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Applying Principal Component Analysis in order to Assess Potential Gross Domestic Product in Central and Eastern Europe Region

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Abstract. The potential gross domestic product (GDP), together with the difference between real GDP and its potential amount, are commonly used nowadays for macroeconomic modeling, policy assessment, fiscal sustainability evaluation and measuring the structural budget balance. The European Commission, OECD nations and central banks pay attention to identify potential output and GDP gap due to their great significance. The paper provides estimation of potential GDP and GDP gap for the Central and Eastern European region. The strategy is to combine the Cobb-Douglas structural method with other statistical methods of de-trending, in order to determine an aggregation measure for potential GDP, based on a weighting scheme determined with principal component analysis (PCA). Since a regional evaluation of potential economic growth is helpful for drawing well-structured economic policies, the assessment is based on 2000 – 2017 Eurostat aggregated data for all Central and Eastern European countries, except Albania. Using an aggregation method can help assessing economic growth trend in Central and Eastern Europe (CEE) economies, while capturing the useful information provided by different methods.
Keywords: *Potential GDP, GDP Gap, Cobb-Douglas function, univariate filters, PCA.*

1. Introduction

Potential GDP is a measure of the productive potential of an economy, representing the amount of GDP attainable when the economy operates with full employment or it is characterized by stable inflation.

Apart from its apparent usage as an indicator of inflationary pressures or unused resources level, the production gap, which represents the difference between real GDP and its potential level, serves for other significant medium-term purposes as adjusting cyclically variables in order to reflect the levels that would prevail if the economy were to develop at its potential level.

The subject is widely debated in the literature while current concerns concentrate on a broad range of issues regarding the potential GDP concept, methods of computation, mixing various approaches in order to achieve a more comprehensive assessment, real-time estimation of output gap and economic policy models based on this unobserved indicator.

Although regional assessment of potential economic growth is helpful for drawing well-structured economic policies, European Union Council provides results regarding potential growth and output gap only at country level and for Euro Zone, EU28, EU15 and EU13. Therefore, the aim of this paper is to provide accurate analysis of potential GDP and output gap for Central and Eastern European Countries as a homogenous group of countries, from economic policies point of view, during the studied period. Formatting the title

2. Literature Review

The International Monetary Fund [7] proposes an analysis of the potential output for Central, Eastern and South-eastern Europe in order to reveal if the post-crisis pattern was structural or cyclical. For this reason, there are used different methods for evaluating the potential growth in 18 countries between 2000 and 2015. The analysis is based on three different approaches: multivariate filter, multivariate filter with financial frictions and production function approach. The conclusion of the analysis points out the difficulties encountered in the estimation process of this unobservable macroeconomic variable, due to the significant structural fluctuations.

In a study based on a calibrated multivariate filter, applied in order to assess the Romanian economy between 1995 and 2013, Armeanu et al. [2] state the fact that it is necessary to estimate the potential GDP and output gap for assessing the sustainability of economic growth in the current economic context. Furthermore, they highlight that despite the numerous models proposed by the literature, it is difficult to obtain reliable estimations. The authors show that the approach based on a calibrated multivariate filter is more reliable than the standard HP filter, due to the fact that it incorporates theoretical macroeconomic relationships that have been also validated by empirical studies.

In a different study, based on three different methods, namely a statistical method, the production function approach and a multivariate Kalman filter, Konuki [9] estimates the potential output and GDP gap for Slovakia. The researcher highlights that the multivariate filter approach is more adequate for the studied case, due to the fact that it takes into account more economic information.

3. Methodology

The assessment of the potential output and GDP gap is based on 2000 – 2017 aggregated data for all Central and Eastern European countries, except Albania, due to the lack of data during the analysed period. As demonstrated by many previous studies, statistical univariate approaches and Cobb-Douglas production function are among the most commonly used techniques for evaluating economic growth and determining business cycles.

