COMPUTING POTENTIAL OUTPUT AND THE OUTPUT GAP FOR THE PORTUGUESE ECONOMY*

*Vanda Almeida***

*Ricardo Félix***

1. INTRODUCTION

Gross Domestic Product (GDP) is one of the main welfare indicators in developed economies. It is certainly the most widely used indicator whenever the economic prosperity of a country is an issue to be assessed. In the case of the Portuguese economy, this indicator points towards a weak economic performance in the recent past, and deserves a deeper analysis that goes beyond the usual conjunctural assessment of the evolution of each aggregate demand component. This article suggests an interpretation of this phenomenon based on economic growth theory and on the concept of potential output, enabling an assessment of the supply side conditions and the identification of some structural factors that might have limited the Portuguese economy growth since the beginning of the millennium.

Using appropriate techniques, GDP can be decomposed into a structural component and a conjunctural component. The first one is usually named as "potential output" and it can be defined as "the level of output at which the economy's resources are fully employed or, more realistically, at which unemployment is at its natural rate" (Mankiw, 2003, pp. 246). The second component, usually named "output gap", is the deviation between the actual level of output and the potential output and it includes temporary elements that are shaped by business cycle and other very short-run fluctuations.

The computation of potential output and the output gap for the Portuguese economy enables not only an assessment of economic growth potential, but also the measurement of the cyclical position of the economy and the identification of changes in the pattern of business cycle evolution. These indicators usually play a relevant role in different domains of economic analysis, such as in the computation of structural indicators (for instance, the cyclically-adjusted budget balance) and in the appraisal of inflationary pressures in the economy stemming from the demand side. Additionally, these indicators are also used in the assessment of the overall consistency of the macroeconomic projections for the Portuguese economy.

Potential output is not an observable variable and must therefore be computed using an information set that contains observable variables, using techniques that combine macroeconomic theory with statistics and econometrics. These techniques are usually classified into two broad categories: statistical methods, which decompose mechanically real GDP time series into its trend, cycle and irregular components; and structural methods, which use economic theory in the process of potential output computation. Since potential output resulting from the implementation of the previous methodologies is not an observable variable, it is not possible to evaluate the accuracy of the computed figure based on the usual goodness of fit measures, in contrast to what usually happens with observable variables. Thus,

* The opinions contained in this article belong to the authors and do not necessarily coincide with those of the Banco de Portugal. The authors would like to acknowledge the useful comments of Nuno Alves, João Amador, António Antunes, Mário Centeno, Ana Cristina Leal and José Ferreira Machado, as well as the cooperation of the Banco de Portugal Research Department Forecast Unit. Responsibility for any errors and omissions remains ours.

** Economic Research Department.

the point estimate obtained for each year in the sample should not be taken as the true figure, but as an amount with a strong probability of being close to the true magnitude of the variable.

This article explores some of the most commonly used methods for computing potential output and the output gap and applies them to Portuguese economy data. Among the statistical methods, the Hodrick and Prescott (HP), the Baxter and King (BK) and the Christiano and Fitzgerald (CF) filtering methods were implemented.[1] Concerning the structural methods, the production function approach was considered in two alternative formulations: the CES[2] production function and the Cobb-Douglas function, which is a particular case of the former.

This article is organised as follows: section two describes the alternative methods used to compute potential output; section three discusses the empirical results obtained by applying those methods; and section four, presents the main conclusions of this study and suggests directions for further research.

2. METHODS FOR COMPUTING POTENTIAL OUTPUT

Potential output is a non-observable variable, as it measures a phenomenon that cannot be empirically observed: the quantity of goods and services that an economy can produce by making full use of all its available resources.

The need for computation of potential output has led to the development of several methodologies, which combine distinct subjects of economic analysis such as macroeconomic theory, statistics and macroeconometrics. These methods make use of information on observable variables to obtain results for potential output, and reflect not only the information they use but also the properties of the techniques they apply. In general, these methods are grouped into statistical or structural methods, according to the techniques they use and the information they incorporate.

2.1. Statistical methods

Statistical univariate methods[3] are purely mechanical procedures, which can be used to decompose any time series into different components. They are used for identifying components with strong persistency, usually called tendency, and components with weak persistency, usually associated with cyclical and very short-run movements.

The direct application of these methods to the observed output series produces a smoothed series, called trend output, which is taken to represent potential output. The remaining components (cyclical and erratic) correspond to the output gap.

Univariate statistical methods have a direct interpretation and are generally easy to implement, being a practical way to compute potential output. However, these techniques do not incorporate any macroeconomic theory, which limits the interpretation of the results they produce and restricts its utility in the analysis of the behaviour of the economy. Additionally, statistical methods suffer, in general, from end-of-sample problems, which are usually tackled by extending the output series, introducing, however, a new source of uncertainty in the computation process. Finally, it is also important to account for problems in the treatment of structural breaks, since these methods spread the impact of a break through many periods, influencing potential output growth in several periods instead of having effects strictly at the moment in which the break occurred.

(1) For further details see Hodrick and Prescott (1997), Baxter and King (1999) and Christiano and Fitzgerald (1999).

(2) CES is the acronym for Constant Elasticity of Substitution.

(3) Statistical methods can be grouped into two categories, univariate and multivariate. In this article, we will focus on the univariate methodologies.

In practice, statistical methods simply apply bilateral moving averages to the historical output series, to filter out components with distinct frequencies. Among the several univariate techniques available, this article covers three main methods, which are frequent in the literature on economic growth and business cycles: the Hodrick-Prescott filter (HP) and the band-pass filters Baxter and King (BK) and Christiano and Fitzgerald (CF).

