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USING FILTERS AND PRODUCTION FUNCTION METHOD FOR ESTIMATING OUTPUT GAP AND POTENTIAL GDP FOR ROMANIA

Abstract. *Univariate filters and production function methods are among the most widely recommended methods for estimating potential output and output gap. In this paper we apply the production function method on annual time series covering years 1991-2012 and employ the Hodrick-Prescott filter, Baxter- King and Christiano-Fritzgerald band- pass filters on quarterly data of real GDP covering the period 2000- 2012 to extract potential GDP and output gap for Romania.*

The production function we use is Cobb-Douglas type with constant returns to scale and Hicks neutral technological progress and the potential labor is computed considering both constant NAIRU, estimated with Ball-Mankiw's method (2002), and variable NAIRU resulted from a version of Phillips curve expectation augmented model (Greenslade, Pierse (2003)). Potential output and output gap are calculated using two different values for production elasticity with respect to capital, and both constant and variable NAIRU.

Regarding the empirical applications of the filters, we conclude that the CF filter performed better, and that all the methods used show the economic crisis that affected the Romanian economy during 2008-2010.

Keywords: *Potential GDP, output gap, HP filter, Baxter- King band-pass filter, Christiano- Fitzgerald band-pass filter, production function method, NAIRU, Phillips curve.*

JEL Classification: C29, C39, E24, E29

1. Introduction

Potential output is commonly defined as the highest level of real GDP that can be sustained on the long run considering the full employment of all available production factors.

Measuring potential output is very important in substantiating different policies or determining specific elements. For instance, in monetary policy potential output is required for determining the inflationary pressure (inflation rise/fall when output is above/below potential), while for the fiscal policy, it is needed in establishing the level of cyclical budget deficit. Also, it plays an important role in income policies, especially for wage level and income transfer policies, as well as in labor market policies, for determining the level of structural unemployment.

Because of its importance, the European Commission, OECD countries, individual states, and central banks pay a great deal of attention to determining the potential output and output gaps. The literature on this topic is enormous and many current concerns are focused on a wide variety of issues, covering the concept of potential output, computing methods, comparative analysis of the results, mixing the results obtained through different methods in order to get a more rigorous evaluation, revisions to output gap estimates, real time estimates of the output gaps, and types of economic policy models that use this unobserved indicator.

Bassanetti et al (2010), compute potential output and output gap for the Italian economy, using four alternative methods: Bayesian estimates, time-varying autoregressive model (TVAR) applied to growth rates, the production function approach, structural VAR model of output, inflation, real wages and unemployment rate. In order to reduce the estimating errors, the authors combined the results into a single indicator using model averaging techniques to calculate appropriate weights for combining the output gap measures.

In their work, Borio et al (2013), show that the recent financial crisis and the historical evidence show that it is possible for inflation to remain low and stable while the output is growing on an unsustainable path, when there are financial imbalances. To incorporate the financial indicators in potential output estimates, they represent HP filter in the state space and extend the dynamic system by including financial indicators.

Andrle (2013) presents some methods for determining output gaps (State-Space Forms, Univariate filters, Structural VARs, Production Function Approach) and decompose the computed output gaps into contributions of observed data on output such as: inflation, unemployment, and other variables.

Cacciotti et al (2013), using quarterly data for potential output estimates, follow the interest for mixed frequency dynamic factor models that decompose a vector of time series available at different frequencies in one common non-stationary component and some idiosyncratics, specific to each series, both following autoregressive standard processes.

Lin and Chen (2013), analyzing the impact of seasonality on various potential output measures for Taiwan's data, used state space model and the Kalman Filter, Watson's decomposition, Apel and Jansson's decomposition. The same authors developed in 2012 the corresponding Bayesian estimates for Taiwan economy for the two decompositions.

Ehlers et al (2013), besides the production function and HP filter approach, apply the SARB's Potential General Equilibrium Model (PGEM) that uses a general equilibrium approach to model the potential output level of the South African economy.

Oliveira, Portugal (2013) estimate the output gap for Brazil by applying the major methodologies referenced in the literature such as: HP filter, production function, linear and quadratic trends, Beveridge-Nelson decomposition, unobserved component model and also a variant of the standard new Keynesian dynamic stochastic general equilibrium (DSGE) model.

Bouis et al (2012), use the Cobb-Douglas production function with Harrod neutral labour augmenting technical progress to estimate the output gaps for OECD economies during the recent crisis and then use the results in the Taylor rule to determine the influence on monetary policy.

In their work, Basu and Fernald (2009) used two models: a standard one-sector model and a two-sector model with differential technological change across sectors. They conclude that the two-sector model, which allows for a change in the price of capital, outperforms the simple one-sector model. Regarding the definition of the concept, Basu and Fernald (2009) argue that the appropriate notion of potential output is the steady state of an economy with no distortions.