Thus, in this paper, we assess the potential production and production gap for CEE countries, using the univariate approaches suggested by the European Union Council, which are usually recommended for this purpose: Hodrick-Prescott (HP) filter, Baxter-King (BK) filter and Christiano-Fitzgerald (CF) filter, applied to quarterly data. Due to the fact that filters are purely statistical tools which do not take into account assumptions regarding the structure of the economy, the estimation of potential GDP and production gap is achieved by decomposing the output into trend and cyclical components, taking also into account the data frequency. Even if the HP filter is the oldest and most commonly computational tool used for determining potential GDP, the Band-Pass filters, as BK and CF, generally outperform it, although all these methods are facing end-sample problems which may be solved by extending the datasets with forecasted values.

The Cobb-Douglas production function is another method proposed by European Union Council for estimating these unobservable macroeconomic variables. This method approximates the potential labor using the non-accelerating inflation rate of unemployment (NAIRU), which is often assumed in the literature to be the trend component of unemployment, as depicted by Fabiani and Mestre [5]. Cobb-Douglas function allows determining the relative contributions of labor (L), capital (K) and total factor productivity (TFP) to potential output, taking into account the elasticity coefficient that is set to the value of 0.35, as stated by European Commission in the paper regarding the production function methodology for calculating potential growth rates and output gaps, published in 2014:

$$Y_t = TFP_t K_t^{\alpha} L_t^{1-\alpha} \tag{1}$$

$$L = A \cdot (1 - U) \cdot (1 - NAIRU) \cdot H \tag{2}$$

The production function (1) is transposed to a linear equation, by applying a logarithm function, in order to extract the total factor productivity. The linear production function can be decomposed based on trend and cyclical components of the variables, as stated in equation (4).

$$y = \alpha k + (1-\alpha)l + tfp \quad (3)$$

$$y = \alpha k + (1-\alpha)(l^T + l^C) + (tfp^T + tfp^C) \quad (4)$$

To proceed forward, the variables trend components are extracted by applying Hodrick-Prescott filter. The potential GDP is estimated based on equation (5).

$$y^T = \alpha k + (1-\alpha)l^T + tfp^T \quad (5)$$

In a study estimating potential GDP for the Romanian economy, Altăr et al. [1] propose further investigation for determining an aggregated potential GDP based on the Cobb-Douglas and other univariate filters results by using an equal weighting scheme. Therefore, this paper presents an integrated methodology, based on applying principal component analysis (PCA) over the results obtained from different estimation methods, in order to produce a weighting scheme to estimate aggregated potential GDP.A composite indicator is a mathematical synthesis of individual indicators describing various dimensions of a concept. Therefore, the development of a composite indicator includes few different steps which involve subjective judgment regarding the selection of the individual indicators, treatment of missing values, selection of aggregation method and the weighting scheme. The purpose of the PCA is to identify how different variables shift in relation to each other or whether they are correlated. This is done by transforming initial variables, which are correlated, into a set of uncorrelated variables using covariance or correlation matrix. The uncorrelated variables are a linear combination of the initial ones and must be sorted in descending relevance order, according to the variance they account from the original variables.

4. Results

Univariate filters are applied to the original quarterly series of real GDP based on 2010 prices. The graphic representation shows the non-stationarity of the series thus, in order to decompose the output in structural components, using the BK and CF filters, it must be specified that the series has random walk. The parameters used for these filters are (12,6,32), while for HP filter 1600 is used as smoothing parameter. It is easily observable that the trend component extracted with BK (Figure 2) and CF (Figure 3) technique fits better the original data than the one determined by using HP (Figure 1) method. However, all univariate filters face issues regarding end-period data, therefore, while constructing the aggregated potential GDP based on PCA, the removal of end-sample data is needed.

