wage and price equations can be replaced by expressions for potential output and productivity obtained from the production function. Similarly, the expression for the natural rate of unemployment obtained from the unemployment equation is an input into the wage equation. Such an approach constrains the estimates of equilibrium unemployment and output to be consistent with each other (otherwise, one is often assumed when estimating the other; for instance, when using the Okun's relationship to estimate potential output, equilibrium unemployment is often an exogenous input).

The equation system used is, in its bare elements, as follows :

$$U = \alpha_0 + \alpha_1(y - y^*) + \alpha_2(Z_u) + \varepsilon_u \tag{22}$$

$$\mathrm{d}w = \mathrm{d}p_e + \beta_1(U - U^*) + \beta_2\mathrm{d}q^* + \beta_3 Z_w + \varepsilon_w . \tag{23}$$

$$y = \delta_0 + \delta_1 h + \delta_2 k + \varepsilon_y \tag{24}$$

$$\mathrm{d}p = (\mathrm{d}w - \mathrm{d}q^*) + \delta_f(y - y^*) + \varepsilon_p . \tag{25}$$

Lowercase letters represent logarithms, and dx stands for a change in variable x. w, q, y, U and p represent the wage rate, productivity, output, the unemployment rate and the price level respectively. The superscript * represents a natural or trend value, while the subscript e represents expectations. Z represents other – often structural-variables. (22) is an Okun's relation, (23) is a Philips Curve equation. The other two relationships represent a production function (h and k are labour and capital inputs respectively) and a price equation where the output gap and unit labour costs determine the growth of prices.

The way the single-equation estimates are combined within a system can be seen by focusing on, say, the unemployment equation. From equation (22), the natural rate of unemployment is estimated. This is done by including a number of structural variables related to the labour market, but without incorporating any information on wage and price developments. Some assumption about trend output will also be required. The equation is estimated in a dynamic form, the long-run version of which is

$$U^* = a_0 + a_1 NWLC + a_2 UIRR + a_3 RMW + a_4 UNN, \qquad (26)$$

UNN being the degree of unionization, *UIRR* the average weekly unemployment insurance replacement ratio, *NWLC* employer's social security contributions as a proportion of total wage costs, and *RMW* the minimum wage – multiplied by the labour force share of the age group 16–24, who are the ones most likely to be affected.

Then, when the system is estimated as a whole, the natural rate term in the Philips Curve equation for wages is replaced by the expression (26) for the natural rate obtained from an individual equation. Similarly, in the unemployment and price equations, trend output term is replaced by the expression for potential output derived from the production function – which is derived from an individual equation with assumptions about the level of equilibrium factor inputs. These substitutions, which amount to cross-equation restrictions, ensure that the estimates of potential output and the equilibrium unemployment rate obtained are consistent with each other.

But though the estimated potential values are consistent, the weaknesses of the individual equations are carried over into the system estimation. Thus, the assumed level of equilibrium factor inputs – note here there is no energy input specified – in the production function do still influence the derived potential values. Though a proxy variable, the input of research and development, is used to capture total factor productivity growth, a time trend is used in addition so that this approach is really not "fully structural".

VIII. STOCHASTIC APPROACHES: UNIVARIATE FILTERS

The system approach described in the previous section attempts to come up with structural determinants of the shifts in potential output and the natural rate of unemployment, avoiding the use of shift dummies and ad hoc trend fitting (as far as feasible, at least). However, the estimates derived by this purely structural approach have been rather wide off the mark. Presumably, there is still insufficient knowledge about the important structural determinants (a common criticism of any macromodelling activity), especially since modelling the political decision making process – even those that lead to supply shocks such as energy price increases – is next to impossible. This has led to the increased adoption of less detailed models that still use structural information, but are well-suited for the stochastic environment. But before coming to the description of such multi-variate filters complemented with structural inputs, used for instance extensively by the Bank of Canada, the univariate approach for the determination of potential output will be discussed.