Although there are an impressive number of articles that study output gap in different countries, only a few estimate potential output and output gap for Romania. The most significant studies are the ones elaborated by Dobrescu (2006), Albu (2006), Alter et. al (2010), or by the experts from the National Bank of Romania (NBR) and the National Commission for Economic Forecasting (NCEF), whose results we briefly present below.

In the NBR study (Gălăţescu A., Rădulescu B., Copaciu M., 2007) the authors apply several univariate and multivariate methods for potential output estimation such as: HP filter, band pass filter, unobservable components based on Kalman filter, production function method and SVAR, and their results, that are robust to different methods and specifications, indicate an acceleration of potential output growth from 3%-4% between 2000-2002 up to 6-6.4% between 2003-2006.

Scutaru, Stănică (2004) evaluate the output gap and the effect of inflationary shocks on the economy, using the Blanchard-Quah decomposition and considering three variables: unemployment and inflation rates and real GDP and three different shocks: productivity, adverse shocks on the labor market and the adverse shocks on the goods market.

In the NCEF study (Ghizdeanu I., Tudorescu V., 2007), the authors apply the HP filter and the production function method and their results show an increase of potential GDP from 2.1% in 2001 to 4.2% in 2005 as well as a forecast of 6.4% for 2009 and, at the same time, a cut of one percentage point in output gap that would represent 3.5% of potential GDP in 2009 compared to 4.4% in 2005.

An important target for policy makers is to identify the rate of capacity utilization that is sustainable, in the sense that it is consistent with reasonably stable inflation, over the medium to longer term. The most common measure for the labor utilization is NAIRU, which is used as a benchmark to identify and distinguish sustainable trends in output and unemployment.

Altăr, Necula and Bobeică (2010) calculated potential GDP using production function methods, and estimated potential labor using NAIRU. Their results suggest that an average annual growth rate of the potential output of 5.8% for the period 2001-2008, but on a descending slope, due to the adverse developments in the macroeconomic context.

Albu (2006) estimated NAIRU for different data and noticed the sensitivity of the results to the changes in frequency of data. He also conceived a simple autonomous model in order to estimate the growth of a so-called “pure” productivity independently from the actual level of employment and to compare its dynamics with that of natural rate of unemployment.

Another important contribution to the theoretical and empirical studies on potential output belongs to Dobrescu (2006), that calculated output gap using the inflation - output gap relationship: $\Delta p = \beta(y - y_P)$, where Δ is the first order difference operator, p is logarithm of price level, y and y_P are actual and potential output in logarithms, respectively.

As many of the above presented studies show, statistical univariate methods are among the most employed tools for analysing economic growth and business cycles. In this paper we estimate the potential output and output gap for Romania using the conventional methods proposed by the European Union Council, which are widely recommended for this purpose: Hodrick-Prescott filter, Baxter- King and Christiano-Fritzgerald, with quarterly data covering the period 2000- 2012.

Another conventional method proposed by the European Union Council to estimate potential output and output gap is the production function method. We apply this method for a Cobb-Douglas production function and approximate potential labor with NAIRU. The data used are the annual series for real GDP, capital stock (as gross capital formation), civil active population and unemployment rate, during 1991-2012. For estimating constant NAIRU we use the Ball-Mankiw method and for variable NAIRU we use Greenslade, Pierse (2003), based on a version of “accelerationist Phillips curve model”.

This paper is structured in three parts: first consists of a brief presentation of the three filters used for estimating potential output (HP, BK and CF filters), the second refers to production function method, and constant and variable NAIRU estimating methods, while the last presents the main results and conclusions.

2. Estimating Potential Output using HP, BK, CF filters

Statistical univariate methods are purely mechanical procedures, which can be used to decompose a time series into components that show a strong persistency, called tendency, and components with weak persistency, usually associated with cyclical and very short-run movements.

In macroeconomic literature, the application of these methods to the observed real GDP series produces a smoothed series, called trend, which is considered to represent potential output, while the remaining components correspond to the output gap.

Although these methods are very easy to implement, their interpretation is limited to the results they produce. Some of the most employed univariate methods for analysing economic growth and business cycles are: the Hodrick-Prescott filter (HP), and Baxter-King (BK) and Christiano-Fitzgerald (CF) band-pass filters, that we further consider in our paper.

2.1.1. Hodrick –Prescott filter

HP filter Hodrick and Prescott, 1997 is a univariate method that can be used to decompose real output in two components: potential output and output gap. HP filter estimates potential output by minimizing the sum of squared deviations between output and potential output for each moment with respect to a restriction referring to potential output variation.

Potential output or trend is the solution of the following minimization problem that represents HP filter:

$$\min \sum_{t=1}^{T}\left(y_t-\tau_t\right)^2+\lambda\sum_{t=2}^{T-1}\left[\left(\tau_{t+1}-\tau_t\right)-\left(\tau_t-\tau_{t-1}\right)\right]^2 \qquad (1)$$

and the output gap or cyclical component, c_t, can be derived as residual or deviation from trend:

$$c_t=y_t-\tau_t \qquad (2)$$

where y_t denotes a time series that contains real output values, τ_t represents the trend (the potential output), and c_t is the cyclical component, that is the excess demand[1].