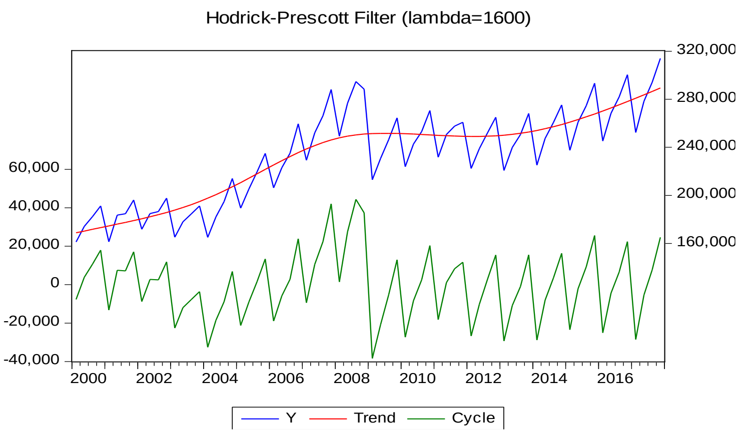

Figure 1. Results of HP Filter Applied to Quarterly GDP Series

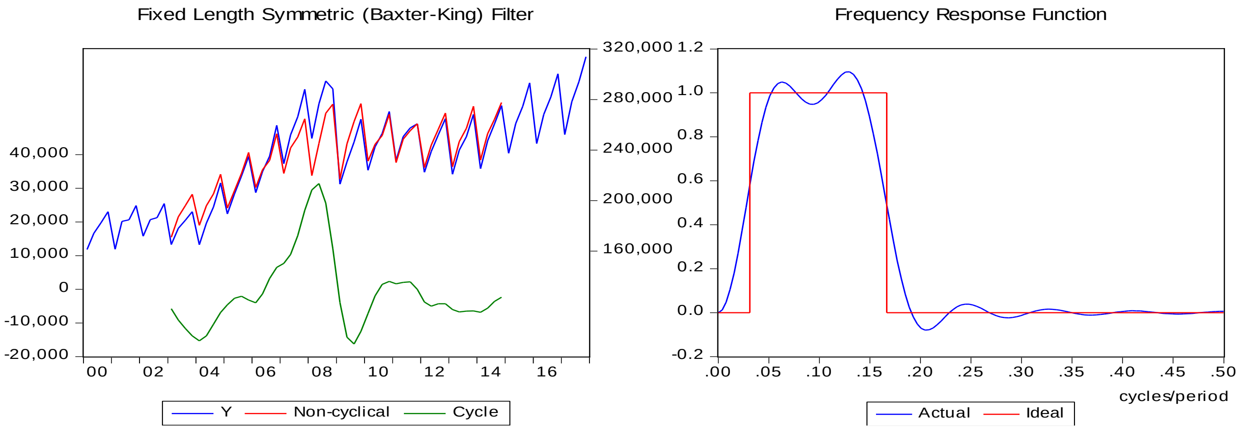

Figure 2. Results of BK Filter Applied to GDP Series

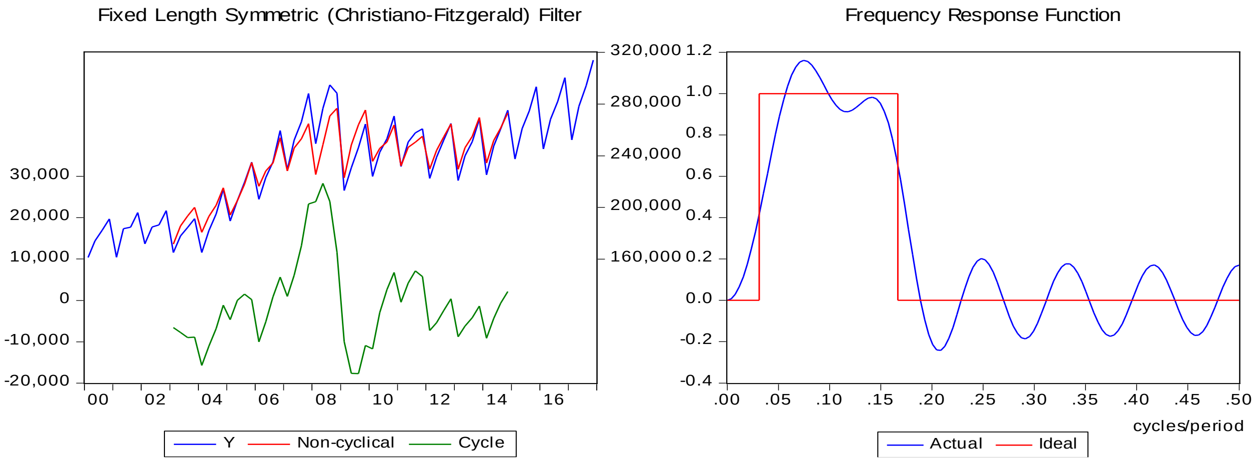

Figure 3. Results of CF Filter Applied to GDP Series

In order to determine potential output based on Cobb-Douglas production function, the data used are quarterly IMF and Eurostat series for real GDP (Y) based on 2010 prices, gross capital formation (K), active