The HP filter is a simple smoothing procedure that extracts a non-linear trend component from observed output by minimising a weighted average of the variability in the trend and its deviations from actual output. Formally, trend output is obtained through the minimization of the following loss function:

$$\min_{y_t^T} L = \sum_{t=1}^{S}(y_t - y_t^T)^2 + \lambda\sum_{t=2}^{S-1}(\Delta y_{t+1}{}^T - \Delta y_t{}^T)^2 \tag{1}$$

where y_t and y_t^T are the logs of observed and trend output respectively,[4] S is the number of observations and λ is a smoothing parameter. The minimization of the loss function implies a choice of a value for the smoothing parameter, which represents a penalty for variability in the growth of trend output: a higher value for λ implies smoother estimates for trend output and consequently a smaller output gap.

The HP filter has some good features that have contributed to its wide utilisation, including the fact that it renders the output gap stationary, as presented in King and Rebelo (1993), and the fact that it is flexible and simple to implement. However, there are also some problems associated with the HP filter. The first one comes from the choice of the appropriate smoothing parameter λ, which is largely discretionary and far from being consensual. A second shortcoming is commonly known as the end-of-sample problem, which results from the fact that towards the edges of the sample, as leads and lags become unavailable, the HP filter gradually turns into an asymmetric filter, overemphasising the importance of the last observations.[5] This way, estimates of trend output for recent history suffer from bias, which is particularly serious because estimates for recent periods are typically those in which policymakers are more interested for purposes of policy decision. A common way of tackling this issue is to extend the output series forward using reliable projections. Finally, many studies refer[6] that when used with data that is integrated or nearly integrated, the HP filter can induce spurious cycles, i.e. it can generate cycles even if they are not present in the original data.

Another univariate type of filtering technique is the band-pass filter, which relies on the theory of spectral analysis of time series data. This methodology is used to transpose time series fluctuations represented in the time domain, to fluctuations in the frequency domain. Assuming that business cycle fluctuations correspond to a well-defined band of frequencies, it is then possible to apply the filter to the observed output series, and isolate the observations corresponding to the pre-defined band, obtaining the output's cyclical component. In practice, the filtered series consists of a weighted average of the original time series, where the weights attributed to each component of the series are determined according to the frequencies we wish to retain. The filter is the array of weights that, when applied to the original series, produces the cyclical component of output. More formally, the filtered series is given by:

$$B(L)y_t = \sum_{j=-\infty}^{\infty} b_j L^j y_t \tag{2}$$

where $B(L)$ represents the band-pass filter, b_j corresponds to the weight attributed to y_{t-j}, and L^j stands for the usual lag operator.[7]

(4) Variables in small letters represent the natural logarithms of the correspondent variables in big letters.

(5) For further details see Giorno *et al.* (1995), Cerra and Saxena (2000) and Mohr (2005).

(6) See, for example, Harvey and Jaeger (1993) or Cogley and Nason (1995).

(7) For any variable X_t, the lag operator L^j is defined such that $L^j X_t = X_{t-j}$.

The BK and CF filters are probably the two most widely used band-pass filters. The BK filter performs a finite and symmetric bilateral moving average, imposing the same number of leads and lags and symmetry of weights, which implies that observations in a similar position on each side of the central observation are given equal weights. These characteristics have the advantage of assuring that the filtered series has no phase shift, i.e., that the timing of peaks and troughs is consistent with the behaviour of the unfiltered series. However, this is achieved at a cost of losing observations at the beginning and end of the sample. Usually, to solve this problem, the series are extended using the same type of techniques mentioned for the HP filter.

The CF filter, contrary to the BK filter, uses all observations available in the sample, forward and backwards, implying that in each period, the number of leads differs from the number of lags, which turns the filter asymmetric with a varying weighting scheme. This way, the CF filter overcomes one of the limitations of the BK filter, the loss of observations at the beginning and the end of the sample, but it may introduce the phase-shift problem already explained.

2.2. Structural methods: the production function approach

Structural methods, contrary to statistical, take economic theory into account in the process of computation of potential output and the output gap. They establish a link between potential output and other macroeconomic variables, which introduces the opportunity of examining the underlying economic factors that drive changes in potential output and therefore gives the possibility of deriving some economic interpretation from the evolution of the obtained results, instead of just assessing their value. However, the application of this type of methods implies a prior choice of an adequate model, which necessarily consists of a simplification of reality and relies on a set of assumptions about the structure of the economy that may or may not be entirely correct. In addition, these methods require a large amount of information, which may be a problem in situations where there are limitations in assessing the data or when their quality is questionable. It is also worth noting that, in general, structural methods are still dependent on the utilization of statistical univariate methods to calculate trend components for some variables used in the computation process, which revives the limitations associated with statistical methods, already discussed.

One of the keystones among structural methods is the production function approach. This approach looks at the supply side conditions of the economy, postulating an aggregate production function that explicitly models output as the outcome of a production process, depending on: the available quantity of factors of production, the productivity of these factors, and their weight in output. Potential output is obtained as the result of the defined production function when its contributing inputs and productivity are at their sustainable long-run levels.

When compared to other structural methods, the production function approach has the important advantage of allowing for an explicit growth accounting exercise, which expresses potential output growth as a function of the growth rate of each of its determinants.

2.2.1. The CD and CES production functions

The functional form adopted for the production function synthesizes in a very simple way the technology used in the productive process, i.e. the way factor inputs are combined to produce output. There is not, however, a consensus as to the best functional form to adopt, and several different forms have been proposed in the literature. Among these, the two most widely used, in the literature on economic growth, are the CES production function, and a particular case of it, the CD function. These functions differ in many aspects, including in the complexity of their functional form and in the restrictions they impose on the technology underlying the production of goods and services in the economy.

The CD function is, most probably, the most widely used functional form for the production function, mainly due to the fact that it is analytically simple and straightforward to calibrate. Furthermore, when one looks at data concerning long periods of time, the characteristics of the CD function seem to be compatible with the observed facts for a wide range of economies.