King and Rebelo, 1993 showed that removing a trend estimated by the HP filter is equivalent to a high-pass filter and that the filter would make integrated processes of order 4 or less stationary. The HP filter only allows the components of stochastic cycles at or above a specified frequency to pass through, while removing the low frequency trend components. Therefore, the high-frequency stochastic components remain in the estimated component, c_t.

HP filter uses a single parameter, λ, to control the smoothness of the trend series, and it is common to consider λ= 1600 for quarterly data, λ=6.25 for annual data, and λ=129.000 for monthly data (Ravn and Uhlig , 2001).

2.1.2. The Baxter –Kingband-pass filter

The ideal band-pass filter is defined in the theory of linear filtering as a moving average of infinite order that would eliminate all frequencies outside the desired frequency range completely.

In their attempt to get an appropiate filter to approximate the optimal one, Baxter and King (1999) propose a band-pass filter that minimizes the error between the filter coefficients and the ideal band-pass filter coefficients.

The Baxter-King (BK) filter implies applying a K^th^ order moving average to the original time series:

$$y_t^f = \sum_{k=-K}^{K} a_k y_{t-k} \tag{3}$$

under the hypothesis of symmetric moving average coefficients: $a_k = a_{-k}$.

As in equation (2), the data to be filtered, y_t, is the sum of an unobserved, nonstationary trend τ_t and a stationary cycle around this trend c_t.

Unlike HP filter, the BK filter is designed to remove both the long-run trend and the high-frequency movements in the original time series and pass through only components with fluctuations between 6 and 32 quarters (1.5- 8 years), which are usually associated with periodicities of typical business cycles (Guay and St-Amant, 2005, Murray, 2002).

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1 The output gap is positive when actual output exceeds the economy's potential and negative when actual output is below potential output. A positive output gap is also referred to as excess demand and a negative output gap is referred to as excess supply.

When applied to quarterly data, the band-pass filter proposed by Baxter and King takes the following form:

$$y_t^f = \sum_{k=-12}^{12} a_k y_{t-k} = a(L) y_t \tag{4}$$

where L is the lag operator and $a_k = a_{-k}$, is, again, the symmetry condition.

Murray (2002) demonstrates that the BK filter, and more generally any band-pass filter, does not isolate the cycle when the trend component of the series to be filtered is integrated, neither do the first order differences remove a stochastic trend- they merely renders it stationary. Therefore, while band-pass filtering can render an integrated series stationary, the properties of the filtered series will depend on the trend in the unfiltered series. Thus, the BK filter which is constructed to extract the business cycle component from a time series with deterministic or stochastic trends and eliminate deterministic linear or quadratic trends, will render stationary series that are integrated up to order two.

Another disadvantage of BK filter is the trade off in chosing the number of coefficients to approximate the infinite-order ideal filter. The larger the number, the closer it gets to the ideal filter, but at the expense of dropping additional observations at each end of the filtered series, which means it provides no values for recent quarters.

2.1.3.Christiano- Fitzgerald (CF), bandpass filter

Probing bandpass filters, Christiano and Fitzgerald, 2001 conclude that optimal filter approximations violate some of BK's six desired properties (see Guay and St-Amant, 2005), e.g., the weights are not symmetric in future and past values of the data, and they vary over time.

Therefore, they have developed the Christiano-Fitzgerald (CF) filter, also named Random Walk (RW) filter, that is, compared with BK filter, a better approximation of the optimal bandpass filter. The CF filter minimizes the mean squared error between the estimated component and the true component, assuming that the time series follows a random-walk process.

The filter isolates the components of a x_t series, according to the period of oscillation (between p_l *and* p_u, $2 \le p_l < p_u < \infty$).

The random walk filter approximation (Christiano and Fitzgerald, 2001) will be:

$$\hat{y}_t^f = B_0 y_t + B_1 y_{t+1} + ... + B_{T=1=t} y_{T=1} + \tilde{B}_{T=t} y_T + B_1 y_{t=1} + ... + B_{t=2} y_2 + \tilde{B}_{t-1} y_1$$

$$t = 3,4,...T - 2 \tag{5}$$

$$B_j = \frac{\sin(jb) - \sin(ja)}{\pi j},\ j \geq 1$$

$$B_0 = \frac{b-a}{\pi},\ a = \frac{2\pi}{p_u},\ b = \frac{2\pi}{p_l} \tag{6}$$

where $\tilde{B}_{T=t}$ and $\tilde{B}_{t-1}$ are linear functions of B_j and π is the mathematical constant.