In the use of *univariate* filters for such as the Hodrick-Prescott (HP) filter, the underlying assumption is that the potential output is driven by a stochastic process. The filter helps to decompose an observed shock into a supply (permanent) component and a demand (temporary) component – the identifying difference being that supply shocks have lasting, permanent effects, while demand shocks have only transitory effects. Of course, in practice, when the demand shocks are of a longer duration, it will be difficult to separate the two, especially at the end of a cycle. Nevertheless, such a mode of classification has been used popularly since the work of Blanchard and Quah (1989).

The HP filter is derived by minimizing the sum of the squared deviations of output from its trend, subject to a smoothness constraint that penalizes deviations in the trend. So HP trend values are those that minimize.

$$\phi = \Sigma(y_t - y_{p,t})^2 + \lambda\Sigma((y_{p,t+1} - y_{p,t}) - (y_{p,t} - y_{p,t-1}))^2 \qquad (27)$$

In (27), y is output, with the subscript p representing the trend or potential value. The first term is the so-called global distance, while the second term represents the fluctuating part, the fluctuations assumed to be dominantly transitory, due to demand disturbances. The choice of the smoothing parameter, the multiplicator for the second term that penalizes deviations, plays a key role. With a vary large value chosen for the smoothing parameter, the restriction becomes dominant, and potential output is just modelled as a linear trend – the assumption being that demand disturbances have relatively large variances which are thus minimized, leaving only the supply or the permanent component. A very small value of the smoothing parameter will mean almost no restriction at all, and the potential series will follow the actual very closely.

The Central Bank of Sweden (Apel, Hansen and Lindberg (1996) has used the HP filter method for measuring the output gap, and compared the results with those obtained from an unobserved components method. As mentioned in section II, Kinwall (1996) has made a comparison of the results for the output gaps obtained using the HP filter method and the Okun's Law. The relative merits of these different methods are taken up in section X, which also discusses the approaches of various national and international organizations to this issue.

The *unobserved components* method may be considered to be a combination of univariate filter approach with appropriate – often ad hoc – structural information that helps in locating the path of unobservable potential variable values. The work of Assarson and Jansson (1996) on these lines to differentiate between permanent and cyclical components of unemployment was discussed in section Apel, Jansen and Lindberg (1996) of the Central Bank of Sweden (Riksbanken) have a similar approach, drawing inferences about unobserved potential output from observable changes in actual output and inflation:

$$y_{p,t} = \mu + y_{p,t-1} + \varepsilon_t \tag{28}$$

$$dy_t = \beta_0 + \beta_1 (y_{p,t-1} - y_{t-1}) + u_t. \tag{29}$$

$$d\pi = \gamma_1 (y_{p,t-1} - y_{t-1}) + e_t. \tag{30}$$

In (28)–(30), subscript p represents trend values, while the operator d stands for a one-period change. The last terms in all equations represents random influences. Equation (29) implies that output tends to return to a trend, and resembles the minimization of the deviation of actual from trend values represented by the first term in the HP filter. Equation (30) relates the changes in inflation to the output gap – an effect which may not be all that strong for Sweden, according to Kinwall (1996) and Koskinen and Öller (1996) – who are discussing the unemployment gap instead. The observable variables, actual output and its change, and the change in inflation, are used to determine the level of potential output. The estimation of potential output is carried out using a Kalman filter, which is basically an iterative process: it proceeds by guessing the initial value of potential output in period $t - 1$, and then makes estimates of changes in output and inflation; then, the prediction errors with respect to these variables are used to update the initial estimate of potential output.

and the process is repeated until the latest observation is reached, thus generating a time series for potential output.

IX. THE STOCHASTIC-STRUCTURAL APPROACH: MULTIVARIATE FILTERS WITH STRUCTURAL INPUTS

Essentially, if a univariate filter method is complemented by the addition of structural information, it is termed a multivariate filter. But in more elaborate versions the filter is applied to more than just one variable in the process of estimating the potential value for the final target variable.

Laxton and Tetow (1992) present a *multivariate filter* in which the HP filter's univariate approach with its fluctuation restriction is complemented by information from a Philips Curve inflation rate equation and an unemployment rate equation. The general minimization problem has the usual HP filter's penalty function and the global distance term for the output gap, but also gap terms for inflation and unemployment, all the gap term attached with time-varying weights. This allows the incorporation of information from other sources. The intutive idea is illustrated by the following reasoning: if inflation is rising, and it is not due to other factors, then output must be above its potential level.