The most popular functional form, for the CD production function, considers two productive factors, capital and labour, and is formally expressed as:

$$Y_t = A_t L_t^{\alpha} K_t^{1-\alpha}, \ 0 < \alpha < 1 \tag{3}$$

where A_t represents total factor productivity (TFP), K_t corresponds to the capital stock, L_t is total employment, and α is a constant that corresponds to the elasticity of output with respect to labour. This elasticity is calibrated to match the empirical average labour share obtained from the national accounts data, being in line with one of the major assumptions of the CD function, the stability of the income factor shares in output. It is therefore important to keep in mind that in order to be able to apply the CD function, the historical information on the income factor shares must point to their constancy over time. Furthermore, this assumption has the important implication of unitary elasticity of substitution between factors of production. This is a rather restrictive assumption, meaning that an increase in the relative price of one of the factors will always be accompanied by a proportional decrease in the relative utilisation of that factor.

A more general alternative to the CD functional form is provided by the CES production function. In this article, we use the following specification:

$$Y_t = \left[\delta (B_t L_t)^{\frac{\sigma-1}{\sigma}} + (1-\delta)(X_t K_t)^{\frac{\sigma-1}{\sigma}} \right]^{\frac{\sigma}{\sigma-1}}, \ 0 < \delta < 1 \text{ and } \sigma > 0 \tag{4}$$

where B_t and X_t are indexes of labour and capital augmenting technical progress respectively, δ is the distribution parameter capturing the functional distribution of income and σ is the elasticity of substitution.

This framework implies that factor income shares vary proportionally to factors' real cost and productivity, which contrasts with the constancy assumption underlying the CD function. Furthermore, the CES specification introduces an important advantage over the CD form since it does not impose the substitution parameter to be equal to one, and thus gives the possibility of estimating it from the data. It can be shown that when the elasticity of substitution is unitary, the CES function converges to a CD function.

We see that the CES production function is markedly less restrictive than the CD function, allowing for much richer results, specifically to test the validity of the CD formulation through the realization of a statistical test on the estimate obtained for the elasticity of substitution. In addition, the CES formulation adopted in this article includes technical progress specific to each factor,[8] which is not possible with the CD function, since only total factor productivity is identified.

(8) The utilization of a CES production function with technical progress for capital is compatible with a stationary model only if technical progress is itself stationary. For further details see Barro and Sala-i-Martin (1995).

2.2.2. The computation of potential output and the growth accounting exercise

In order to compute potential output, it is necessary to know beforehand the levels of potential factor utilization and productivity, and estimates of the parameters needed for the production function.

Regarding factors of production, the computation of their potential levels follows the same procedure for both the CD and CES functions. For capital input, it is quite common to use the actual capital stock to measure both actual and potential capital, since capital is a relatively fixed input, at least in the short run. This assumption seems valid, as long as there is no noticeable deviation of the capital stock from its long-run level. As for potential employment, it is generally obtained through the natural rate of unemployment and active labour force. Thus, potential factor levels are given by:

$$K_t^* = K_t \quad (5)$$

$$L_t^* = PA_t\left(1 - u_t^*\right) \quad (6)$$

where PA_t corresponds to the observed active labour force and u_t^* is a measure of the natural rate of unemployment, with both variables being exogenous.

The parameter α of the CD function is calibrated using the average labour income share obtained from the national accounts data. Knowing this parameter, the unobservable total factor productivity is obtained by computing the Solow Residual by solving the production function to A_t:

$$A_t = \frac{Y_t}{L_t^{\alpha} K_t^{1-\alpha}} \quad (7)$$

The resulting Solow residual is then smoothed[9] to obtain an estimate of trend factor productivity, A_t^*. With potential capital input K_t^*, potential labour input L_t^*, and trend TFP A_t^* we can now easily compute potential output by plugging these values into the production function.

$$Y_t^* = A_t^*\left(L_t^*\right)^{\alpha}\left(K_t^*\right)^{1-\alpha} \quad (8)$$

This expression can be directly applied to the growth accounting exercise, since it is log-linear in the factors of production. Differentiating both sides of the production function in logs yields:

$$\underbrace{\Delta y_t^*}_{\text{Potential ouput growth rate}} = \underbrace{\Delta a_t^*}_{\text{TFP contribution}} + \underbrace{\alpha \Delta l_t^*}_{\text{Labour contribution}} + \underbrace{(1-\alpha)\Delta k_t^*}_{\text{Capital contribution}} \quad (9)$$

In the case of the CES production function, the computation process is more complex, since there are two unknown parameters and, using the formulation adopted in this article, there are two specific productivities to calculate. Solving the profit maximization problem with CES technology, we obtain the first order condition for labour demand, which is given by:

$$y_t - l_t = \sigma\left(w_t - p_t\right) + \left(1-\sigma\right)b_t - \sigma \ln \delta \quad (10)$$

Equation (10) can be interpreted as a long-run relation between output per worker, $y_t - l_t$, the real cost of labour, $w_t - p_t$ and the labour-augmenting technological progress, b_t. It is therefore possible to consider this equation as a cointegration relation, and estimate the elasticity of substitution between factors using Johansen's maximum likelihood method,[10] which produces efficient estimates for the parameters of a cointegration relation.

(9) In this article, as commonly accepted in the literature, we use the HP filter as a smoothing technique to obtain trend TFP.
(10) A detailed description of Johansen's method can be found in Johansen (1995).

