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WITH AN APPLICATION TO CYPRUS

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METHODOLOGIES FOR ESTIMATING THE OUTPUT GAP

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Alexandros Polycarpou[♣]

Abstract

Output gap estimates are used in the calculation of structural fiscal balance indicators which are subsequently employed for the surveillance of economic growth and stability. This paper reviews the main methodologies for estimating the potential output and output gap. Methodologies can be grouped into two categories: the non-structural ones, which are not based on economic theory and are mainly statistical procedures; and the structural methodologies, which are based on economic foundations. The main advantages and disadvantages of each group of methodologies are discussed. Special attention is given to the production function approach adopted by the European Commission for the surveillance of the EU member states.

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Περίληψη

Σε αυτή την μελέτη περιγράφονται οι κυριότερες μέθοδοι εκτίμησης του δυνητικού προϊόντος και του παραγωγικού χάσματος. Οι μέθοδοι μπορούν να ομαδοποιηθούν σε δυο κατηγορίες: στις μη-δομημένες (non-structural) που δεν βασίζονται στην οικονομική θεωρεία αλλά είναι κυρίως στατιστικά φίλτρα και στις δομημένες μεθόδους που βασίζονται σε οικονομικές αρχές και μοντέλα. Παράδειγμα μη δομημένων μεθόδων αποτελούν το φίλτρο Hodrick-Prescott (HP), η διάσπαση Beverige-Nelson, η μέθοδος μη παρατηρούμενων συστατικών και το φίλτρο Band-Pass. Παράδειγμα δομημένων μεθόδων αποτελούν η μέθοδος συνάρτησης παραγωγής, το δυναμικό και στοχαστικό μοντέλο γενικής ισορροπίας (DSGE model) και το structural autoregressive (SVAR) μοντέλο.

Τα κυριότερα πλεονεκτήματα των μη δομημένων μεθόδων είναι η απλότητα, και ο μικρός αριθμός πληροφοριών που χρειάζονται στην εφαρμογή τους. Παρόλα αυτά η μη στήριξη τους σε οικονομικές αρχές, τις καθιστά μη κατάλληλες για εξαγωγή συμπερασμάτων πολιτικής για βελτίωση της απόδοσης της οικονομίας. Από την άλλη πλευρά, οι δομημένες μέθοδοι επιτρέπουν την εξαγωγή συμπερασμάτων πολιτικής και κατευθυντήριων γραμμών για τον σχεδιασμό οικονομικής πολιτικής όμως χρειάζονται πολλή πληροφορία (οικονομικά στοιχεία) και είναι λιγότερο ευέλικτες σε σχέση με τις μη δομημένες μεθόδους. Στην βιβλιογραφία έχουν προταθεί υβριδικές μέθοδοι (πολύμεταβλητές μέθοδοι) μέτρησης του δυνητικού προϊόντος που είναι ουσιαστικά επέκταση των μη-δομημένων μεθοδών με την συμπερίληψη οικονομικών σχέσεων. Το πλεονέκτημα των υβριδικών μεθόδων είναι ότι το δυνητικό προϊόν και το παραγωγικό χάσμα μπορεί να εξηγηθεί με την χρήση της οικονομικής θεωρίας. Παρόλα αυτά, οι πολυμεταβλητές μέθοδοι είναι περισσότερο περίπλοκες, λιγότερο ευέλικτες και χρειάζονται περισσότερα στατιστικά στοιχεία σε σχέση με τις μονομεταβλητές μεθόδους.

Η Ευρωπαϊκή Επιτροπή για μέτρηση του παραγωγικού χάσματος στις χώρες μέλη της έχει υιοθετήσει την μέθοδο της συνάρτησης παραγωγής. Στην μελέτη περιγράφεται η μεθοδολογία, τα στατιστικά στοιχεία, καθώς και οι υποθέσεις που χρησιμοποιεί η ΕΕ. Η μεθοδολογία της ΕΕ βασίζεται στην μέθοδο συνάρτησης παραγωγής Cobb-Douglas με σταθερές αποδόσεις κλίμακας όπου το τελικό προϊόν εξαρτάται από τον συντελεστή ολικής παραγωγικότητας της οικονομίας που μετράει τον βαθμό χρησιμοποίησης και αποδοτικής χρήσης των συντελεστών παραγωγής. Το δυνητικό προϊόν της οικονομίας επιτυγχάνεται όταν όλοι οι συντελεστές παραγωγής είναι στο δυνητικό τους επίπεδο και χρησιμοποιούνται αποτελεσματικά. Σαν δείκτης του δυνητικού επιπέδου του κεφαλαίου χρησιμοποιείται το αποθεματικό κεφάλαιο της οικονομίας. Το δυνητικό επίπεδο της εργασίας, που μετριέται σε ώρες, ορίζεται σαν ο αριθμός των ωρών που επιτυγχάνονται όταν η συμμέτοχή στην αγορά εργασίας και οι ώρες εργασίας είναι στο επίπεδο μακροχρόνιας τάσης τους, και το ποσοστό ανεργίας είναι στο NAWRU επίπεδο. Το δυνητικό επίπεδο του συντελεστή ολικής παραγωγικότητας δίνεται από το φιλτραρισμένο Solow κατάλοιπο με την χρήση του Kalman filter. Τα στοιχεία για τον υπολογισμό του δυνητικού προϊόντος και του παραγωγικού χάσματος προέρχονται από την στατιστική βάση AMECO του DG-ECFIN και την EUROSTAT.

Η ΕΕ εκτιμάει και δημοσιεύει το δυνητικό επίπεδο προϊόντος και το παραγωγικό χάσμα με την χρήση της μεθόδου συνάρτησης παραγωγής αλλά και με την χρήση του Hodrick-Prescott filter για όλες τις χώρες μέλη της. Στην μελέτη παρουσιάζονται οι εκτιμήσεις για το δυνητικό προϊόν και το παραγωγικό χάσμα στην Κύπρο, με βάση τις δυο μεθόδους, για την περίοδο 1998 με 2017. Τα αποτελέσματα δείχνουν ότι οι δυο μέθοδοι δίνουν διαφορετικά και σε αρκετές περιπτώσεις αντιφατικά ευρήματα, κάτι που υπονοεί ότι η εκτίμηση του παραγωγικού χάσματος είναι πολύ ευαίσθητη στο μοντέλο που χρησιμοποιείτε και στις

υποθέσεις που γίνονται. Τα αποτελέσματα στηρίζουν την τρέχουσα πρακτική της ΕΕ να χρησιμοποιεί την ίδια μεθοδολογία για τον υπολογισμό του παραγωγικού κενού σε όλα τα κράτη μέλη της, παρόλα αυτά, εγείρουν ερωτήματα σχετικά με την χρήση κοινών υποθέσεων για όλες τις χώρες.

Μελλοντική δουλειά περιλαμβάνει την περεταίρω μελέτη της ευαισθησίας των εκτιμήσεων του παραγωγικού χάσματος από τις υποθέσεις που γίνονται για την εφαρμογή των εναλλακτικών μεθόδων εκτίμησης. Επίσης θα χρησιμοποιηθούν τεχνικές προβλέψεων ώστε να εκτιμηθεί η βραχυχρόνια (τρία με πέντε χρόνια) εξέλιξη του πραγματικού προϊόντος, του δυνητικού προϊόντος και του παραγωγικού χάσματος στην Κύπρο.

1. Introduction

The output gap is the deviation of actual output from the potential. In the short run, potential output is defined as the level of output that can be produced without inducing supply constraints and inflationary pressures. The long run potential output is linked more to the future evolution of technical progress and to the likely growth rate of labour potentials and physical capital.

In general, potential output gives an indication of the aggregate supply capacity of the economy and the possibilities of non-inflationary growth. The level of potential output - and of the associated output gap - plays an important role in the design of macroeconomic policy. When the economy is producing below its potential level, then fewer jobs are available and less tax revenue is received. In addition, the output gap can be used for explaining price and wage inflation.

Potential output is unobserved and the variety of methods proposed for its estimation often give different results. Estimates that rely on statistical filters were very popular in the past mainly due to their simplicity. Statistical filters, however, are not based on economic theory; thus it is generally not possible to give structural interpretation to the results and guidance for economic policy. Thus, nowadays, multivariate statistical filters that combine economic variables with non-structural measures of business cycle or structural theory based methods are used.