The parameters p_u and p_l are the cut-off cycle length in months. Cycles longer than p_l and shorter than p_u are preserved in the cyclical term c_t presented in equation (2).

The CF filter is optimal for a random-walk process and also works well on processes that are close to being random walks or random walks with drift.

3. Multivariate methods: Production function methods

Production function methods are multivariate methods used for estimating potential output as a function of total factor productivity, capital and labor, all employed at their potential level. One of the advantages of the production function method is that it reflects the supply side of the economy. Another advantage resides in their ability to provide useful information regarding input contribution to potential output, but the estimates depend on the techniques employed for input smoothening and require longer time series. The synthesis of the main advantages of the production function method is well highlighted by Altar et al (2010).

Standard methods for estimating output gap followed by international organizations (OECD, European Commission) include production function based methods that require previous estimation of NAIRU and/or NAWRU. In our previous works Andrei et al (2009) and Andrei, Paun (2011), we used NAWRU indicator to approximate potential labor. However, during the economic crisis, due to the government's austerity policy, the wages were cut by 25% in the public sector while the prices continued to rise. Therefore, the relationship between wage inflation and unemployment was affected, and NAWRU could no longer be considered a good indicator for reflecting the correlation between unemployment and stable wage inflation. On the other hand, NAWRU is affected by labor market frictions, such as real wage rigidities, the institutional features of labor markets i.e. the job protection, social protection for the unemployed, or the level of labor taxation.

Both NAIRU and NAWRU computing methodologies are controversial. Therefore, researchers use a variety of methods for determining the NAIRU and

NAWRU and compare the results, or calculate a composite indicator, as presented by Bassanetti et al (2013) for output gap.

3.1. Cobb-Douglas Production Function

The existing literature defines potential output with reference to the full (economic) utilization of factor inputs and to inflation developments (eg. Okun (1962), Mishkin (2007)), that is, in order to compute potential output, it is necessary to know the levels of potential factor utilization and productivity, and exogenous estimates of the parameters needed for the production function. The utilization of that method usually implies two important assumptions: constant returns to scale and constant elasticity of substitution between the production factors.

For estimating potential output and output gap we consider the following Cobb-Douglas production function with constant returns to scale and Hicks neutral technological progress as total productivity factor:

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

Linearizing (1) by applying logs, yields:

$$y_t = tfp_t + \alpha k_t + (1-\alpha) l_t \tag{8}$$

in which small letters denote log values.

For a given α, the log value of total factor productivity $(tfp_t = \ln A_t)$ is the Solow residual derived from the equation:

$$tfp_t = y_t - [\alpha k_t + (1-\alpha) l_t] \tag{9}$$

We assume that tfp_t has a linear dependence on t, thus we regress the equation below to obtain the parameters a and b:

$$tfp_t = a + bt + \varepsilon_{y_t} \tag{10}$$

The production function for potential output is given by:

$$Y_t^{pot} = A_t^{pot} \left(K_t^{pot}\right)^{\alpha} \left(L_t^{pot}\right)^{1-\alpha} \tag{11}$$

where A_t^{pot} represents the HP filtered total factor productivity, $A_0 e^{bt}$, and $K_t^{pot} = K_t c_t^{NAICU}$ is the potential capital stock corresponding to the capacity utilization rate that does not accelerate inflation (NAICU- Non Accelerating Inflation Capacity Utilization Rate) that is derived by HP filtering capital stock.

For potential labour we employ the equation that was proposed by Giorno et al (1995):

$$L_t^{pot} = L_t^S \left(1 - u_t^{NAIRU}\right) \tag{12}$$

where L_t^S represents civil active population at time t filtered with HP filter and u_t^{NAIRU} is the unemployment NAIRU rate (Non Accelerating Inflation Rate of Unemployment) that is also HP filtered. Therefore, L_t^{pot} corresponds to the number of people that could be employed if the unemployment rate equaled its natural rate given by NAIRU.

Considering the above-mentioned notations, potential output can be written as:

$$Y_t^{pot} = Ae^{\theta t} \left(K_t^{NAICU}\right)^{\alpha} \left(L_t^S \left(1 - u_t^{NAIRU}\right)\right)^{1-\alpha} \tag{13}$$

and the output gap is defined as the difference between real and potential output, divided by potential output:

$$output \quad gap\_FP = \frac{Y_t - Y_t^{pot}}{Y_t^{pot}} * 100 \tag{14}$$

If the output gap takes positive values (when real output is greater potential output), then the aggregate demand growth exceeds the aggregate supply growth and this could lead to inflation, which is why it is called inflationary gap. However, if output gap values are negative, then we have a recessionary gap that could lead to deflation.

In order to estimate NAIRU, we use two methods: the first is the well known Ball -Mankiw (2002) method that leads to a constant NAIRU, and the second generates a variable NAIRU estimate and is based on expectations augmented Phillips curve.