To obtain the labour productivity index, we make use of a standard procedure in the literature,[11] and assume that it grows at a constant rate. This way, its level can be well approximated by a linear trend, which converts equation (10) into:

$$y_t - l_t = \sigma(w_t - p_t) + (1-\sigma)\left(\mathbb{C} + \eta^L t\right) - \sigma \ln\delta \qquad (11)$$

where η^L is the average growth rate of labour productivity, t is a deterministic trend and $\mathbb{C}$ is an unknown scale constant. Even though the elasticity of substitution has been estimated, the distribution parameter δ and the scale constant $\mathbb{C}$ are still unknown. However, using the fact that the CES function corresponds to a CD function in the case of unitary elasticity of substitution, δ can be calibrated using the equivalent parameter in the CD function (i.e., labour income share in value added, α), which is in line with what is usually done in the literature. Using the obtained estimates for the parameters δ and σ it is then possible to use equation (10) to find the scale constant, $\mathbb{C}$, and the labour productivity index B_t, given by the following expression:

$$B_t = \left(\frac{Y_t}{L_t}\right)^{\frac{1}{1-\sigma}} \left(\delta \frac{P_t}{W_t}\right)^{\frac{\sigma}{1-\sigma}} \qquad (12)$$

Finally, the capital-augmenting technological progress can be recovered by solving the production function to X_t:

$$X_t = \left(\frac{1}{1-\delta}\left(\frac{Y_t}{K_t}\right)^{\frac{\sigma-1}{\sigma}} - \frac{\delta}{1-\delta}\left(\frac{B_t L_t}{K_t}\right)^{\frac{\sigma-1}{\sigma}}\right)^{\frac{\sigma}{\sigma-1}} \qquad (13)$$

The calculated B_t and X_t series are then smoothed using an HP filter, to obtain their trend levels, B_t^* and X_t^*, which corresponds to the same procedure used to smooth the Solow residual in the CD case.

Having obtained potential factor levels, their productivities, and the production function parameters, potential output can finally be calculated by directly substituting them in the production function:

$$Y_t^* = \left[\delta\left(B_t^* L_t^*\right)^{\frac{\sigma-1}{\sigma}} + (1-\delta)\left(X_t^* K_t^*\right)^{\frac{\sigma-1}{\sigma}}\right]^{\frac{\sigma}{\sigma-1}} \qquad (14)$$

For the CES production function, the growth accounting exercise is more complex than in the CD case, since the CES function is not log-linear. The approach adopted in this article is to take the log of the production function and then linearise it around the previous period, applying a first order Taylor expansion. After some algebraic manipulation we get:

$$\underbrace{\Delta y_t^*}_{\substack{\text{Potential output}\\ \text{growth rate}}} = \underbrace{\omega_t^L \Delta b_t^*}_{\substack{\text{Labour productivity}\\ \text{contribution}}} + \underbrace{\omega_t^L \Delta_t^* l_t^*}_{\substack{\text{Labour}\\ \text{contribution}}} + \underbrace{\omega_t^K \Delta x_t^*}_{\substack{\text{Capital productivity}\\ \text{contribution}}} + \underbrace{\omega_t^K \Delta k_t^*}_{\substack{\text{Capital}\\ \text{contribution}}} \qquad (15)$$

where:

$$\omega_t^L = \frac{\delta\left(B_{t-1}^* L_{t-1}^*\right)^{\frac{\sigma-1}{\sigma}}}{\delta\left(B_{t-1}^* L_{t-1}^*\right)^{\frac{\sigma-1}{\sigma}} + (1-\delta)\left(X_{t-1}^* K_{t-1}^*\right)^{\frac{\sigma-1}{\sigma}}} \text{ and } \omega_t^K = \frac{(1-\delta)\left(X_{t-1}^* K_{t-1}^*\right)^{\frac{\sigma-1}{\sigma}}}{\delta\left(B_{t-1}^* L_{t-1}^*\right)^{\frac{\sigma-1}{\sigma}} + (1-\delta)\left(X_{t-1}^* K_{t-1}^*\right)^{\frac{\sigma-1}{\sigma}}}$$

represent the weights of the labour force and capital stock in output, which vary with time. In the case of $\sigma = 1$, these weights are given by $\omega_t^L = \delta$ and $\omega_t^K = 1-\delta$, which exactly correspond to the income shares of each factor in value added, since δ was calibrated using the labour share of the CD function.

(11) See, for example, Dimitz (2001) and Jalava (2005).

3. POTENTIAL OUTPUT AND THE OUTPUT GAP FOR THE PORTUGUESE ECONOMY

Potential output and the output gap for the Portuguese economy can be computed using the methods presented in Section 2 and the available data. The results obtained are extremely useful in the assessment of the evolution of economic activity, enabling, in particular, the identification of supply side factors that lie behind the weak economic growth witnessed in Portugal in recent years.

3.1. The dataset for the Portuguese economy

The dataset used in this article is mostly taken from the “Quarterly Series for the Portuguese Economy: 1977-2005” published in the summer 2006 issue of the Banco de Portugal Economic Bulletin.[12]

The time series for compensation per worker was built using employees’ wage bills and assuming that a self-employed worker earns on average 75 per cent of an employee. Concerning the natural rate of unemployment, it was assumed that it has remained broadly unchanged throughout the sample period at 5.5 per cent of the labour force;[13] nevertheless, the recent increase in long-term unemployment may raise some doubts on the maintenance of the estimated natural rate of unemployment. The capital stock time series was built using the perpetual inventory method, assuming a slightly increasing depreciation rate that captures the faster depreciation of some types of investment goods (in particular, electronic equipment and computer systems). The value-added time series as well as the respective deflator were computed from GDP at market prices by subtracting indirect taxes. Finally, income per unit of capital was obtained using the resource constraint and the previously mentioned time series:

$$R_t = \frac{P_t Y_t - W_t L_t}{K_t} \quad (16)$$

It should not be disregarded that this is a very inaccurate measure of income per unit of capital, since both compensation per worker and capital stock lie on the assumptions previously referred and do not correspond to effectively observed figures. Thus, all measurement errors related with both labour income and capital stock will translate directly to measurement errors in the income per unit of capital considered.

3.2. Statistical methods

The implementation of the univariate methods described in section 2.1 implies not only the choice of the parameters’ values for each of the filters considered, but also an extension of the actual real GDP data to avoid the end-of-sample problems previously mentioned. Thus, the actual real GDP time series was extended up to 2010, using the Banco de Portugal projections published in the summer 2006 issue of the Economic Bulletin for 2006 and 2007 and the average growth rate recorded in the period 1993-2005 for the rest of the extension period.