Policy making institutions like the OECD and the EU have an officially adopted method for the estimation of output gap that combines a flexible production function methodology with other economic relations for estimating variables like employment and potential capital and univariate filters for calculating trend variables like participation rate, hours worked and total factor productivity. On the other hand, some institutions (e.g. ECB and IMF) do not have an official method for computing potential output and, depending on the country under study, they may use the production function or some other structural approach; or a non-structural statistical method like the Hodrick-Prescott (HP) filter.

Output gap estimates, together with other output elasticity indicators are used in the calculation of structural fiscal balance indicators which are used for the surveillance of the economic growth and stability of the country. Also the output gap estimates can be used as an indicator for the position of the economy in the business cycle and thus inflationary pressures can be prevented using counter-cyclical macroeconomic policies. For example, estimates of the output gap are used by the EU for the surveillance of the EU member states.

In this paper we examine the most popular methods for estimating the potential output and the output gap. In general, methodologies can be grouped into two categories; the non-structural methodologies which are not supported by economic theory and the structural methodologies which are based on economic theory. The main advantages and disadvantages of each group of methodologies are discussed. In particular, we focus on the production function approach for the estimation of the output gap. This approach is adopted by the EU and, being based on economic theory yields results that can be given a clear economic interpretation and lead to conclusions guiding macroeconomic policy.

Section 2 gives a brief review of the methods for estimating the potential output and the output gap. Section 3 focuses on the production function methodology adopted by the EU. Section 4 summarises and concludes the paper.

2. Methods for estimating the output gap

In the literature alternative methods have been proposed for estimating the potential output and the associated output gap. The methodologies can be grouped into the univariate and multivariate ones. Each of these categories can then the be grouped into non-structural and structural methods, depending on whether they are simply statistical or based on economic foundations.[1] In this section we briefly describe these methods and point out their advantages and/or limitations.

2.1 Non-structural univariate methods

In the non-structural measures of the business cycle we include all the methods which are based on statistical procedures and do not refer explicitly to economic theory. The most well-known non-structural univariate methods is the linear detrending, the Hodrick-Prescott Filter, the Band-Pass filter, the Beverige-Nelson Decomposition and the Unobservable Component (UC) method.

2.1.1 Linear detrending

The simplest way to calculate the potential output is by using a linear trend on the assumption that GDP can be decomposed into two uncorrelated deterministic components: trend and cyclical. The potential output can then be obtained from estimation of linear regression of the log of real GDP on a constant and a time trend, i.e.

$$y_t = \beta_0 + \beta_1 t + u_t,$$

where y_t is the real GDP, t is the time trend and the residual u_t is the estimated output gap. Since we have a logarithmic specification, $\widehat{\beta_1}$ gives the average trend growth over the period under investigation. As the OLS estimation assumes that the residual has zero mean, the application of this method also implies that the mean output gap over the period under investigation is zero.

2.1.2 Hodrick-Prescott filter

The Hodrick-Prescott (HP) filter (Hodrick and Prescott, 1997) is a popular method for detrending macroeconomic time series, in general. It basically uses a long-run, symmetric, moving average to detrend real output y_t. In particular, the HP filter sets the potential output to minimize the loss function

$$\min_{y_t^*} \sum_{t=1}^{T} (y_t - y_t^*)^2 + \lambda \sum_{t=2}^{T-1} [(y_{t+1}^* - y_t^*) - (y_t^* - y_{t-1}^*)]^2,$$

where y_t is the real GDP, y_t^* is the trend component of real GDP (i.e. the potential GDP) and λ an exogenous detrending parameter that sets the degree of smoothness of the trend (i.e. how responsive potential output is to movements of actual output).

Broadly speaking the HP procedure contains two parts: (i) minimization of the distance between the actual and the potential output, and (ii) minimization of the change of the potential output.

- For high values of λ, the loss function is minimized by penalising changes in potential growth which is done by making potential output growth more constant (linear trend growth rate).

[1] Also a method for the direct measurement of the potential output is available, but is rarely used because of data and methodological limitations.

- For small values of λ, the loss function is minimized by eliminating the difference between actual and potential output, which is done by making potential output equal to actual output.[2]

2.1.3 Beverige-Nelson decomposition

Beveridge and Nelson (1981) proposed a method for decomposing a time series (y_t) to a trend (τ_t) and cyclical (c_t) part. This methodology assumes real GDP to be integrable of degree 1 {I(1)}, i.e. it becomes stationary when expressed in first differences. Based on this assumption, the trend component follows a random walk with drift, while the cyclical component is stationary.

The model can be described using the following equations:

$$y_t = \tau_t + c_t$$

that shows the real GDP decomposition into its trend and cyclical part;

$$\tau_t = b + \tau_{t-1} + \alpha\varepsilon_t$$

that shows that trend is a random walk with drift b and an error term $\alpha\varepsilon_t$; and

$$c_t = \varphi_p^*(L)c_t - \psi_r^*(L)\varepsilon_t + (1-\alpha)\varepsilon_t$$

that assumes y_t to be an $ARIMA(p,1,q)$ process with drift, where L is a lag operator, $\varphi_p^*(L) = \varphi_1 L + \varphi_2 L^2 + \cdots + \varphi_p L^p$ and $\psi_p^*(L) = \psi_1 L + \psi_2 L^2 + \cdots + \psi_r L^r$.

The Beverige-Nelson decomposition methodology imposes a very specific functional form on the trend component and, also, assumes that trend and cycle shocks are perfectly correlated. Using the parameters obtained from the estimation of the equations above, the real GDP can be transformed into a stationary series so that an ARMA model can be applied to forecast the time series over a given horizon. Also since the filter depends on the past values of GDP, no end point problem ensues. Nevertheless, in practical application the Beverige-Nelson method does not give very convincing results, as it creates very noisy cycles and, in some cases, negative correlation between cycles and actual GDP growth.

2.1.4 Unobservable component method

The UC method (Harvey, 1990) rests on the assumption that both the potential GDP and the output gap are unobservable. Thus the statistical techniques which are used to decompose the GDP should not postulate a priori the nature of the trend.

According to the UC methodology, the output y_t can be decomposed into a permanent (y_t^p), a transitory (z_t) and a white noise error (ε_t) component,

$$y_t = y_t^p + z_t + \varepsilon_t$$

The permanent component represents the potential GDP, whereas the transitory component the output gap. The potential output can be assumed to follow a random walk with a drift (μ^y)

$$y_t^p = \mu^y + y_{t-1}^p + \varepsilon_t^y$$

and the output gap an AR(2) process

$$z_t = \varphi_1 z_{t-1} + \varphi_2 z_{t-2} + \varepsilon_t^z.$$

[2] For quarterly data, a smoothing factor of 1600 is the standard in the literature.

Usually, it is assumed that the two components are uncorrelated with each other in order to achieve identification of the overall model. The UC model is estimated by Maximum Likelihood and is performed using the Kalman filter approach, which requires setting some initial values for the parameters and reformulating the model in state-space format.

2.1.5 Band-Pass filter

The widely known known Band-Pass filter was developed by Baxter and King (1999). The idea behind this filter is that business cycles can be defined as fluctuations of a certain frequency. So, unlike the HP filter (which takes cycles up to 15-16 years into account and then gradually reduces the weight of longer cycles) the Band-Pass filter has a sharp cut point at an exogenously specified cycle length. The filter attaches weight equal to (i) zero to very slow moving components and to very high frequently components and (ii) one to components with the specified cycle length. The band-pass filter has properties similar to those of the HP filter since it represents finite order, two sided and symmetric moving averages able to eliminate stochastic trends. In addition, it is flexible and the filter construction can be easily changed when the frequency changes. However, it suffers from the end point bias problem since it has no value for the recent quarters.

2.1.6 Advantages and disadvantages of non-structural methods

The main advantage of the non-structural methods is the simplicity and the limited information needed for their application. In addition, the procedure followed is standard, in the sense that it does not depend on the particular time-series under consideration. Thus, the non-structural methods can be used for modelling and estimation of any economic series of interest.

A limitation of the non-structural methods is that it is not possible to separate the demand from the supply shocks in a univariate framework (Quah, 1992). Also, since these methods do not have an economic foundation, no clear policy conclusions for improving the performance of the economy can be obtained. Furthermore, the implicit assumption that business cycles have very similar duration and are systematic, cannot be empirically tested because they are ruled out by assumption; as is output persistence.

Finally, subjective judgment can play an important role in non-structural methods when setting the exogenous parameters of the model. Thus, researches using the same non-structural method may end up with different estimates of the output gap.

2.2 Structural methods

Unlike non-structural methods, structural ones are based on specific economic foundations. The most well-known methods are based on the Okun's Law, the production function approach, the long-run restrictive models, and the NK-DSGE models.