The HP filter identifies supply and demand shocks in a rather mechanical fashion, which may falter when the shock occurs towards the end of the sample. Laxton's and Tetlow's extension also does not include much information about the determination of output. However, Butler (1996), in a technical report for the Bank of Canada, uses a decomposition of output combined with considerable structural information to distinguish supply and demand shocks, in an extensive combination of the stochastic and structural approaches. Other work in this area follow the lead set by Blanchard and Quah (1989), and use VAR methods – with their impulse responses – to estimate the supply and demand components of each innovation, only the supply components considered to feed into potential output. The extended multivariate filter of Butler (1996), in contrast to Laxton's filter, which is directly applied to potential output, *decomposes* output into its components and applies the filter at disaggregated levels. The decomposition used has some practical measurement advantages:

Starting out form a Cobb-Douglas production function

$$Y = (TFP)N^{a}K^{1-a}, \tag{31}$$

Where N is labour input, K capital and a the labour share or labour-output elasticity, and nothing that the marginal product of labour is

$$\frac{\delta Y}{\delta N} = a\frac{Y}{N} \qquad (32)$$

Output is, in *log terms*

$$y = n + \mu - \alpha, \qquad (33)$$

where the three right hand side variables stand for labour input, marginal product of labour (MPL) and labour-output elasticity respectively.

Equilibrium values of these variables are needed for the estimation of the potential level of output.

The equilibrium level of employment is given as the multiple of the total population, equilibrium participation rate and the equilibrium employment (1-equilibrium unemployment) rate. The *equilibrium* participation rate is obtained by fitting it to the *observed* participation rate and a *trend estimate* of the participation rate. Separate weights are given to these two gaps, and the smoothness parameter – similar to the HP filter smoothness parameter – is also chosen appropriately.

The general method used is to specify an objective function that constrains the weighted average of the squared errors (deviations) from each of the conditioning terms. The value of the unobservable variable that best explains the conditioning terms, or minimizes the squared error terms – subjected to restrictions, here an end-of sample growth restriction and a smoothness constraint similar to that in the HP filter – is the filter's estimate of the unobserved variable. Thus, the filter's estimate of the equilibrium participation rate is that which minimizes the sum of the weighted, squared deviations of the gaps of the equilibrium rate from a trend estimate and an observed participating rate, subject to the restrictions imposed.

The NAIRU estimate – needed for calculating equilibrium labour input, n, – uses a structural estimate of the trend unemployment rate developed in a cointegration analysis by Cote and Hostland of the Bank of Canada (1996), the previous period's NAIRU, and a Philips Curve relation. The objective function that is minimized is given as

$$(u - u_n)^2 W_1 + (u_{n-1} - u_n)^2 W_2 + (c - u_n)^2 W_3 + e^2 W_4,$$

where u is the actual unemployment rate, c is the trend unemployment rate, subscript n denotes the NAIRU, with the additional subscript (−1) representing a lagged value, e is the residual from a Philips Curve equation, and the W_s are the – priori – chosen weights. There is also an end-of-the sample growth restriction, and a smoothness restriction similar to that used in the HP filter.

The use of the growth restriction in the objective function above reduces the importance of the last two observations. The previous period's NAIRU is used to prevent large variations. 'e' is the residual from an asymmetric Philips Curve with the property that a negative gap between actual unemployment and the NAIRU is more inflationary – in absolute terms – than the disinflationary effect of an identically sized positive gap.

The estimation of potention output in (33) also requires an estimate of the equilibrium values of the marginal product of labour and the labour-output elasticity. Under the CD production function assumption and perfect competition, labour's share of income is equal to the labour-output elasticity. To remove cyclical variations in this, the HP filter is applied with the smoothness parameter set to a high value of 10000 (the usual choice is 1600) to the measured income share to get the equilibrium value.