The ball-Mankiw method starts from constant NAIRU Phillips curve:

$$\pi_t = \pi_{t-1} - \beta(u_t - u^{NAIRU}) . \tag{15}$$

The above equation can be conveniently written as:

$$\Delta\pi_t = -\beta u_t + \beta u^{NAIRU} = \alpha - \beta u_t \tag{16}$$

and parameters α and β could then be estimated econometrically.

The principal controversy on this method is the constant NAIRU resulted since in reality NAIRU is not constant because of a wide set of factors, especially hysteresis (Blanchard, Summers(1986)).

The second method is used to generate a variable NAIRU estimate and is based on expectations augmented Phillips curve:

$$\Delta\pi_t = -\beta u_t + \beta u_t^{NAIRU} + \varepsilon_t \tag{17}$$

We work under the assumption that u_t^{NAIRU} follows a stochastic random walk process and the supply shock ε_t follows the stochastic white noise process. The equation above shows that if unemployment falls below NAIRU level, it will put upward pressure on inflation, which will tend to rise unless this is offset by the effects generated by other variables.

The above Phillips curve could be written as:

$$\frac{\Delta\pi_t}{\beta} + u_t = u_t^{NAIRU} + \frac{\varepsilon_t}{\beta} \tag{18}$$

The left side of the above equation is calculated on statistical data considering parameter β (that could be interpreted as the speed of transfer of unemployment deviation on the inflation rate deviation), which is being estimated from the following equation, with all three series totally known:

$$\Delta\pi_t = -\beta(u_t - u_{t-1}) + \varepsilon_t \tag{19}$$

So, if we denote the resulted series of data, with β calculated previously by:

$$A_t = \frac{\Delta\pi_t}{\beta} + u_t, \tag{20}$$

we can then apply the HP filter to determine the trend, that represents the variable NAIRU (u_t^{NAIRU}), and the cyclical deviation given by $\frac{\varepsilon_t}{\beta}$.

4. Results and conclusions

4.1 Filters results

We apply the filters presented above to logarithms of quarterly data on real GDP covering the period 2000 to 2012, as reported by the National Institute of Statistics.

Recall that by applying statistical filters such as: HP filter, Baxter King or Christiano Fitzgerald Band Pass filters to the output data, we obtain a new stochastic variable that represents the cyclical component of real GDP. The potential output, which is reflected by the trend is then calculated by removing the cyclical component from the original GDP data.

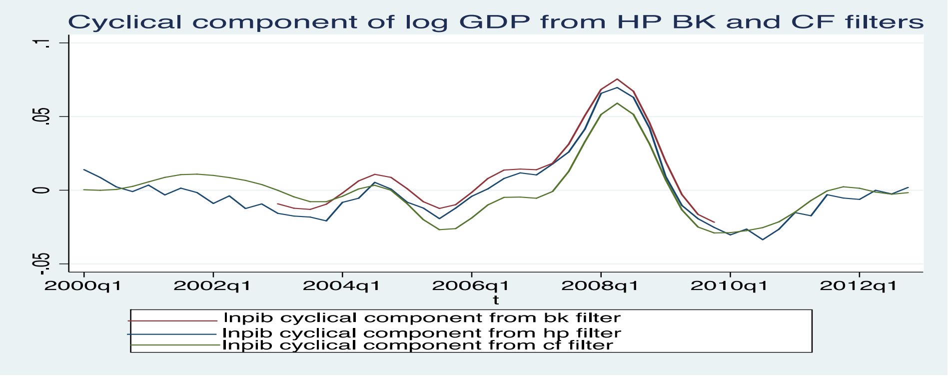

Figure 1. Cyclical components

The cyclical component resulted from applying all three filters clearly shows the economic crisis that affected the Romanian economy during 2008q3-2010q2 and the boom recorded in 2007 and early 2008. Comparing these methods with the production function methods used by the authors in previous papers (Andrei and Paun 2011), we notice that the three filters emphasize the economic cyclicity and marks the effects of economic shocks on GDP. We also noticed from the figure below that the three filters produce similar trends to capture potential GDP.