2.2.1 Okun's Law

The first structural method for calculating the potential output was introduced by Okun (1962) by connecting the level of unemployment with the gap between potential output and actual output. Okun's Law takes the following form

$$u_t = c + d(y_t - y_t^*)$$

where u_t is the unemployment rate and y_t^* is the potential output, defined as the output under conditions of full employment. When the unemployment level is relatively low the economy produces as much as possible without generating inflationary pressures. Based on Okun's Law, the constant c can be interpreted as the unemployment rate at full employment;

while the coefficient d is expected to be negative since actual output is above its potential at low and below its potential at high unemployment rate.

The problem with this methodology is that potential output and full employment are not observed. Okun (1962) assumes that full employment occurs when unemployment is 4 percent (average post war level for the US). Based on that, and assuming that the coefficient of output gap is close to 0.3, Okun (1962) was able to construct a series of potential output values. Notably, changes in the assumptions about the unemployment rate under full employment can have a significant effect on the level of potential output.

2.2.2 Production function approaches

The potential output and the output gap can be estimated on the basis of the aggregate production function. This methodology requires a lot of information: (i) an assumption about the empirical specification of production function, (ii) the estimation of equilibrium employment, and (iii) information on the level of capital stock and of the total factor productivity. Nevertheless, it is widely used because it relies on well-defined economic theory; and, thus, can yield parameters with meaningful economic interpretation and provide guidance for policy design.

The majority of the empirical work on estimating the potential output using the production function approach relies on the Cobb-Douglas with constant returns to scale empirical specification. Thus, total output (Y) is produced using labour (L) and capital (K) according to the equation

$$Y_t = (TFP_t)L_t^a K_t^{1-a},$$

where TFP is the total factor productivity which depends on the degree of utilisation and the level of efficiency (technology) of the factors of production.

The potential output is calculated by substituting the trend (potential) level of inputs and efficiency in the production function to obtain

$$Y_t^* = (TFP_t^*)L_t^{*a} K_t^{1-a},$$

where L_t^* is the potential level of labour which is defined as $L_t^* = pop_t\, parts_t^*(1 - u_t^*)$, where pop_t is the working age population, $parts_t^*$ the potential participation level and u_t^* the potential unemployment rate. TFP_t^* is the potential level of efficient use of factor inputs and is measured as a filtered Solow residual, i.e. by subtracting the contribution of labour and capital from total output. The capital stock is not detrended and its maximum potential contribution is given by full utilisation of the existing capital in the economy.

In a structural model, the potential level of variables (star variables) are meant to be computed endogenously using macroeconomic relations and models. However, in most of the cases, the production function method applied for the estimation of the output gap is a hybrid one, in the sense that it uses both economic relations (e.g. Philips curve to generate u_t^*) and non-structural univariate filters (e.g. the HP filter) for detrending variables on which very limited information is available.

2.2.3 Long-run restrictive models

This methodology is based on a structural autoregressive (SVAR) bivariate model that uses structural assumptions about the sources of economic disturbances to estimate potential output and the output gap. The methodology was first proposed by Blanchard and Quah (1989).

Based on the SVAR methodology the actual output is decomposed into three components: the deterministic component, the part attributed to supply shocks and the part attributed to demand shocks. The potential output is given by the deterministic component of the model and by the impact of supply shocks; whereas the output gap is given by the demand shocks. The distinction between supply and demand shocks is an important advantage of this methodology over univariate detrending methods, as the latter fail to decompose these two types of shocks. [3]

The SVAR model contains a system of two equations describing the unemployment rate and output. In each equation, information about the lagged value of the dependent variables as well as other variables like productivity level, the price level, nominal wage and money supply are used. The key identification assumptions of the model for decomposing the two type of shocks is that they are uncorrelated with each other, they do not have a long-run effect on unemployment but supply shocks have long run effect on output whereas demand shocks only have short–run effects.

2.2.4 DSGE models

A recent approach for estimating the potential output is based on Neo-Keynesian Dynamic Stochastic General Equilibrium (NK-DSGE) models (Smets and Wouters, 2003). General Equilibrium (GE) models describe the economy as a whole by analysing the interactions of decisions taken by the economic agents: consumers, firms and - possibly - the government. A GE is termed dynamic when it studies how the economy evolves over time; and stochastic when the possibility of random shocks (technology changes and fluctuation in oil prices etc) are taken into account.

The basic NK-DSGE model represents a closed economy without capital and habit formation in consumption. It assumes monopolistic competition in both goods and labour markets, in the context of which prices are set. Firms set prices to maximize their profits given demand for produced goods and households set wages to maximize their utility given demand for labour by firms. In equilibrium firms set prices equal to a mark-up over marginal cost and households set wages equal to a mark-up over the marginal rate of substitution between consumption and hours worked.

In log-linearized form the equilibrium is described by the following equations

$$0 = \lambda_{p,t} + (w_{n,t} - p_{n,t}) - ({}^{1}/_{\alpha})a_t + ({}^{1}/_{\alpha} - 1)y_{n,t} - \log\alpha$$

$$(w_{n,t} - p_{n,t}) = \nu l_{n,t} + c_{n,t} + \lambda_{w,t}$$

$$y_{n,t} = \alpha l_{n,t} + a_t$$

$$y_{n,t} = c_{n,t},$$

where subscript n denotes natural equilibrium values, $\lambda_{p,t}$ is the (log) price mark-up, $w_{n,t}$ the (log) nominal wage, $p_{n,t}$ the (log) output price, a_t the (log) technological shock, $y_{n,t}$ the (log) output, $\lambda_{w,t}$ the (log) wage mark-up, $l_{n,t}$ the (log) employment, $c_{n,t}$ the (log) consumption, α the technology parameter, and ν the parameter measuring disutility from labour. The first equation describes the optimizing behaviour of firms, the second the optimizing behaviour of households, the third the production function and the fourth the goods market equilibrium.

[3] In the latter methods, by definition, supply shocks do not enter the output gap.

In the NK-DSGE model three different notions of potential output can be analysed: trend output, efficient output and natural output. The trend level of output is equal to the sequence of permanent stochastic technology shocks that characterise the stochastic balanced-growth path of the model. The corresponding output gap measures the business cycle component of output and is closely related with the more traditional measures of output gap. The efficient level of output is the level that would prevail if goods and labour market were perfectly competitive; the corresponding output gap measures the relevance of imperfect competition and nominal rigidities. The natural level of output is the level that would prevail under flexible wage processes and perfectly competitive markets; the relevant output gap measures only the relevance of nominal rigidities.

Combining the equations above yields the relationship

$$y_{n,t} = \left({}^{\alpha}/_{(1+\nu)} \right) \log \alpha + a_t - \left({}^{\alpha}/_{(1+\nu)} \right) \left(\lambda_{p,t} + \lambda_{w,t} \right),$$

where the first two terms on the right hand side correspond to the efficient output and the third term to the output distortion due to imperfect competition. This equation shows the relationship between natural output and efficient output and implies that the natural output is more volatile than efficient one, since the exogenous mark-up shocks make the distortions time-varying.

In the context of NK-DSGE models Bayesian estimation methods are usually used for estimation of the structural parameters. After estimation the system is represented in state-space form using Kalman filter algorithms.

2.2.5 Advantages and disadvantages of structural methods

The main advantage of the structural methods is the direct link between the estimations and the economic theory. This allows for reaching policy conclusions and provide guidelines to policy makers. However, this advantage comes with a number of limitations. Structural methods are data demanding and in many cases some of the information needed may not be available. In addition, they are less flexible compared to non-structural methods since for each particular economic series the correct economic theory and the most realistic assumptions should be used. Also the models for economic series depend on unobserved variables; thus, statistical methods are also needed for their estimation.

2.3 Multivariate methods

As said previously in this paper, linear detrending, the UC method and the HP filter are non-structural statistical tools that do not use economic or structural information. In this section we consider extensions of the non-structural methods that also incorporate economic information on the supply side of the economy and on the stage of the business cycle. This information is often contained in economic relations (the Philips curve and Okun’s Law) and economic indicators (e.g. capacity utilisation).

2.3.1 Multivariate Beverige-Nelson decomposition

Forni and Reichlin (1998) propose a multivariate extension of the Beverige-Nelson decomposition. The trend part is still assumed to be a random walk but the stochastic shocks driving this trend are assumed to be linear combinations of innovations of GDP or other macroeconomic variables which contain long run information for forecasting the GDP. Similarly, with the univariate case, shocks of trend and cycle are correlated. Potential output in the Beverige-Nelson decomposition is defined as the level of output that is reached after all transitory dynamics have worked themselves out. The multivariate Beverige-Nelson decomposition encounters the same problems as the univariate one. In addition, the trend growth rate depends highly on the additional variables used.