The *equilibrium marginal product of labour* is estimated more elaborately, the following conditioning information being used, with appropriate weights given to the squared gaps: previous period's equilibrium MPL, the real producer wage W, the residual from an inflation-MPL relation, and the residual from a modified Okun's relation relating changes in the output gap to lagged changes in the MPL gap. The Okun's modified relation is included since it can be a pointer, as when the marginal product rises above the equilibrium level, firms hire more, reducing the unemployment gap. The inflation-MPL relation provides another similar pointer. The usual growth and smoothness restrictions are also applied.

In comparison with HP filter estimates of potential output for Canada, the extended multivariate filter estimates fare well, current estimates needing less revision, according to Butler (1996). But it may be possible to improve the quality of the structural information provided (some of the conditioning information in Butler (1996) is of a somewhat indirect nature), taking some inputs from the simultaneous system approach that uses basic macroeconomic relationships with clear causality. Also, open economy aspects may be incorporated more, particularly in NAIRU determination.

X. THE VARIOUS METHODS: THEIR USE IN ORGANIZATIONS, MERITS AND DRAWBACKS

The so-called pure smoothing or trend-fitting methods – which find scarce use now anywhere – are characterised by lack of information concerning the determinants of potential output or the natural rate of unemployment. These totally atheoretic methods derive estimates of potential values by fitting trends to ouput data, usually through the peaks of cycles, embodying the notion of a maximum capacity output as the level of potential output. So the cyclical position of the last observation becomes very important, even when the fit is through a limited number of successive peaks only. The basic advantage of this method is its simplicity, requiring no information at all about economic relationships, the level of factor employment and utilisation etc. But this also constitutes its basic disadvantage in times of economic disturbances, and is bound to give inflated estimates in periods of, say, supply side shocks, regardless of the degree of smoothing and sophistication. In stable periods, the trend estimates thus obtained may be used as rough bench marks to note whether labour and product markets are getting heated.

The Okun's Law, considered a basic macroeconomic relationship between changes in unemployment and the growth rate of output, has been used extensively in the U.S – by the President's Council of Economic Advisors and economists attached to The Brookings Institution, for instance – to derive estimates of potential output. The Okun's Coefficient is quite stable over fairly long periods marked by the absence of supply shocks, which together with the underlying relatively constant output growth and unemployment rates even prompted the belief that simple trend-fitting could do the job as well. The demerits of the Okun's methods are clear: no consideration is given to factor markets other than the labour market; and even for the labour market, the wage and price dynamics which provides the key influences, are ignored. So any period of large relative price changes will push this method's estimates wide off the mark. But authors using this broad approach, for instance, Perry (1977), have often worked at disaggregated levels of the labour market, isolating important structural determinants of unemployment.

The production function approach, in contrast, can claim the merit of decomposing potential output into all its components, and is, in this way, a fully disaggregated approach, especially if aggregated labour input is also disaggregated into its various determinants. In fact, extended versions of the Okun's Law approach use a production function – in which this relation is embedded – to obtain the *isolated* effects of changes in unemployment. Yet, theuse of a production function for estimating potential output values does not amount to a *fully* structural approach, since equilibrium or potential values of the various inputs are exogenous. Often, the natural rate of unemployment that is needed to get the equilibrium labour input is assumed to be the fairly constant rate that has or had prevailed over a period, and potential total factor productivity is determined – at least partially, even when proxies such as the input of research and development are used – by the trend method. Also, the assumption of a particular form of production function itself can be unduly restrictive. The problem of determining the potential input capital is usually got around by the use of the actual stock of capital. The production function approach is now being used by the OECD, in preference to the HP filter method that was in use earlier, and has also been used by the staff at IMF. The Central bank of Sweden (Apel, Jansen and Lindberg (1996)) has also used the production function approach and compared results with those obtained using HP filter and unobserved components methods.

The system approach is more comprehensive than the production function method in that much of the exogenous inputs in the latter are endogenized here – and is thus put forward as being a fully structural, simultaneous approach. As seen in section VIII, the IMF's system method determines the potential level of output and the natural rate of unemployment simultaneously, including inputs from the wage-price sector and considering structural factors in the labour market. Yet, while consistency can be thus maintained between the estimates of potential output and unemployment, some of the weaknesses of the individual equations, which with cross-equation restrictions combine to form the consistent system, remains. For instance, the production function depends at least partially on an estimate of trend productivity from outside the system; in this sense the approach is not fully structural, and an important part of the estimation does not possess the advantage claimed for it.