population (A), unemployment and weekly working hours, covering the period 2000-2017. Where needed, trend components are determined by applying HP filter. The results of applying HP filter to unemployment rate and gross capital formation are presented in Figure 4. Based on this we proceed in calculating the labour output. Figure 5 presents the potential labour and TFP trend.

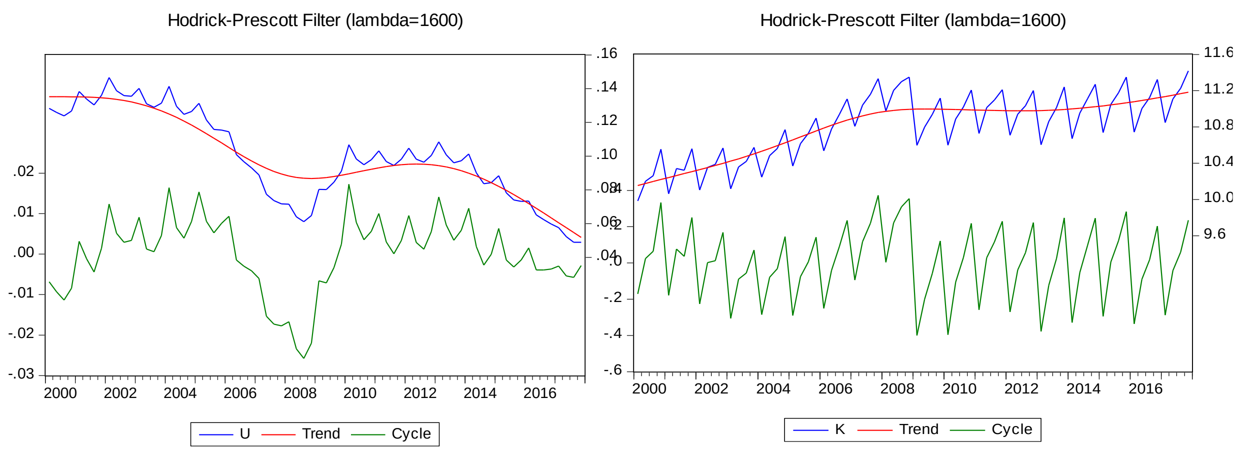

Figure 4. Results of HP Filter Applied to Unemployment and Gross Capital Formation