2.3.2 Multivariate Hodrick-Prescott filter

Laxton and Tetlow (1992) propose a multivariate HP filter which incorporates some economic information. In particular, the Philips curve equation, the Okun's Law equation and a capacity utilisation equation are used in estimation.

The Philips curve is given by the equation

$$\pi_t = \pi_t^e + A(L)(y_t - y_t^*) + \varepsilon_{\pi,t},$$

which shows that the actual inflation rate will be above expectations when the level of output is above its potential level.

The Okun's Law is given by the equation

$$u_t = nairu_t + B(L)(y_t - y_t^*) + \varepsilon_{u,t},$$

which shows that the unemployment rate will be above the non-accelerating inflation rate of unemployment (NAIRU) when the level of output is below the potential output.

Finally, the capacity utilisation is given by the equation

$$cu_t = cu_t^* + C(L)(y_t - y_t^*) + \varepsilon_{cu,t},$$

which shows that the capacity utilisation is above the trend when output is above its potential level.

The residuals of the above equations are used in the minimisation of the loss function as follows:

$$\min_{y_t^*} \sum_{t=1}^{T} (y_t - y_t^*)^2 + \lambda \sum_{t=2}^{T-1} [(y_{t+1}^* - y_t^*) - (y_t^* - y_{t-1}^*)]^2 + \sum_{t=1}^{T} \mu_t \varepsilon_{\pi,t}^2 + \sum_{t=1}^{T} \beta_t \varepsilon_{u,t}^2 + \sum_{t=1}^{T} \psi_t \varepsilon_{cu,t}^2$$

Frequently, computational problems arise in the estimation of the above equation. Thus, although in theory all the coefficients of the model can be estimated, in most papers in the literature the weights of the influences in the filter are either fixed or assumed to be equal to the ratio of the sum of squared output gap to the sum of squared residuals in each of the conditioning equations.

2.3.3 Multivariate UC method

Gerlach and Smets (1999) extent the univariate UC method to take into account additional information about the inflation rate process. In particular, they estimate the following model

$$y_t = y_t^p + z_t$$

$$y_t^p = \mu^y + y_{t-1}^p + \varepsilon_t^y$$

$$\pi_{t+1} = \alpha(L)\pi_t + \beta z_t + \varepsilon_{t+1}^\pi$$

$$z_{t+1} = \varphi_1 z_t + \varphi_2 z_{t-1} + \lambda(i_t - \pi_t) + \varepsilon_{t+1}^z$$

where output y_t can be decomposed into potential output (y_t^p) and output gap (z_t). The potential output follows a random walk with a drift; the inflation rate is linked to the lagged inflation rate and the lagged output gap; and the output gap depends on its own lags and the real interest rate. The analysis and estimation of the multivariate UC is similar to the univariate case.

2.3.4 Advantages and disadvantages of multivariate methods

The main advantage of the multivariate methods is that the results about the level of potential output and of the output gap can be supported by economic reasoning. Also, it overcomes many limitations of the univariate methods, like the decomposition of the supply and demand shocks, the symmetry of the business cycles and the use of subjective judgement by the researches. However, using multivariate instead of univariate methods is more complicated and requires substantially more information. Also the need for specific treatment of each economic series implies less flexibility compared to univariate methods.

3. The EU methodology for estimating the output gap

In 2002 the European Policy Committee of the EU decided to adopt an economic and, in particular, the production function approach to estimating the potential output and output gap for surveillance of the member states.

This decision was based on the requirement for the operational surveillance tools of the member states to adhere to the following principles:

- they should be relatively simple and fully transparent where the key inputs and outputs are clearly defined,
- the equal treatment for all of the EU's Member States should be assured, and
- false optimism or unjustified pessimism should be avoided to promote unbiased estimates of the past and future evolution of potential growth.

The production function approach satisfies the above requirements. In addition, as an economic based methodology, it allows creating a meaningful link between policy reform measures and actual output. It also highlights the close relation between potential output and Non-Accelerating Wage Rate of Unemployment (NAWRU) concepts through its requirement to estimate the "normal" or equilibrium rate of unemployment. In addition the production function methodology gives the opportunity of making forecasts or building scenarios of possible future prospects by making explicit assumptions on the future evolution of demographic, institutional and technological trends (Havik et al., 2014).

3.1 Cobb-Douglas production function

The production function methodology requires production technology, the returns of scale, the technological process and the representative utilisation of the production factors to be specified. In most empirical applications, including the EU ones, the Cobb-Douglas specification is used because it greatly simplifies estimation and exposition. According to this specification output (Y) is produced using labour (L) and capital (K) according to the production technology defined by the functional form

$$Y = (U_L\, L\, E_L)^a (U_K\, K\, E_K)^{1-a} = (TFP) L^a K^{1-a},$$

where U_L and U_K are the degree of excess utilisation of labour and capital, respectively; E_L and E_K the level of efficiency of labour and capital, respectively; and TFP the total factor productivity

$$TFP = \left({E_L}^a {E_K}^{1-a}\right)\left({U_L}^a {U_K}^{1-a}\right),$$

which depends on the degree of utilisation and the level of efficiency of the factors of production.

The main assumptions of the Cobb-Douglas specification are constant returns to scale and factor price elasticity equal to one. These assumptions, although made mainly for simplicity, are supported by empirical findings. The output elasticity of labour and capital is given by a and $(1-a)$, respectively. These elasticities are based on the assumption of constant returns to scale and perfect competition and can be estimated by the wage share. The EU use the average wage share of the member states and estimate a to be equal to 0.63 and $(1-a)$ to be equal to 0.37. Although the output elasticities of labour and capital of member states deviate from these values, the EU contention is that such differences should not seriously bias the potential output results.

The potential level of output is calculated by substituting the trend (potential) level of inputs and efficiency in the production function and is given by

$$Y^* = (TFP^*){L^*}^{a}{K^*}^{1-a},$$

where K^* is the potential level of capital, L^* the potential level of labour and TFP^* the potential level of total factor productivity.

The potential level of capital is defined as the maximum output contribution of capital obtained by the full utilisation of the existing capital stock in the economy. Capital stock is a good indicator of overall capacity.[4] Thus, defining the potential level of capital is straightforward and approximated using the existing capital stock of the economy.

The potential level of total factor productivity is given when factor inputs are fully utilized (U_L and U_K are equal to one) and used at the normal (trend) level of efficiency. The latter is measured using a bivariate Kalman Filter model which exploits the link between the TFP cycle and the degree of capacity utilisation in the economy. In particular, it is measured as a Kalman filtered Solow residual, i.e. by subtracting the contribution of labour and capital from total output.

The potential level of labour is defined as the maximum potential output contribution of labour and is determined in terms of hours. The potential labour is approximated by $L^* = popw * parts * (1-u_t^*) * hourst$, where: $popw$ is the working age population, $parts$ the smoothed participation rate and u_t^* the NAWRU; and $hourst$ the trend average hours worked.

The NAWRU indicator is based on the Neo-Keynesian Philips (NKP) curve and the idea that actual unemployment below equilibrium unemployment is associated with wage inflation above its expected value. In the NKP curve rational expectations are assumed as opposed to adaptive expectations assumed by the Traditional Keynesian Philips curve (TKP). In empirical applications a hybrid NKP which allows for a combination of backward and forward looking behaviour is allowed. Assuming that the unemployment gap follows an AR(2) process then the hybrid NKP curve used by the EU is given by

$$\Delta rulc_t = \alpha \Delta rulc_{t-1} - \beta_1(u_t - u_t^*) + \beta_2(u_{t-1} - u_{t-1}^*),$$

[4] Since unsmoothed series of capital stock are rather stable in the EU, there is no reason for using the smoothed capital series as the potential level of capital.

where $\Delta rulc_t$ is the growth rate of real unit labour cost (wage) at period t, u_t the unemployment rate at period t, u_t^* the NAWRU level of unemployment; $\beta_1 < 0$, $\beta_2 > 0$, and α are parameters.[5]

In summary the model can be described as follows:

- the potential labour input is given by $L_t^* = popw_t * parts_t * (1 - u_t^*) * hourst_t$,
- the potential capital input by: $K_t = I_t + (1-\delta)K_{t-1}$ where $I_t = IYPOT * Y_t^*$,
- the potential output by: $Y_t^* = {L_t^*}^{0.65} {K_t}^{0.35} SRK$, and
- the output gap is given by: $Y_t^{gap} = \left({Y_t}/{Y_t^*} - 1 \right)$.