Concerning the HP filter, the smoothness parameter was set to $\lambda = 7680$, which, according to Raven e Uhlig (2002), corresponds to a smoothness parameter of 30 for annual data, corresponding to the

(12) This database corresponds to an update of the one published in Castro and Esteves (2004) and follows the methodology presented there.
(13) In line with the results published in Dias, Esteves and Félix (2004).

benchmark usually considered in the Eurosystem exercises.[14] In terms of the band-pass filters, a low-pass specification was considered, removing all the fluctuations with a frequency lower than 12 years.

The annual average growth rates of the computed potential output using the HP, BK and CF filters for the whole sample period as well as for the sub-samples are plotted in Charts 3.2.1 and 3.2.2. An immediate conclusion is that the discrepancies resulting from alternative univariate methods (which are visible in Chart 3.2.2) tend to vanish whenever averages of sample periods are considered. The results suggest an annual average growth rate at around 3 per cent for the whole sample period (1986-2005). However, an inspection of sub-sample periods reveals that this annual average growth rate does not result from a broadly flat profile, since annual average growth rates differ quite substantially across periods. In fact, the results suggest an annual average growth at around 4 per cent in the sample period 1985-1994 and only 2 per cent in the sample period 1995-2005, revealing a continued decline in the potential output growth rate throughout the last 20 years. In particular, a closer inspection of the last 5 years of the sample suggests that the potential output annual average growth rate was probably not more than 1.5 per cent.

The computed output gap is plotted in Chart 3.2.3. In general terms, one can easily conclude that despite the fact that point estimates do not coincide, the computed output gap is broadly similar across the alternative methods used and the turning points tend to coincide. The results suggest that by the time of Portuguese accession to the European Union in 1986, output was significantly below its potential level. In the following years, real GDP growth surpassed potential output growth, determining a computed output gap at around 4 per cent in 1990. Subsequently, the significant slowdown in real GDP growth led to a decline in output gap that reached a close to zero position in 1993, declining further until 1995. In the period 1995-2001, the Portuguese economy returned to economic activity growth rates above potential with the output gap reaching 3 per cent in 2001. Thereafter, the accumulation of disequilibria with non negligible impact on aggregate demand level has limited real GDP to growth

Chart 3.2.1

POTENTIAL OUTPUT GROWTH – STATISTICAL METHODS (SUB-SAMPLES)

Annual average growth rate, in percentage

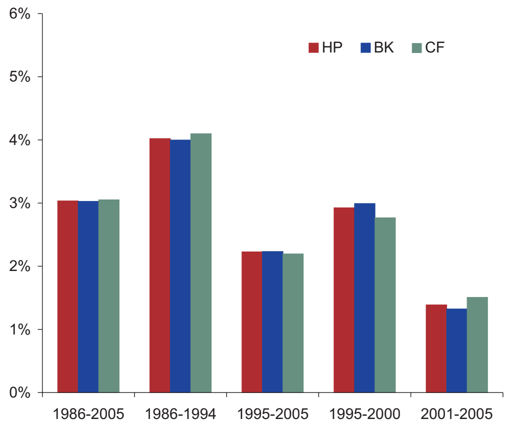
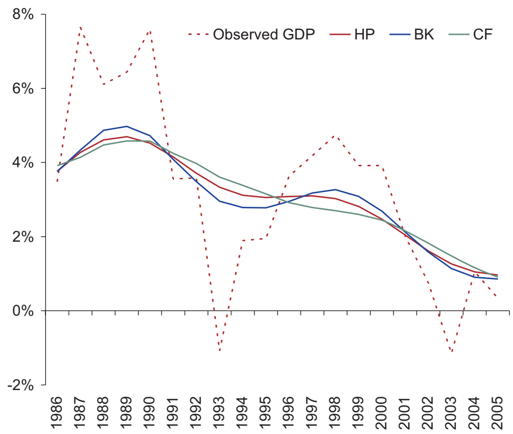


Chart 3.2.2

POTENTIAL OUTPUT GROWTH – STATISTICAL METHODS

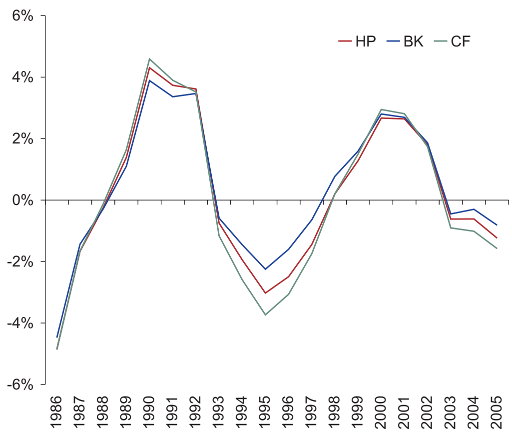
Annual average growth rate, in percentage



(14) As already referred in Section 2, the choice of the HP filter smoothing parameter is to a large extent discretionary. One must emphasize that the choice of alternative smoothness parameters only affects the amplitude of the business cycle, while maintaining both the average potential output growth and the turning points of each business cycle. In particular, the utilisation of the smoothness parameter value originally suggested in Hodrick and Prescott (1997), $\lambda = 1600$, leads to the computation of business cycles with a smaller amplitude and to a more volatile potential output growth rate.

Chart 3.2.3

OUTPUT GAP – STATISTICAL METHODS
As a percentage of potential output



rates below potential, determining the progressive closure of output gap until 2003 and its return to negative grounds in subsequent years.

In conclusion, the results obtained by implementing the alternative univariate statistical methods are identical and allow for a general characterisation of the trend component of the actual output time series. One may highlight the fact that, irrespective of the method, potential output growth of the Portuguese economy has decelerated substantially in the last 20 years and that the results point towards an annual growth rate ranging from 1 to 1.5 per cent in the last 5 years.