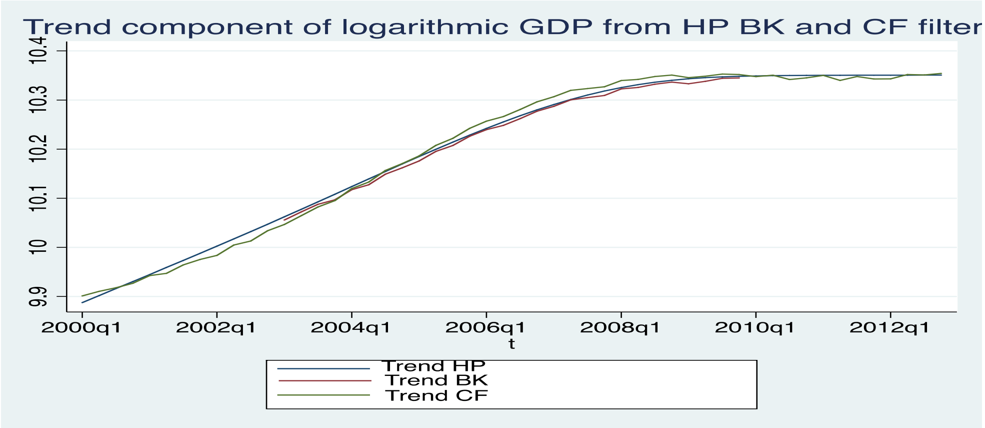

Figure 2. Trend components

We also plotted the periodograms[2] for all three filters estimates of the business-cycle component and analyze the results. If the filters successfully removed all the stochastic cycles outside the specified range of frequencies, the periodograms would show a horizontal line at the minimum value of −6 for the frequencies outside the band delimited by the vertical lines. However, if the periodograms take on values greater than −6 outside the specified range, this is an indication of the inability of the filters to pass through only the components of frequencies inside the specified band.

Comparing the periodograms we notice that, although the HP and BK filters performed adequately, the CF filter performed much better. The relative performance of the CF filter is explained by the fact that the logarithm of GDP is well approximated by a random walk with drift process.

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[2] A periodogram is an estimator of a transform of the spectral density function and displays the results in natural frequencies, which are the standard frequencies divided by 2π (the lower natural-frequency cutoff is 1/32 = 0.03125 and the upper natural-frequency cutoff is 1/6 ≈ 0.16667.

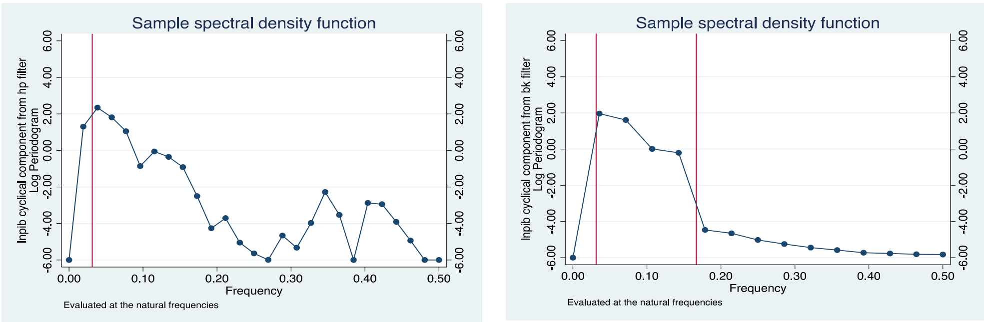
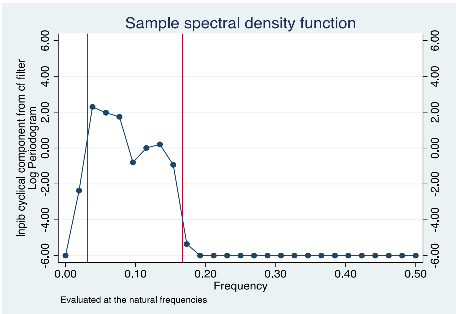


Figure 3. (a) Spectral density function for HP filter (b) Spectral density function for BK filter



(c) Spectral density function for CF filter

4.2 Production function results

As mentioned before, the output gaps were calculated using Cobb-Douglas production function with constant returns to scale and constant elasticity of substitution between the production factors.

For output elasticity with respect to labor we chose two values: $\alpha = 0{,}44$ and $\alpha = 0{,}65$. The first value is consistent with those employed in similar studies (Denis et al., 2006; Dobrescu, 2006; Galatescu et al., 2007). The second value is also used in previous studies and is calculated using the National Accounts data, as the ratio of the compensation of employees to the gross valued added (Altar et al, 2010).

Regarding the econometric estimation of the Cobb Douglas production function parameters, we concluded that, similarly with previous research (Altar et al (2010), Galatescu et al (2007)), in case of Romania, these are not suitable. This is because GDP increased while the employment decreased as a result of reduced natality rate and intensive work migration (at least after 2007). A way to elude this inconvenient is to use another indicator for labor, such as the working hours, calculated as the product of employment multiplied by the average number of actual weekly hours (Altar et al, 2010).

Considering the assumption that labor productivity has risen with a rate much higher than the labor supply, Basu, Fernald (2009) considered the work of Jorgenson et al (1987) and proposed the approximation of actual labor as a function of hours worked and labor „quality"(composition), defined as the mix of hours across workers with different levels of education, experience and so forth.

We estimate constant and variable NAIRU based on annual unemployment rates and price index series reported by the National Institute of Statistics, covering years 1991-2012 and use these estimates to calculate potential labor.