The variables $popw_t$ (working age population), $parts$ (smoothed participation rate), u_t^* (non-accelerated wage rate level of unemployment), $hourst$ (trend average hours worked), $IYPOT$ (investment to potential output ratio) and SRK (Kalman filtered Solow Residual) are exogenous; whereas the variables L_t^* (potential labour input), I_t (investment), K_t (capital stock) and Y_t^* (potential output) are endogenous.

3.2 Application to Cyprus

3.2.1 Data

For the estimation of the Cyprus output gap five datasets are created: cyAMECO_2015I_Final, cySRKf_2015I_Final, cy_POP2013, cy_NAWRU_2015I_Final and cy_csmdpart.

- The main source of information for the cyAMECO_2015I_Final data is the Annual macro-economic database (AMECO) of the European Commission's Directorate General for Economic and Financial Affairs (DG ECFIN).[6] Table 1 shows the description of the variables from the AMECO dataset. The majority of the variables are obtained directly from the AMECO dataset, though some variables (mainly regarding growth rates like the growth rate of GDP at current prices as well as at constant 2010 prices) are constructed from information in the AMECO dataset.
- The cySRKf_2015I_Final data contains two variables: the cy_tfpf and the cy_srkf, which are the total factor productivity (TFP) and the trend total factor productivity, respectively, for the years 1995 to 2025. The cy_tfpf is estimated using the RATS program for output gap when instead of output gap the TFP input series is asked to be prepared.
- The cy_POP2013 data contains two variables, the cy_poptf and cy_popaf, which are projections for the total and working age population (aged 15 to 74 years), respectively, up to the year 2080. The source of information is the EUROSTAT and in particular the Europop2013 which is the latest population projections released by Eurostat (Population and social conditions/Population projections/EUROPOP2013-Population projection at national level/Projected population/Main scenario - Population on 1st January by age and sex (proj_13npms)).

[5] The parameter α determines the degree of forward looking behaviour: when $\alpha = 0$ then the purely forward looking case emerges; whereas, when $\alpha \approx 1$ forward looking behaviour becomes irrelevant.

[6] This database contains data for EU-28, the euro area, EU Member States, candidate countries and other OECD countries (United States, Japan, Canada, Switzerland, Norway, Iceland, Mexico, Korea, Australia and New Zealand). Other source of data for the cyAMECO_2015I_Final data is the EUROSTAT, the statistical office of the EU with the task is to provide comparative statistics across EU countries and regions.

- The cy_NAWRU_2015I_Final contains three variables; the cy_lur which is the rate of unemployment obtained from the AMECO dataset, the cy_trend_smoothed which is the estimate NAWRU from the GAP program and the cy_NAWRU which is the cy_trend_smoothed variable adjusted by adding the correction factor -0.08 to get the NAWRU variable used in the output gap rats program.
- The cy_csmdpart data contains one variable, the cy_awgdpart, which is a projection of the year by year change of the labour market participation rate of the working age population (aged 15 to 74 years) up to the year 2060. The source of information is the Ageing Working Group's (AWG) Budgetary projections (2015 AR) which are based on the Cohort Simulation Model (CSM).

Technically the TFP is the Solow residual from the estimation of the GDP on labour input and capital stock. The cy_srkf is the TFP trend and is estimated from the Solow residual by using a bivariate Kalman filter method that exploits the link between the TFP cycle and capacity utilization. For the estimation of the TFP trend the GAP program, which is a program developed

Table 1: Description of variables from AMECO dataset

Variable	Description	Source
cy_er	ECU-EUR exchange rates (annual averages) : Units of national currency per EUR/ECU	AMECO 13.1 - Monetary Variables/Exchange rates and purchasing power parities/National currency units per ECU-EUR (XNE)
cy_gdphp	Trend gross domestic product at 2010 reference levels	AMECO 6.6 - Domestic Product /Trend gross domestic product at constant prices/Trend gdp (OVGDT)
cy_gdpn	Gross domestic product at current prices	AMECO 6.1 – Domestic product/Gross domestic product/At current prices (UVGD)
cy_gdpne	Gross domestic product at current prices: Reference level for excessive deficit procedure	AMECO 6.1 – Domestic product/Gross domestic product/At current prices, EU member states: excessive deficit procedure (UVGDH)
cy_gdpng	Growth rate of gross domestic product at current prices (constructed as the growth rate of cy_gdpn)	
cy_gdpq	Gross domestic product at 2010 reference levels	AMECO 6.1 – Domestic product/Gross domestic product/ At constant prices (OVGD)
cy_gdpqg	Growth rate of gross domestic product at 2010 reference levels (constructed as the growth rate of cy_gdpq)	
cy_hpere	Average annual hours worked per person employed	AMECO 6.4 - Domestic product/ Gross domestic product per hour worked/Average annual hours worked per person employed (NLHA)
cy_hwcdw	Nominal compensation per employee: total economy	AMECO 7.4 - Gross domestic product (income approach), labour costs/Nominal compensation per employee, total economy/Total economy (HWCDW)
cy_in	Gross fixed capital formation at current prices: total economy	AMECO 3.1 - Capital formation and saving, total economy and sectors/ Gross fixed capital formation, total economy/At current prices (UIGT)

cy_iq	Gross fixed capital formation at 2010 prices: total economy	AMECO 3.1 - Capital formation and saving, total economy and sectors/ Gross fixed capital formation, total economy/ At constant prices (OIGT)
cy_kt	Net capital stock at 2010 prices: total economy	AMECO 8.1 - capital stock/Net capital stock at constant prices, total economy/ Net capital stock (OKND)
cy_lf	Total labour force (Labour force statistics)	AMECO 1.2 - Population and employment/Labour force statistics/ Total labour force (NLTN)
cy_lu	Total unemployment :- Member States: definition EUROSTAT	AMECO 1.3 - Population and employment/Unemployment/ Total (NUTN)
cy_lur	Unemployment rate: total :- Member States: definition EUROSTAT	AMECO 1.3 - Population and employment/Unemployment/ Percentage of civilian labour force (ZUTN)
cy_nulc	Nominal unit labour costs: total economy (Ratio of compensation per employee to real GDP per person employed.)	AMECO 7.7 - Gross domestic product (income approach), labour costs/ Nominal unit labour costs, total economy/ Nominal unit labour costs (PLCD)

Table 1 (continued)

Variable	Description	Source
cy_pce	Price deflator private final consumption expenditure ((constructed as the ratio of price deflator between two consequence years)	AMECO 2.1 - Consumption /Private final consumption expenditure/ Price deflator (PCPH)
cy_pgde	Price deflator gross domestic product	AMECO 6.1 - Domestic product/Gross domestic product/Price deflator (PVGD)
cy_popa	Population: 15 to 64 years	AMECO 1.1 - Population and employment/ Population/ 15 to 64 years (NPAN)
cy_popa1	Population 15 to 74 years	EUROSTAT - Population and social conditions/Demography and migration/Population/ Population on 1 January by age and sex (demo_pjan)
cy_popt	Total population (National accounts)	AMECO 1.1 - Population and employment/ population/Total (national accounts) (NPTD)
cy_ppp	GDP purchasing power parities :- Units of national currency per PPS (purchasing power standard)	AMECO 13.1 - monetary variables/Exchange rates and purchasing power parities/ GDP purchasing power parities, national currency units per PPS (KNP)
cy_sle	Civilian employment, national (NECN)	AMECO 1.2 - Population and employment/Labour force statistics/ Civilian employment, national (NECN)
cy_sle1	Employment, persons: total economy (National accounts)	AMECO 1.4 - Population and employment/Employment, persons (national accounts)/ Total economy, national (NETN)
cy_sled	Employment, persons: all domestic industries (National accounts)	AMECO 1.4 - Population and employment/Employment, persons (national accounts)/ Total economy, domestic (NETD)
cy_uwcd	Compensation of employees: total economy	AMECO 7.1 - Gross domestic product (income approach), labour costs)/Compensation of employees/ Total economy (UWCD)

by the Joint Research Centre of the European Commission is used[7]. The input variables are the Solow residuals and the capacity utilization (CUBS).