3.3. Structural methods: the production function approach

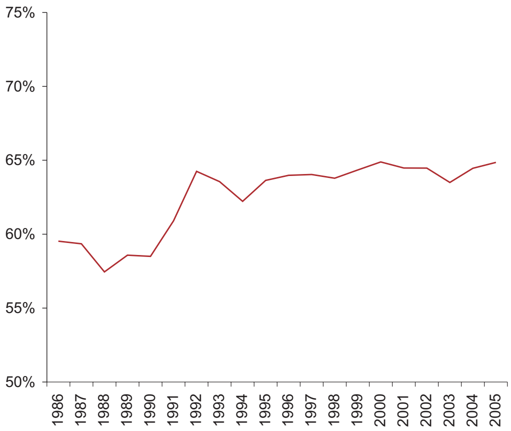
The production function approach draws on the specification of a function that is compatible with the most evident stylised facts of the economy. One of these facts, first suggested in Kaldor (1965), is that the income share of each one of the productive factors in value added is broadly constant. The evolution of labour income share as a percentage of value added in the Portuguese economy since 1986 is plotted in Chart 3.3.1. This information was used to calibrate the parameters α and δ of the CD and CES production functions, respectively, since they were set at the average labour income share for the period 1992-2005 (64 per cent). It should be noted that while the labour income share fluctuated for the period 1986-1992, since then it has remained broadly stable.

To evaluate the reasonability of the CD specification, a CES production function was considered and the elasticity of substitution among factors was estimated using quarterly data for the sample period 1988-2005 based on the methodology presented in Section 2.2. The estimated elasticity of substitution is 0.65 and the corresponding standard deviation is 0.06, meaning that the null hypothesis of a unit elasticity of substitution (in case of a unit elasticity of substitution the CES production function collapses to CD production function) is rejected at a 1 per cent significance level.[15] Thus, the results suggest that the unit elasticity of substitution is not supported by empirical evidence for the sample period considered.

(15) The result obtained for the elasticity of substitution is similar to the one published in Lucas (1990) for the US economy.

Chart 3.3.1

LABOUR INCOME SHARE
As a percentage of value added



To assess both the impact of using a CD production function (when a CES production function seems to be, according with available evidence, the one that is more adequate) and the differences arising from the utilisation of structural methods instead of univariate methods, potential output and the output gap were computed using CD and CES production functions and compared with the results obtained using the HP filter, which was used as the univariate benchmark method.[16]

The potential output growth rate and the corresponding output gap estimates computed using the HP filter and the alternative production function specifications are plotted in the charts 3.3.2, 3.3.3 and 3.3.4. The most evident finding is the coincidence of the results obtained using the alternative production function specifications. Additionally, the output gap results obtained using both the production function approach and the univariate statistical methods are qualitatively identical, despite slightly higher amplitude of the output gap when the HP filter is used.

Moreover, the results plotted in Chart 3.3.3 show that potential output growth computed using the production function approach usually tends to be more volatile than the one computed using univariate statistical methods. This feature results from the fact that the production function approach, due to its structural nature, reflects not only trend productivity growth (which is necessarily smooth since it is obtained from a univariate filtering procedure), but also the growth of the available production factors, which is not necessarily smooth, reflecting supply side shocks, in particular in the labour force.

A comparison of the annual average growth rate of potential output for the whole sample period (1985-2005) and for the sub-sample periods that were previously used in the case of univariate statistical methods is presented in Chart 3.3.2. The results obtained suggest that the computed annual average potential output growth is very similar across methods both for the whole sample period and for the sub-samples.

To sum up, the results obtained using the production function approach seem to confirm the deceleration of the potential output growth rate already shown by the univariate statistical methods. However, in contrast with the statistical methods, structural methods provide some indication of the factors that are likely to be behind potential output deceleration through the growth accounting exercise.

(16) The choice of the HP filter as the univariate benchmark method is due to the fact that it is a widely used method in the literature whenever potential output and output gap figures are required.

Chart 3.3.2

POTENTIAL OUTPUT GROWTH – STRUCTURAL VS STATISTICAL METHODS (SUB-SAMPLES)

Annual average growth rate, in percentage

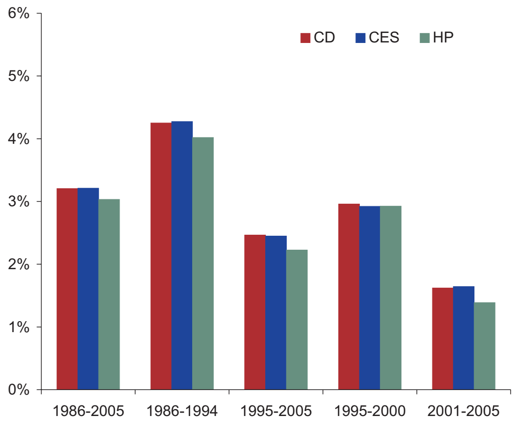


Chart 3.3.3

POTENTIAL OUTPUT GROWTH – STRUCTURAL VS STATISTICAL METHODS

Annual average growth rate, in percentage

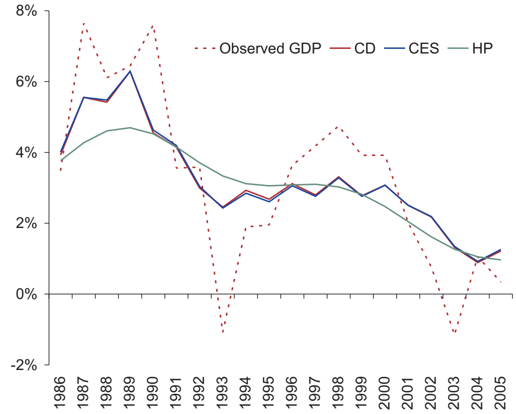
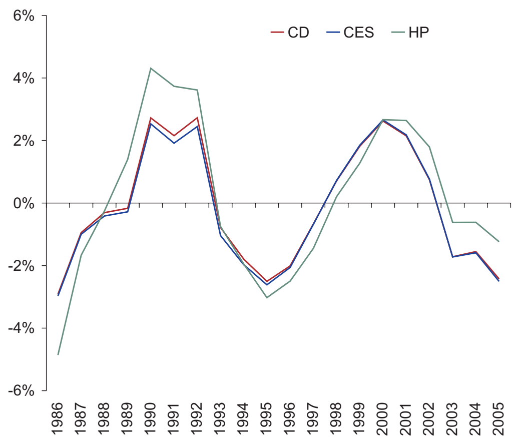