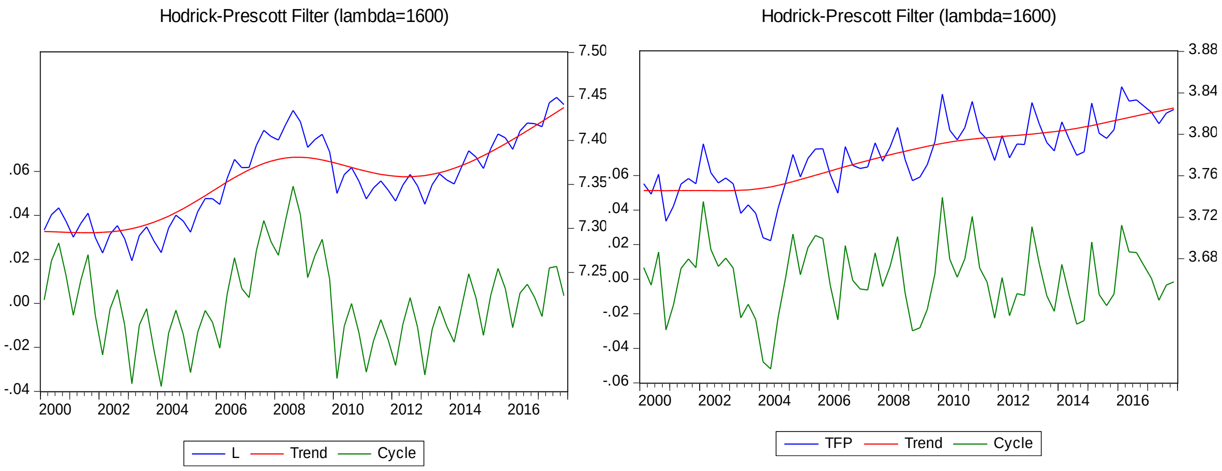

Figure 5. Results of HP Filter Applied to Labor and TFP

In order to apply PCA, quarterly values of potential output between 2003 and 2014, determined by using Cobb-Douglas function and HP, BK and CF univariate filters, are selected. The descriptive statistics of the series are presented in Table 1.

Table 1. Descriptive Statistics of the Potential Output Series Determined Using Cobb-Douglas Function and Univariate Filters

	CD	CF	HP	BK
Mean	235655.3	236362.5	236771.3	236511.3
Median	248826.6	244926.2	249220.5	242817.7
Maximum	258168.2	276748.3	258990.8	277622.3
Minimum	187002.2	171703.1	187741.8	170940.9
Std. Dev.	21704.47	26932.71	21300.50	27415.34
Skewness	-1.061166	-0.609170	-1.111624	-0.461320
Kurtosis	2.614771	2.533386	2.750605	2.416249

It can be noticed that the standard deviation is quite high in all cases, which means the series have a strong time-varying tendency, presenting a high degree of spikes.

Table 2. Correlation Matrix Between Potential Output Series Determined Using Cobb-Douglas Function and Univariate Filters

Correlation	CD	CF	HP	BK
CD	1.000000			
CF	0.873592	1.000000		
HP	0.999588	0.876136	1.000000	
BK	0.833280	0.992032	0.834599	1.000000

A quick interpretation of the correlation structure indicates that all the components are highly positively correlated. The purpose of PCA is to reflect how different variables may change in regards to each other, or the way they are associated. This is achieved by converting the original correlated variables intro a new data set of uncorrelated variables, based on the covariance or correlation matrix. Therefore, PCA assumes decomposing covariance or correlation matrix into eigenvalues, but only after the original variables are standardized. However, due to the fact that, in this case, the variables are expressed in the same measure units and have the same magnitude, this transformation is not needed.

Table 3 summarizes the details on eigenvalues, which are sorted taking into account the information explained by each of them. The first principal direction explains a high amount of information contained in the correlation matrix (92.6%), while the second one explains 7.2%. This means that the cumulative proportion of the information explained by these two principal directions is 99.8%.

Table 3. Eigenvalues of the Correlation Matrix

Number	Value	Difference	Proportion	Cumulative Value	Cumulative Proportion
1	3.704845	3.414876	0.9262	3.704845	0.9262
2	0.289969	0.285067	0.0725	3.994813	0.9987
3	0.004902	0.004618	0.0012	3.999715	0.9999
4	0.000285	---	0.0001	4.000000	1.0000

In the light of Kaiser`s criterion which states that the number of principal components needed to be taken into account is determined by the number of eigenvalues larger than 1, we consider, in order to assess the original information, it is sufficient to retain only the first principal component, with the eigenvalue of 3.7. Moreover, usually, sufficient components to explain between 70% and 80% of the total information, should be retained. In our case, choosing the first principal component satisfices both criteria.