The CUBS variable is a composite index of three elements: the capacity utilization in industry (CU), the economic sentiment indicator for services sector (ESI.SERV) and the economic sentiment indicator for construction sector (ESI.BUIL). Information about these elements are obtained from the Joint Harmonized EU Programme of Business and Consumer Surveys. The CU indicator is derived from answers to question Q13 of the industry survey. Data are quarterly and for the needs of the TFP estimation are transformed to annual by taking the average of the four quarters. The ESI.SERV and ESI.BUIL series are obtained from answers to questions Q1-Q3 of the services survey and Q3-Q4 of the construction survey, respectively. Again, the data are monthly and are transformed to annual by taking the average of the twelve months.

The CUBS variable is defined as the weighted average of CU, ESI.SERV and ESI.BUIL only when all three indicators are available. For the years where either ESI.SERV or ESI.BUIL is not available the CUBS variable is set equal to CU; and the CUBS variable is missing when the CU indicator is not available. The weights used for combining the three indicators into one are taken to be the shares of the corresponding sectors in the total economy. Before the weighted average is calculated, each indicator is rescaled so that its volatility matches the volatility of the value added series (provided by AMECO) of the given sector. This is because when the indicators are not rescaled the resulting aggregate CUBS indicator would be biased towards the sector with the most volatile survey index.

As we have already mentioned, for the estimation of the TFP-trend a Kalman filter approach is used to exploit the link between the TFP and the capacity utilization. All computations and estimations are made by the GAP program, which was developed by the EU. In the estimation of the TFP-trend the Bayesian approach over the standard Maximum Likelihood estimation (MLE) method is preferred because it overcomes some of the stability problems encountered in the context of the MLE. In addition, the Bayesian approach gives the opportunity to include in the estimation additional information that is not included in the data in the form of prior distributions of the parameters.

As shown earlier, based on the Cobb-Douglas production function, the TFP is given by

$$TFP = \left({E_L}^{a}{E_K}^{1-a}\right)\left({U_L}^{a}{U_K}^{1-a}\right),$$

where ${E_L}^{a}{E_K}^{1-a}$ represent the trend component (P), since efficiency is a persistence process; and ${U_L}^{a}{U_K}^{1-a}$ represents the cyclical component (C), since capacity utilization depends on current economic conditions. For the cycle-trend decomposition of TFP the following bivariate model is used

$$tfp_t = p_t + c_t$$

$$u_t = \mu_U + \beta c_t + e_{Ut};\ V(e_{Ut}) = V_U$$

The unobserved components dynamics are given by

[7] The GAP program use maximum likelihood or Bayesian inference in the estimation of the model parameters and the unobserved quantities (forecasts) are produced using a Kalman filter and a smoother. As output, GAP returns trend-cycle estimates of unemployment or TFP.

$$\Delta p_t = \mu_{t-1}$$

$$\mu_t = \omega(1-\rho) + \rho\mu_{t-1} + a_{\mu t}\,;\; V(a_{\mu t}) = V_\mu$$

$$c_t = 2A\cos\left(2\pi/_\tau\right)c_{t-1} - A^2 c_{t-2} + a_{ct}\,;\; V(a_{ct}) = V_c$$

In the Bayesian approach all parameters are considered as random variables with initial distribution that reflects prior knowledge. Table 2 presents the assumptions imposed for Cyprus regarding the distribution, the mean, the standard deviations and the support of each parameter of the model:

- the TFP annual growth is set to have a mean of 1.5% with standard deviation 0.02;
- the persistence of the slope of the trend has a mean of 0.8 and a standard deviation of 0.238;
- the mean cyclical periodicity is set to 7 with standard deviation 2 and the mean cyclical amplitude to 0.42 with standard deviation 0.17; and

Table 2: Prior assumptions in TFP trend-cycle decomposition

Variable	Distribution	Mean	Std	Range
		Trend		
ω	Normal	0.015	0.02	(-0.02 , 0.05)
ρ	Normal	0.7988	0.238	(0 , 0.99)
V_μ	Inverted Gamma	$1.418\text{x}10^{-5}$	$1.76\text{x}10^{-5}$	
		Cycle		
τ	Beta	7	2	(2 , 17)
A	Beta	0.4246	0.17	(0 , 1)
V_c	Inverted Gamma	0.001002	0.001001	
		Capacity Utilization		
β	Student-t	1.4	0.705	(0 , 5)
μ_U	Student-t	0	0.03292	(-0.1 , 0.1)
V_U	Inverted Gamma	0.004036	0.004038	

- the capacity utilization parameters β is set equal to 1.4 and μ_U equal to 0, with standard deviations 0.7 and 0.03, respectively.

The value of β is considered as a measure of the link between capacity utilization and TFP. The priors of the variance of the shocks, V_μ, V_c, and V_U, are calibrated to better fit the data using an Inverted Gamma distribution with 6 degrees of freedom. In the table the mean and standard deviation are presented as set for spring 2015 forecast.

The NAWRU is linked to the Philips curve and, implicitly, is given when the labour market is in equilibrium. The Philips curve implies a negative relationship between cyclical unemployment and the expected growth rate of real unit labour cost (wage inflation). The way expectations are formed plays an important role in the Philips curve model specification. In the context of the TKP expectations about the wage inflation can be either static or adaptive. Under adaptive expectations exogenous variables like the labour productivity and the terms of trade are used to model the wage setting mechanism and productivity growth expectations. When the NKP curve is adopted rational expectations are assumed.[8] Thus, the NKP implies forward looking behaviour, i.e. the growth rate of real wage is not affected by the change in the general price level of the previous contract period but only by the change of the general price level during the period of the contract.

As pure forward looking behaviour is not realistic a hybrid NKP with both backward- and forward- looking behaviour is used in empirical analysis. The resulting specification is described by the equation

$$\Delta rulc_t = \beta(s\Delta rulc_{t+1}^{e} + (1-s)rulc_{t-1}) - \lambda(u_t - u_t^{*})\ with\ \beta \leq 1\ and\ 0 \leq s \leq 1,$$

where $\Delta rulc_t$ is the growth rate of real unit labour cost (wage) at period t, u_t the unemployment rate at period t, u_t^{*} the NAWRU level of unemployment, while s indicates the share of forward looking wage setters. Expectations need to be formed only about the future (not the current) real unit labour cost growth since the wage contracts are assumed to span more than one period.

Assuming that the unemployment gap follows an AR(2) process then the hybrid NKP curve is given by

$$\Delta rulc_t = \alpha\Delta rulc_{t-1} - \beta_1(u_t - u_t^{*}) + \beta_2(u_{t-1} - u_{t-1}^{*})$$

where $\beta_1 < 0$, $\beta_2 > 0$, and α are parameters. As said in the previous section, the parameter α determines the degree of forward looking behaviour: $\alpha = 0$ corresponds to the purely forward looking case; whereas, $\alpha \approx 1$ implies that forward looking behaviour is irrelevant.

The structural unemployment rate - i.e. the unemployment rate which is consistent with constant wage inflation (non-accelerated wage rate of unemployment, NAWRU) - is estimated using the GAP program, where the rate of unemployment (LUR variable) and the change in real unit labour cost (wage inflation minus labour productivity growth minus private consumption inflation) are the endogenous variables. For Cyprus no exogenous variables are used in the estimation of the trend unemployment rate and a purely forward-looking specification of the NKP is used.[9]

Changing the methodology from the TKP to the NKP for estimating NAWRU results in a downward revision of the NAWRU for Cyprus by 0.9pp in 2013, 1.7pp in 2014 and 2.9pp in 2015 (Havik et al., 2014). Also, this methodology change results in the output gap revised downward by 0.6pp in 2013, 1.2pp in 2014 and 2.3pp in 2015; while the structural balance increases by 0.3, 0.5 and 1 pp in 2013, 2014 and 2015, respectively.

The NAWRU, which is estimated in the context of the NKP specification, is assumed to obey the zero-mean restriction on the unemployment gap. This is equivalent to restricting the NAWRU average to be equal to the average unemployment rate. The TKP specification does not impose such restriction and, thus, the two specifications may give different NAWRU average. A solution to that can be the imposition of a zero-mean unemployment gap restriction also on the TKP model. Alternatively, as done by the EU, the NKP specification

[8] Also, the wage settings are assumed to be agreed in the middle of the period instead in the beginning of the period as in the TKP.
[9] Candidate exogenous variables include the wage share (the log of "total compensation of employees" over the GDP level), the lagged one and two periods wage share, the second difference of the wage share, the percentage change in labour productivity (annual percentage change of GDP per person employed), the lagged one period percentage change in labour productivity, the first difference of the percentage change in labour productivity, the lagged one period first difference of the percentage change in labour productivity, the first difference of terms of trade (difference between the PCE and GDP deflator) and the lagged one period first difference of terms of trade.

can be adjusted to have the same average NAWRU value as the TKP one. Two steps are taken for this adjustment: (i) the mean difference between the NKP and TKP NAWRU is computed; and (ii) if the mean difference is positive, the NKP NAWRU is shifted downward by the amount of the difference. For Cyprus the NKP adjustment factor is -0.08.