Chart 3.3.4

OUTPUT GAP – STRUCTURAL VS STATISTICAL METHODS

As a percentage of potential output



It should be noted that the CD production function only allows for identification of the contribution of trend total factor productivity, while the CES production function formulation considered enables identification of the contribution of the trend productivity growth of each one of the production factors for potential output growth. In addition, it must be referred that the current formulation implicitly considers a constant capital stock utilisation rate[17] and the maintenance of the number of hours per worker, meaning that any decline in these variables determines an overestimation of the amount of factor services effectively used and an underestimation of the specific productivity of the factor under consideration, since it is obtained as a residual. In the case of capital services, this type of bias tends to be bounded since capacity utilisation is likely to be a stationary variable; in the case of labour, however, the bias

(17) The available information on capacity utilisation for Portugal refers to the manufacturing sector and does not take into account, for instance, the services sector, which accounts for a significant share in overall production.

might be more significant since the number of hours per worker has declined since 1986. Nevertheless, according to the latest issue of the Employment and Labour Market Statistics published by the OECD,[18] the decline in the number of hours per worker is near 8 per cent in the period 1986-2004, meaning that an eventual underestimation in the annual trend productivity growth should not exceed 0.5 per cent on annual average terms. Thus, the results obtained and their interpretation in qualitative terms is likely to be robust to the measurement problems previously mentioned.

The contribution from production factors and associated productivities to potential output growth is mapped in Charts 3.3.5 and 3.3.6. According to the results obtained, the contribution of each factor, as well as the contribution of trend total factor productivity is similar irrespective of the production function used and thus the growth accounting exercise is robust to the production function specification considered. This conclusion applies both for the whole sample and for each of the sub-samples.

A first conclusion that can be drawn from the results obtained for the period 1986-1994 is that the growth rate of factor productivity and the increase in capital stock played a crucial role in the real convergence process observed since the accession of Portugal to the European Union.[19] The growth of labour has played a limited role, since it depends to a large extent on the evolution of demographic structure, which is characterized by the ageing process.

Secondly, comparing the period 1995-2005 with the period 1986-1994, the reduction in the contribution of productivity is crucial to understand the reasons behind the decline in potential output and the same applies to capital stock, though to a lesser extent. The CES production function results, which allow for identification of the productivity contribution of each factor, suggest that this decline in productivity is common to both capital and labour factors.

Finally, decomposing the sample period 1995-2005 into two sub-samples (1995-2000 and 2001-2005), one can conclude that the decline in potential output growth that is estimated to have occurred in the last years stems essentially from a smaller contribution of capital stock growth rate and from associated productivity, despite the slight decline in productivity associated to the labour factor.

Chart 3.3.5

GROWTH ACCOUNTING
COBB-DOUGLAS

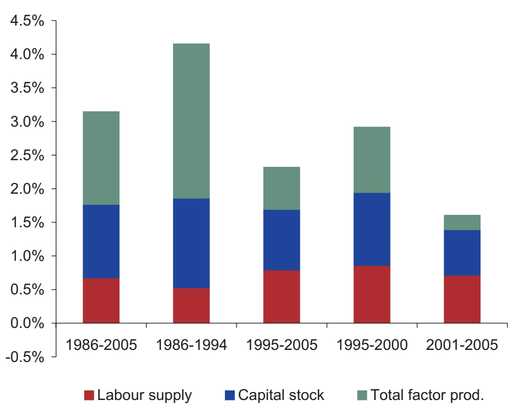
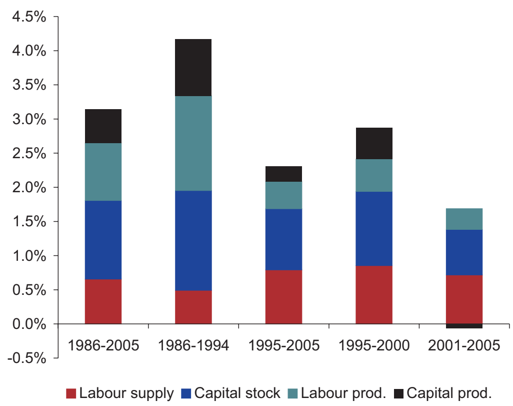


Chart 3.3.6

GROWTH ACCOUNTING
CES



(18) OECD (2006), "Average annual hours actually worked per worker", *Employment and Labour Market Statistics*, 2006, release 01.
(19) This result is in line with the conclusions presented in Cavalcanti (2004).

The decline in the contribution of capital stock reflects a distinct behaviour of investment in each one of the sub-samples. Thus, while in the period 1995-2000 investment grew at around 8 per cent, in annual average terms, it recorded an annual average decline of 3 per cent in the period 2001-2005. Moreover, the decline in productivity associated to the capital factor may also be related with the progressive obsolescence of the capital stock already installed, since the decline in investment might have also eventually limited the normal process of replacement of the capital stock that depreciated in the meantime.

The main conclusion that can be drawn from the structural approach is that the deceleration of potential output recorded in recent years essentially reflects the unfavourable behaviour of investment and its role in the maintenance of efficient conditions of production.

4. CONCLUDING REMARKS

This article presents computations for potential output and the corresponding output gap for the Portuguese economy, using alternative methods.