Table 4. Eigenvectors Associated with the Eigenvalues

Variable	PC 1	PC 2	PC 3	PC 4
CD	0.500309	-0.499584	0.168254	-0.686875
CF	0.504940	0.426341	-0.740260	-0.123632
HP	0.500831	-0.493239	-0.060803	0.708651
BK	0.493857	0.570407	0.648081	0.103596

Table 4 depicts the eigenvectors associated with the eigenvalues. They reveal each variable weight in each principal component. Potential output determined with Cobb-Douglas function accounts 25.03% (=100* 0.500309^2) of the overall direction length in the first principal component. We can actually see that in this component, the variables have almost same weight. However, if we analyse the second principal component, we can observe that the weights slightly vary. We proceed in determining the score vector for the retained principal component, based on its eigenvalue and eigenvector and on each variable weight.

Table 5. Score Vector and Variables Weights

Variable	SV1	W
CD	1.853567297	0.250162
CF	1.870724434	0.252478
HP	1.855501226	0.250423
BK	1.829663637	0.246936

In order to determine quarterly potential GDP between 2003-2014 in CEE, we can conclude, based on Table 5, that the aggregated potential output takes into account 25.01% from the result provided by Cobb-Douglas Function, 25.24% from CF filter result, while 25.04% is based on HP filter and 24.69% on BK filter.

Table 6. Aggregated Potential GDP and GDP Gap between 2003-2014

Time	Real GDP	Aggregated Potential GDP	GDP Gap
2003Q1	165,159.42	179,358.61	(14,199.19)
2003Q2	177,983.99	187,925.80	(9,941.80)
2003Q3	184,463.81	193,225.71	(8,761.90)
2003Q4	191,222.12	198,357.70	(7,135.58)
2004Q1	165,061.63	188,718.99	(23,657.35)
2004Q2	182,087.86	197,127.51	(15,039.65)
2004Q3	194,933.16	203,166.33	(8,233.17)
2004Q4	213,984.72	212,038.19	1,946.53

Time	Real GDP	Aggregated Potential GDP	GDP Gap
2005Q1	189,452.71	201,817.73	(12,365.02)
2005Q2	205,258.68	209,837.14	(4,578.46)
2005Q3	219,554.36	218,266.79	1,287.57
2005Q4	235,008.42	228,444.60	6,563.82
2006Q1	206,328.65	218,733.11	(12,404.46)
2006Q2	223,059.58	227,013.45	(3,953.88)
2006Q3	235,136.73	232,148.92	2,987.82
2006Q4	259,561.79	244,004.81	15,556.98
2007Q1	229,245.85	231,318.14	(2,072.29)
2007Q2	252,100.45	242,221.62	9,878.82
2007Q3	266,363.68	247,441.66	18,922.01
2007Q4	288,175.43	255,050.75	33,124.68
2008Q1	249,316.54	234,931.83	14,384.72
2008Q2	276,730.45	247,780.57	28,949.88
2008Q3	294,723.95	259,873.65	34,850.30
2008Q4	288,428.99	263,544.65	24,884.34
2009Q1	213,075.36	235,548.39	(22,473.03)
2009Q2	230,712.64	248,977.97	(18,265.33)
2009Q3	246,369.74	257,319.32	(10,949.58)
2009Q4	264,479.01	263,686.55	792.45
2010Q1	223,965.89	242,264.68	(18,298.79)
2010Q2	242,658.57	247,954.91	(5,296.35)
2010Q3	253,141.13	250,800.69	2,340.44
2010Q4	270,660.00	258,105.29	12,554.70
2011Q1	231,741.70	240,492.93	(8,751.23)
2011Q2	250,695.32	248,520.53	2,174.79
2011Q3	257,640.78	251,081.97	6,558.81
2011Q4	260,866.09	253,493.64	7,372.46
2012Q1	222,401.11	238,443.27	(16,042.17)
2012Q2	238,867.03	246,499.00	(7,631.97)
2012Q3	252,118.78	252,281.61	(162.83)
2012Q4	265,005.23	258,165.79	6,839.44
2013Q1	220,804.17	239,052.90	(18,248.73)
2013Q2	239,969.82	248,501.75	(8,531.93)
2013Q3	250,719.28	253,722.44	(3,003.15)
2013Q4	268,229.23	262,278.67	5,950.55
2014Q1	225,235.79	243,491.55	(18,255.75)
2014Q2	247,439.86	253,794.18	(6,354.32)
2014Q3	260,700.84	259,802.89	897.95
2014Q4	275,271.27	266,956.83	8,314.44