3.2.2 Results

The EU reports estimates on the output gap for the member states three times a year; for winter, spring and autumn. Table A1 in the Appendix shows the output gap estimates, along with other information used in the output gap calculation, based on the latest 2015 autumn European Commission's report (CIRCA, 2015).

Figure 1: The output gap in Cyprus

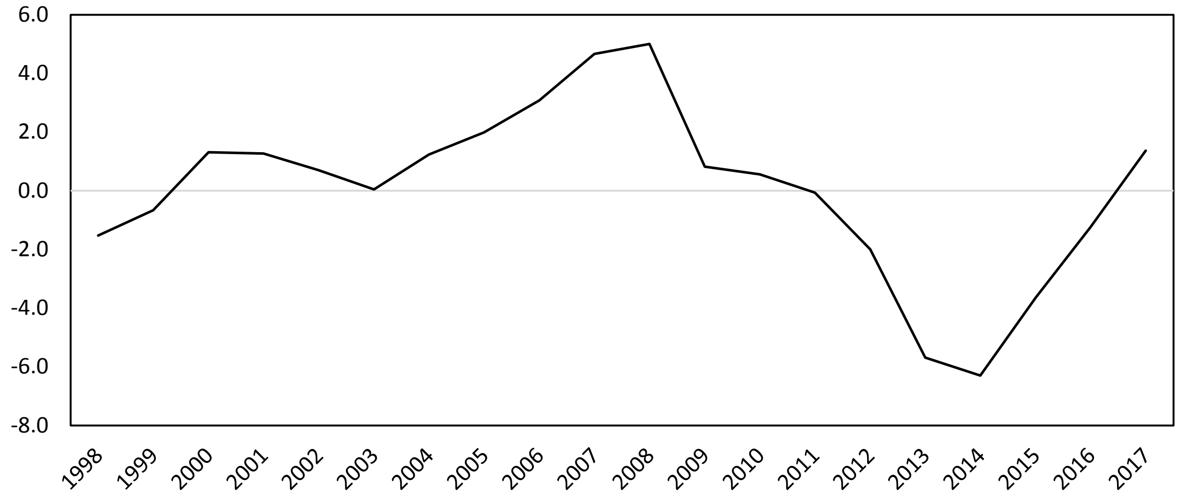
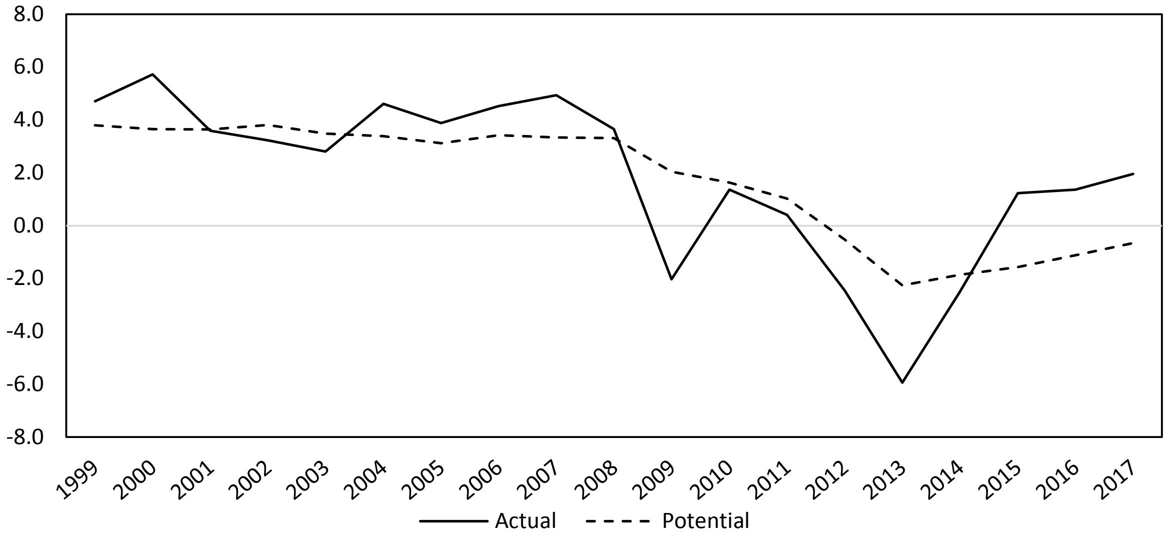


Figure 1 shows the evolution of the output gap from 1998 to 2014, and the forecast for the years 2015, 2016 and 2017.

- In 1998 the output gap was negative, i.e. actual output was by 1.5 percent lower than the potential output of the economy. In 1999 the negative output gap decreased and after 2000 became positive.
- The output gap hit its top level in 2008, when the actual output of the economy was 5 percent higher than its potential level.
- In 2009 the positive output gap declined sharply to 0.8 percent, and in 2010 to 0.6 percent. In the period 2011 to 2014 the output gap followed an increasingly negative path; in 2014 the actual output was by 6.3 percent lower than its potential level.
- The negative output gap is expected to decrease to -3.6 percent in 2015 and to -1.2 percent; whereas in 2016 and in 2017 is expected to become positive at 1.4 percent.

Figure 2: Actual and potential output growth in Cyprus



An important by-product of the output gap calculation is the estimation of the potential output of the economy. Figure 2 shows the growth rate of the actual (solid line) and of the potential (dash line) output for the period 1999 to 2017. The growth of the potential output follows a much smoother pattern compared to the growth of the actual output which varies round the potential output growth line and has more spikes. In the period 1999 to 2008, the potential output was rather stable, with its growth rate ranging between 3.1 and 3.8 percent. On the other hand, the actual output was more volatile.

In the period 1999 to 2001 the growth rate of actual output was above the growth rate of potential output: in 1999 it was 4.7, in 2000 increased to 5.7 percent and in 2001 decreased to 3.6 percent. In 2002 and 2003 the growth rate of actual output decreased further to 3.2 and 2.8, respectively; and was below the growth rate of potential output. In the period 2004-2008 actual output grew more than the potential output: it was 4.6 percent in 2004, decreased to 3.9 percent in 2005, increased to 4.5 percent in 2006 and 4.9 percent 2007, and decreased to 3.7 percent in 2008.

In the period 2009 to 2014 both actual and potential output growth rates followed a decreasing trend, but the negative path of potential output growth rate was smoother and of smaller magnitude. In particular, the growth rate of potential output was 2 percent in 2009, decreased to 1.6 percent and 1 percent in 2010 and 2011, respectively; and became negative in 2012, at -0.5 percent. In 2013 and 2014 the growth rates of potential output decreased further to -2.3 and -1.9 percent, respectively. The decrease in the growth rate of actual output was more substantial over the same period: in 2009 it contracted by -2 percent, but in 2010 and 2011 increased by 1.4 and 0.4 percent, respectively. However, after 2011 the growth rate of actual output was negative: -2.4 percent in 2012, -5.9 percent in 2013 and 2.5 percent in 2014.

As regards the forecasts for the growth rate of potential and actual output for the period 2015 to 2017, actual output is expected to grow more rapidly compared to potential output. Actual output is expected to grow by 1.2 percent in 2015 and by 1.4 percent and 2 percent in 2016 and 2017. On the other hand, the potential output is expected to contract by 1.6 percent in 2015, by 1.1 percent in 2016 and by 0.7 percent in 2017.