The results obtained are robust to the methodology adopted and point towards a deceleration of potential output in Portugal throughout the last 20 years, from an annual growth rate of around 4 per cent, for the period 1986-1994, to an annual growth rate close to 1.5 per cent, for the period 2001-2005. It is worth mentioning that these results are similar to those that can be found in European Central Bank and European Commission working papers.[20]

The implementation of a structural method like the production function approach enables one to go beyond the mere description of potential output deceleration by identifying structural factors that are driving this evolution and that are, ultimately, the genesis of the weak economic growth witnessed in Portugal in recent years. Nevertheless, interpretation of the results must be cautious, since they rely on a number of previously mentioned assumptions.

The results suggest that the deceleration of potential output throughout the last 20 years has been largely determined by a decline in the contribution of capital stock and total factor productivity. In the period 1986-2004, the strong growth in potential output benefited from a very peculiar juncture. As referred in Cavalcanti (2004), this period corresponded to Portuguese accession to the European Union, which may have implied a number of important transformations in the economy, in particular access to new markets and improved financing conditions for the business sector, which are likely to have significantly influenced both the dynamics of investment and improvement in total factor productivity. In the last years (2001-2005), the weak growth of potential output reflects a limited contribution of capital stock, as a result of the continued decline in investment since the beginning of the millennium, as well as the impact of investment in the maintenance of efficiency conditions at factor productivity level, in particular in the case of capital.

This study leaves a number of open questions that deserve some future research not only to reach a deeper understanding of the conclusions and results just presented, but also to test their validity as new information becomes available. Firstly, it seems important to consider the possibility of revisiting the results using reliable information on hours worked instead of the number of workers, since the results obtained for total factor productivity contribution using the production function approach might change. Secondly, the production function approach can be extended in order to account for the possibility of considering imported intermediate goods (for instance, imported energy goods) as an additional factor to evaluate the impact of shocks in the price of these imported goods on potential output

(20) The estimates published by the ECB for potential output growth can be found in Benalal *et al.* (2006), while the estimates published by the European Commission can be found in Denis *et al.* (2006).

level. Finally, the utilisation of methods that are able to combine the production function approach with other structural approaches (for instance using Okun's law and/or the Phillips curve), through multivariate methods will make it possible to test the robustness of the results and conclusions contained in this study using a larger information set.

REFERENCES

Barro, Robert. J. and Xavier Xala-i-Martin (1995): *Economic Growth*, McGraw Hill International Editions, *Economic Series*.

Baxter, Marianne and Robert King (1999): "Measuring Business Cycles: Approximate Band-Pass Filters for Economic Time Series", *Review of Economics and Statistics* (81)4, 573-593.

Benalal, Nicholai, Juan Luis Diaz del Hoyo, Beatrice Pierluigi and Nick Vidalis (2006): ""Output growth differentials across the euro area countries: some stylised facts", *Occasional Paper Series*, n. 45, European Central Bank.

Berndt, Ernst R. and Davis O. Wood (1975): "Engineering and Econometric Interpretations of Energy-Capital Complementarity", *The American Economic Review* vol. 69(3), pp.342-354.

Berndt, Ernst R. and Davis O. Wood (1975): "Technology, prices, and the derived demand for energy", *The Review of Economics and Statistics* vol. 57(3), pp.259-268.

Castro, Gabriela and Paulo Esteves (2004): "Quarterly series for the Portuguese economy: 1977-2003", *Economic Bulletin*, Banco de Portugal, June 2004.

Cavalcanti, Tiago V. (2004): "Business cycle and level accounting: the case of Portugal", in Proceedings of the conference "Portuguese economic development in the European area", March 2004, Banco de Portugal.

Christiano, Lawrence and Terry Fitzgerald (1999): "The Band pass filter", Working Paper 9906, Federal Reserve Bank of Cleveland.

Cogley, Timothy and James M. Nason (1995): "Effects of the Hodrick-Prescott filter on trend and difference stationary time series Implications for business cycle research", *Journal of Economic Dynamics and Control*, Elsevier, vol. 19(1-2), pages 253-278.

Denis, Cécile, Daniel Grenouilleau, Kieran Mc Morrow and Werner Röger (2006): "Calculating potential growth rates and output gaps - A revised production function approach", European Economy, *Economic Papers*, n.247, March 2006, European Commission, Brussels.

Dias, Francisco, Paulo Esteves and Ricardo Félix (2004): "Revisiting the NAIRU estimates for the Portuguese economy", *Economic Bulletin*, Banco de Portugal, June 2004.

Dimitz, Maria A. (2001): "Output-gaps and technological progress in European Monetary Union", *Discussion Paper* 20-2001, Bank of Finland.

Harvey, A. C. and Jaeger, A. (1993): "Detrending, Stylized Facts and the Business Cycle", *Journal of Applied Econometrics*, John Wiley & Sons, Ltd., vol. 8(3), pages 231-47, July-Sept.

Hodrick, R. J. and E. C. Prescott (1997): "Postwar U.S. business cycles: An empirical investigation", *Journal of Money Credit and Banking* 29, 1-16.

Jalava, Jukka, Matti Pohjola, Antti Ripatti and Jouko Vilmunen (2005): "Biased Technical Change and Capital-labour Substitution in Finland, 1902-2003", *EU KLEMS Working Paper Series 4*, EU KLEMS Project.

Johansen, Soren (1995): “Identifying restrictions of linear equations with applications to simultaneous equations and cointegration”, *Journal of Econometrics*, Elsevier, vol. 69(1), pages 111-132, September.

King, Robert G. and Sérgio T. Rebelo (1993): “Transitional Dynamics and Economic Growth in the Neoclassical Model”, *American Economic Review*, American Economic Association, vol. 83(4), pages 908-31, September.

Lucas, Robert E. (1990): “Supply-Side Economics: An Analytical Review”, *Oxford Economic Papers*, New Series, vol. 42(2), pages 293-316, April.

Mankiw, N. Gregory (2003): *Macroeconomics*, Worth Publishers, 5th edition.

Raven, Morten O. and Harald Uhlig (2002):”On adjusting the Hodrick-Prescott filter for the frequency of observations”, *Review of Economics and Statistics* (84)2, May 2002, 371-380.