Thus, not only do methods devoted to comprehensive modelling of the supply side have the irredeemable drawback of being unable to include *all* relevant structural information; they are all dependent to some extent or other on time trend-fitting. But it had been noted earlier that pure time trend methods that tried to handle periods of supply disturbances by using dummy variables didn't work well either. A continuous string of supply shocks permanently lowered potential output in a way that time trends couldn't capture, even with spline and kink modifications. This led to increased adoption of methods that treat the stochastic element of potential output development explicitly, with a basic premise that permanent changes in output are caused by supply shocks.

But *univariate* stochastic methods such as the HP filter method, while they are simple to apply, have the disadvantage that they use only very limited information – even when additional information may be there just for the taking. Only the information from realized output is used to estimate the level of potential output. Given this lack of information, which also implies an inability to distinguish between demand and supply shocks, arbitrary smoothing, based on assumptions about the relative variance of supply disturbances, has to be resorted to for the estimation. There is also the difficulty of separating out persisting demand-side effects from supply disturbances, particularly at the end of the sample.

Multivariate filter methods, in contrast, tend to take in considerable additional information, not restricted to the sole output variable. Often, each of aggregate output's individual components, they themselves disaggregated into structural determinants, are smoothed by filter techniques. Reliance on any pure time trend is avoided, and basic macroeconomic relations as well as ad hoc structural information are used so that they may be termed stochastic-structural methods, which use structural modeling, rather than arbitrary assumptions, about demand and supply shocks. Sometimes informed judgements are also incorporated as inputs, which may be important particularly at end-of-sample points. The Bank of Canada works extensively with these methods for the estimation of potential output and the natural rate of unemployment, which seem to be able to side-step the disadvantages associated with pure structural, time trend, or stochastic methods.

XI. CONCLUSION

A totally structural approach – even of the simultaneous system type – as well as the univariate filter methods seem to have drawbacks that are avoidable. So does the Okun's Law-based method, which may, in fact, be better utilized to predict changes in unemployment using estimates of potential output derived elsewhere – and the Okun's coefficient estimated in a period relatively free of shocks. The output gap may be a better predicator of the unemployment gap than of inflationary surges: the output gap-inflation correlation seems weak for Sweden.

An extended multivariate filter method on the lines of that used by Butler (1996) of the Bank of canada, with additive structural information replacing the a priori restrictions of univariate methods, seems a good candidate for producing better estimates of potential output. It also has the advantage that the filter is applied to each of the component – and often their determinants – of potential output, at a very disaggregated level, and also avoids having to deal with estimations of trend total factor productivity and capital stock (but with some restrictions on the production function). But it should be possible to further improve the quality of structural information fed in, using well-established relationships such as those used in the simultaneous system approach, to replace some of the more indirect or ad hoc relations.

There may be a case for replacing the concept of capacity output in KOSMOS, the macroeconometric model of the National Institute of Economic Research,. Stockholm, with that of potential output based on an estimated natural rate of unemployment. Currently, the level of actual output in industry is derived using an index of deviations in factor utilization from the level of output that corresponds to full employment – that is never ever reached. It may be more intuitive to work with an index of deviations in utilzation from an equilibrium level of employment – that is attainable.

As regards the estimation of the equilibrium level of unemployment, the NAIRU, open-economy influences should be fully incorporated-which is usually not the case even in multivariate filter approaches. Clearly, the NAIRU, as is commonly defined, depends on the real exchange rate. A longer-run equilibrium concept, that imposes strict continuous current account balance may be smacking more of Friedman (1968), and may not be also resonant with the stochastic approaches where supply shocks are deemed to have permanent effects. This does have some identifiable policy implications: in a situation where a current account surplus that leads to or allows a fall in the (endogenous) relative price of imports prevails, the NAIRU is lowered as described in section V. Hence there seems to be an unemployment-current account trade-off which is now in a favorable constellation for beneficial policy action in Sweden.

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