Table 3: Output gap and potential output growth based on the HP-filter and PF method

Year	Output Gap (% of Potential Output)		Potential Output Growth (annual % change)	
	HP Filter	PF method	HP Filter	PF method
1998	-1.75	-1.53	4.17	N/A
1999	-1.25	-0.66	4.18	3.80
2000	0.25	1.32	4.14	3.65
2001	-0.19	1.27	4.05	3.64
2002	-0.85	0.70	3.91	3.81
2003	-1.72	0.05	3.73	3.48
2004	-0.66	1.23	3.48	3.38
2005	0.04	1.99	3.16	3.12
2006	1.77	3.08	2.75	3.42
2007	4.43	4.67	2.26	3.34
2008	6.42	5.01	1.71	3.32
2009	3.08	0.82	1.14	2.04
2010	3.85	0.56	0.62	1.63
2011	4.09	-0.06	0.17	1.02
2012	1.71	-1.99	-0.16	-0.53
2013	-4.00	-5.68	-0.35	-2.26
2014	-6.05	-6.30	-0.37	-1.86
2015	-4.65	-3.64	-0.26	-1.56
2016	-3.27	-1.23	-0.09	-1.12
2017	-1.47	1.37	0.10	-0.66

Source: 2015 Autumn European Commission's output gap results

The EU estimates and reports the level of potential output and the output gap of its member states three times a year: winter, spring and autumn. In these reports the output gap and the potential output growth rate are calculated using the official production function method and the HP filter. Table 3 shows the estimates of output gap and potential output for Cyprus based on these two methods for the period 1998 to 2017.

As we can see the two methods give similar results only for 1998, 2007 and 2014 for output gap; and for in 2002, 2004 and 2005 for potential output growth. For most of the years the estimated output gap, based on the two methods, has the same sign but is different in size; while for a significant number of years the two methods give contradicting results. For example, in the period 2001-2004 the output gap estimated by the HP filter method is negative, whereas the one based on the PF method is positive. Similarly, in the years 2011 and 2012 the output gap is positive when estimated with the HP filter and negative when estimated with the PF method.

4. Summary and Conclusions

This paper reviews the main methodologies for estimating the potential output and output gap. Methodologies can be grouped into two categories: the non-structural ones, which are not based on economic theory and are mainly statistical procedures; and the structural methodologies, which are based on economic foundations. Examples of non-structural methods include the linear detrending, the Hodrick-Prescott filter, the Beverige-Nelson decomposition, the Unobservable Component method, and the Band-Pass filter; while examples of the structural methods include the method based on the Okun's Law, the production function approach, the long-run restrictive models, and the NK-DSGE models.

The main advantage of the non-structural methods is the simplicity and the limited information needed for their application. However, the lack of economic foundations does not make them suitable for economic policy design. On the other hand, structural methods allow for policy conclusions and guidelines to the policy makers but are data demanding and less flexible in their use than the non-structural methods. In the literature hybrid methodologies (multivariate methods) are proposed where structural information is added to statistical methodologies, like the Hodrick-Prescott filter, the Beverige-Nelson decomposition and the Unobservable Component. The advantage of hybrid methodologies is that the results about the potential output and output gap can be supported by economic reasoning. Nonetheless, multivariate methods, are more complicated, less flexible and are more data demanding than the univariate ones.

The EU uses the production function approach to estimate the output gap for its member states. In this paper, the methodology, the data, as well as the assumptions made are reviewed and the Cobb-Douglas production function with constant returns to scales is specified. In the context of this specification the final output depends on the total factor productivity of the economy which measures the degree of utilisation and the level of efficiency of the factors of production. The potential output is obtained when all factors of production are at their potential level and are efficiently and fully utilised. As an indicator of the potential level of capital, the capital stock of the economy is used. The potential level of labour, which is measured in hours, is defined as the number of hours obtained when (i) the participation rate of working age population is at its trend level, (ii) the unemployment rate is at the non-accelerated wage rate level of unemployment and (iii) the level of working hours is at its trend average. The potential level of total factor productivity is given by the Kalman filtered Solow residual. The data for the calculation of the potential output and output gap are drawn from the AMECO (DG ECFIN) and the EUROSTAT databases.

The EU estimates and reports the level of potential output and the output gap obtained from the official production function method and the Hodrick-Prescott filter. Based on these methods, the estimates of output gap and potential output for Cyprus during the period 1998 to 2017 are presented. The findings show that the two methods give different and often contradictory results, suggesting that the estimates of the output gap can be very sensitive to the model used and the assumptions made. The results support the current EU practice of using the same methodology for the estimation of the output gap in all its member states; nonetheless, they raise questions about the suitability of also using the same assumptions across countries in this estimation.

Plans for future work includes further analysis of the sensitivity of the output gap estimates to the assumptions made by alternative methodologies. In addition, forecasting techniques will be utilised in order to estimate the short run (three to five years) evolution of actual output, potential output and output gap.

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Appendix

Table 1A: Potential Output and Output Gap in Cyprus

	Output Gaps (% of Potential Output)	Actual Output Growth (annual % change)	Potential Growth (annual % change)	Contributions to Potential Growth					Determinants of Labour Potential and Capital Accumulation			
				Total Labour (Hours) Contr.	Labour (persons) Contr.	Changes in Hours (per Empl) Contr.	Capital Accumulation Contr.	TFP Contr.	Growth of Working Age Population (annual % change)	Trend Participation Rate (% of Working Age Population)	NAWRU (% of Labour Force)	Investment Ratio (% of Potential Output)
1995	#N/A	9.9	#N/A	#N/A	(0.0)	#N/A	#N/A	#N/A	2.3	65.7	#N/A	#N/A
1996	#N/A	1.6	#N/A	#N/A	#N/A	#N/A	1.7	#N/A	2.1	65.4	#N/A	#N/A
1997	#N/A	2.4	#N/A	#N/A	#N/A	#N/A	1.7	#N/A	2.0	65.1	#N/A	#N/A
1998	-1.5	5.1	#N/A	#N/A	#N/A	#N/A	1.0	#N/A	1.9	65.0	3.4	18.5
1999	-0.7	4.7	3.8	1.4	(1.2)	(0.2)	1.4	1.0	1.8	65.0	3.5	20.7
2000	1.3	5.7	3.7	1.3	(1.2)	(0.1)	1.3	1.0	1.8	65.2	3.7	20.0
2001	1.3	3.6	3.6	1.5	(1.6)	(-0.1)	1.2	0.9	1.8	65.6	3.8	19.4
2002	0.7	3.2	3.8	1.4	(1.7)	(-0.3)	1.6	0.8	1.9	66.2	3.9	21.2
2003	0.1	2.8	3.5	1.3	(1.8)	(-0.4)	1.5	0.7	1.9	66.9	4.3	20.7
2004	1.2	4.6	3.4	1.3	(1.8)	(-0.5)	1.5	0.6	2.0	67.6	4.5	20.9
2005	2.0	3.9	3.1	1.1	(1.6)	(-0.5)	1.7	0.4	2.1	68.1	4.9	21.6
2006	3.1	4.5	3.4	0.9	(1.3)	(-0.4)	2.3	0.2	2.3	68.2	5.3	25.3
2007	4.7	4.9	3.3	0.9	(1.2)	(-0.3)	2.4	0.0	2.8	67.9	5.8	26.4
2008	5.0	3.7	3.3	0.9	(1.1)	(-0.2)	2.6	-0.2	3.3	67.2	6.4	27.9
2009	0.8	-2.0	2.0	0.6	(0.7)	(-0.1)	1.8	-0.3	3.4	66.4	7.3	23.5
2010	0.6	1.4	1.6	0.5	(0.5)	(-0.0)	1.5	-0.3	3.2	65.4	8.0	22.0
2011	-0.1	0.4	1.0	0.3	(0.4)	(-0.0)	1.0	-0.4	3.0	64.4	8.9	19.7
2012	-2.0	-2.4	-0.5	-0.6	(-0.5)	(-0.0)	0.4	-0.4	1.7	63.5	9.9	15.8
2013	-5.7	-5.9	-2.3	-1.9	(-1.8)	(-0.1)	0.1	-0.5	-0.4	62.7	11.0	13.7
2014	-6.3	-2.5	-1.9	-1.2	(-1.0)	(-0.1)	-0.3	-0.4	0.3	62.1	11.8	11.4
2015	-3.6	1.2	-1.6	-1.1	(-1.0)	(-0.1)	-0.3	-0.2	0.2	61.7	12.6	11.9
2016	-1.2	1.4	-1.1	-0.8	(-0.8)	(-0.1)	-0.2	-0.1	0.2	61.5	13.5	12.4
2017	1.4	2.0	-0.7	-0.6	(-0.5)	(-0.1)	-0.1	0.0	0.1	61.5	14.3	13.0
2018			0.0	-0.1	(-0.0)	(-0.0)	0.0	0.1	0.1	61.7	14.7	13.8
2019			0.6	0.4	(0.4)	(-0.0)	0.1	0.1	0.1	62.1	14.7	14.5
2020			0.8	0.5	(0.5)	(-0.0)	0.2	0.1	0.0	62.5	14.7	15.2

Source: 2015 Autumn European Commission’s output gap results.

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