Applying Ball Mankiw's method for determining constant NAIRU, we obtain the following results: $\alpha = 82{,}79, \beta = 10{,}97, u^{NAIRU} = 7{,}54$ that is close to the value of 7.8% obtained by Albu (2006) for data covering the period 1991-2005. We also estimate the parameters required for determining variable NAIRU, and calculate potential labor using both constant and variable NAIRU. The results are presented in table 1 below.

Table 1. Variable NAIRU and potential labor with constant and variable NAIRU

Year	*Unemployment rate* (u_t)	u_t^{NAIRU}	*Active civil population (Ls)*	L_t^{pot} *with* u_t^{NAIRU}	L_t^{pot} *with* u^{NAIRU}
	(%)	(%)	(mil. pers.)	(mil. pers.)	(mil. pers.)
1995	9.5	14.63	10.49	9.05	9.80
1996	6.6	13.65	10.04	8.90	9.53
1997	8.9	12.52	9.90	8.78	9.28
1998	10.4	12.74	9.84	8.57	9.08
1999	11.8	12.44	9.55	8.43	8.90
2000	10.5	11.67	9.64	8.35	8.74
2001	8.8	10.70	9.39	8.30	8.59
2002	8.4	9.60	9.09	8.26	8.45
2003	7.4	8.41	8.96	8.26	8.34
2004	6.3	7.29	8.79	8.30	8.28
2005	5.9	6.36	8.91	8.38	8.27

2006	5.2	5.71	8.93	8.46	8.30
2007	4	5.40	9.09	8.53	8.33
2008	4.4	5.48	9.15	8.54	8.36
2009	7.8	5.81	9.12	8.50	8.35
2010	7	5.99	8.99	8.44	8.30
2011	5.2	6.03	8.83	8.38	8.24
2012	5.6	6.05	8.82	8.31	8.17

The results show that the values of potential labor calculated with both constant and variable NAIRU are smaller than actual ones, and this can be easily explained by the fact that the degree of liberalization is not optimal in Romania as the government sector still retains a higher number of employees than requested by the efficiency conditions.

In terms of the dynamics of the variable NAIRU, we notice that between 1995- 2007 it was steadily decreasing from over 14% to 5.4% but once the economy was hit by the crises, it started to slowly increase. Real GDP recorded a higher volatility before and after Romania's EU entry in 2007. After 2010 Romanian economy resumed its economic growth but NAIRU continued to rise, which suggests a testing of hysteresis persistence in unemployment using methodologies such as those presented in Mikhail et al (2003) might be needed.

Considering the above-mentioned estimates, we estimate potential output and calculate output gap considering constant and variable NAIRU and the two possible values for alpha: 0.44 and 0.65, as mentioned before.

Table 2: Output gaps

Year	*Output gap for:*			
	constant NAIRU and		variable NAIRU	
	alpha=0.44	alpha=0.65	alpha=0.44	alpha=0.65
1992	-5.9625	-6.6850	-2.0155	-0.8681
1993	2.5622	1.9803	6.2785	7.4528
1994	3.1783	2.8579	6.0500	7.0847
1995	5.3861	5.4194	6.3811	6.8853
1996	1.0521	1.4515	0.5355	0.6904
1997	-7.1764	-6.5502	-7.7607	-7.4093
1998	-4.0538	-3.4888	-3.9413	-3.3235
1999	-2.1298	-1.8779	-2.2830	-2.1038
2000	0.8479	0.7522	0.4566	0.1729
2001	3.5012	3.2136	3.0070	2.4806
2002	1.7474	1.4863	1.1893	0.6586
2003	0.5941	0.5060	-0.0063	-0.3828

2004	2.6566	2.7908	2.0851	1.9465
2005	-2.1131	-1.7930	-2.5788	-2.4797
2006	1.6761	2.0023	1.3526	1.5255
2007	1.4982	1.6470	1.3478	1.4251
2008	4.5318	4.4534	4.5692	4.5087
2009	-7.9516	-8.1548	-7.7994	-7.9295
2010	-1.1665	-1.3479	-1.0801	-1.2200
2011	2.9837	2.8536	2.9999	2.8776
2012	0.7132	0.5843	0.7234	0.5995

The calculated output gaps show clear and quite similar cyclical patterns in the past as the actual ones. The results are the more surprising, as, the civil active population continuously declines due to decreasing birth rate and the growth of migration for work. The explanation may be that the phenomena are compensated by a high growth rate of the capital stock.

We also notice strong consistency with the results obtained in our previous works, Andrei et al (2009), Andrei, Paun (2011).

Analyzing the data presented in table 2 and graphs 1-4, we notice a consistency of the results obtained using both constant and variable NAIRU, and the two values for alpha (0,44 and 0,65 respectively). Between years 1993-1996, 2000-2004, 2006-2008 and 2011-2012, the results clearly indicate positive output gaps (that is, real output levels above the potential of the economy, indicating tensions on good and labour markets and hence influencing the future evolution of the prices.

The years 1997-1999, 2009-2010 and 2005, are characterized by negative output gaps, that points to the fact that actual outputs are below the potential of the economy, consequently decreasing degrees of factor utilization. The years 2000-2005 are characterized by significant volatility of the economy due to the macroeconomic decisions that were taken to prepare Romania for entering the European Union that sometimes had, on the short run, contradictory effects. During 2007-2008 data indicates the existence of an overheating of the economy, a period of production factors overuse, accompanied by relatively high rates of real GDP. The period 2009-2010 marked a severe economic crisis in Romania, which is revealed by the large negative values of the output gaps beginning with the fourth quarter of the year 2008. The last quarter of 2010, marks the end of real GDP decrease, as the economy registered positive values due to a very good agricultural production.

Analyzing the results obtained for potential GDP using the filters (Hodrick- Prescott, Christiano- Fitzgerald, Baxter –King) and the production function method for alpha =0.44 or 0.65 and fixed and variable NAIRU, we notice we obtain very similar results and over the 1999-2012 period, all output gaps register the same number of turning points.

Although widely used in modeling monetary policy, and generally, in macroeconomic policy analysis, NAIRU measurement methods as well as the theoretical concept behind it are still controversial. Being non-observable and depending on a wide range of institutional and economic factors, NAIRU can only be estimated with uncertainty, generally as a NAIRU variable, using several methods of estimating and comparing the results in order to draw a pertinent conclusion on the pattern of evolution of this indicator. That is why mixing the resulted NAIRU from different methods as well as the resulted output gaps might turn out to be opportune (Bassanetti et al 2013).

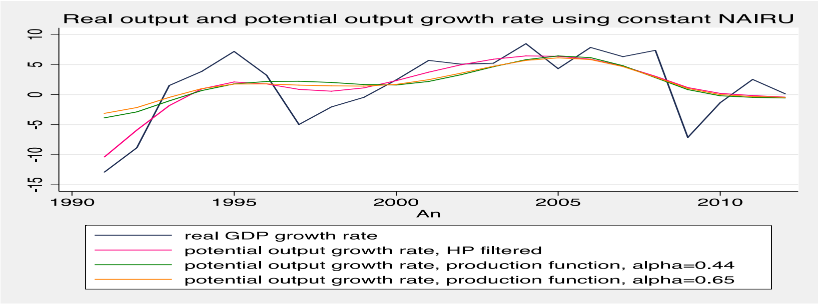


Figure 4. Real output and potential output growth rate, constant NAIRU

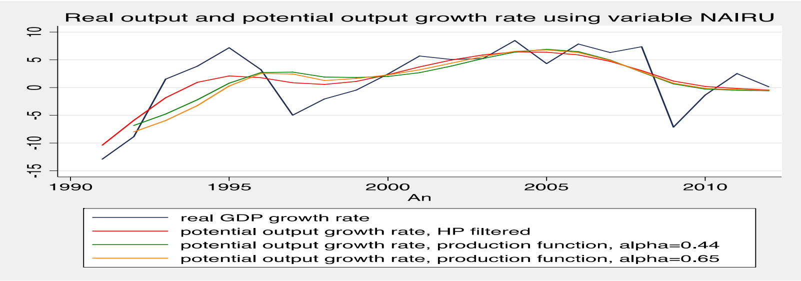


Figure 5. Real output and potential output growth rate, variable NAIRU

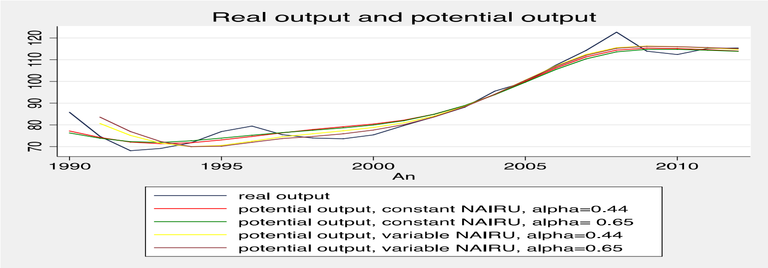


Figure 6. Real output and potential output

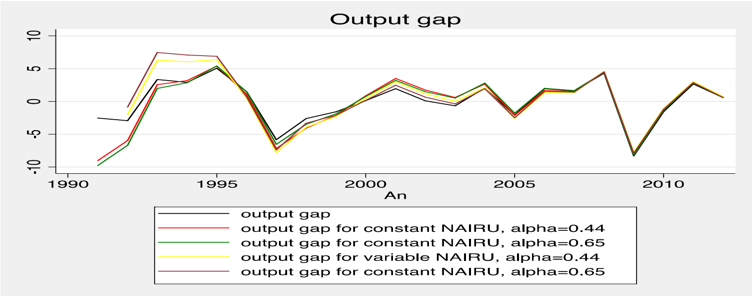


Figure 7. Output gap

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