Table 6 presents the estimated aggregated potential GDP and output gap. As expected, even if the GDP gap faces many spikes during the analysed timeframe, the GDP gap has recorded highly positive values, between 2007Q2 and 2008Q4. This means that, during the financial crisis, the real GDP has remained above its potential level, causing an inflationary gap in the CEE area.

5. Conclusions

Potential GDP is a useful macroeconomic unobservable variable for policymakers, which is why there are many methods developed in order to determine its value and many researchers reach to present comparative assessments.

All methods used in this study have their own advantages and disadvantages, therefore, it is needed to develop an assessment methodology which integrates all these approaches, for a higher degree of accuracy.

Taking into account the most common statistical tools used for estimating potential output and output gap, it can be concluded, in line with previous studies, that Baxter-King and Christiano-Fitzgerald filters are more suitable than Hodrick-Prescott filter for potential GDP assessment in case of the CEE countries, at least during the analysed period.

The different results provided by Cobb-Douglas function and univariate filters could be integrated into a unique assessment of potential output by using principal component analysis for determining the weighting scheme. Thus, it is expected that considering the results of more methods in order to determine potential GDP leads to a more accurate assessment.

The quarterly results provided by the aggregated method highlight the fact that the output gap in Central and Eastern Europe had many spikes between 2003 and 2014. However, during the financial crisis, CEE countries registered seven consecutive quarters of a relatively high positive GDP gap, which led to an inflationary gap.

Moreover, it can be observed that usually, in the fourth quarter of each year, real output has maintained higher than the potential level, with a drop below in the next quarter, a common pattern, widely presented in empirical studies.

For a more accurate assessment of the potential GDP and GDP gap, further studies may include a multivariate filter in the aggregation scheme, beside other statistical methods.

References

[1] Altăr M., Necula C. and Bobeică G. 2010 Estimating potential GDP for the Romanian economy. An eclectic approach. *Romanian Journal of Economic Forecasting*, 3, 5-25

[2] Armeanu D., Crețan G. C., Lache L., Mitroi M. 2015 Estimating Potential GDP for the Romanian Economy and Assessing the Sustainability of Economic Growth: A Multivariate Filter Approach. *Sustainability* 7, no. 3: 3338-3358, https://doi.org/10.3390/su7033338

[3] Baxter, Marianne and Robert G. King 1999 Measuring Business Cycles: Approximate Band-Pass Filters for Economic Time Series, *The Review of Economics and Statistics* 81, 575-593

[4] European Commission 2014 The Production Function Methodology for Calculating Potential Growth Rates & Output Gaps, *European Economy*, Economic Papers

[5] Fabiani S. and Mestre R. 2000 *Alternative measures of the NAIRU in the euro area: estimates and assessment*

[6] Hodrick Robert, Prescott Edward C. 1997 Postwar U.S. Business Cycles: An Empirical Investigation, *Journal of Money, Credit, and Banking* 29 (1): 1–16

[7] International Monetary Fund 2017 *A Fresh Look at Potential Output in Central, Eastern, and Southeastern European Countries*

[8] James D. Hamilton 2018 Why You Should Never Use the Hodrick-Prescott Filter, *The Review of Economics and Statistics*, vol 100(5), pages 831-843

[9] Konuki T. 2010 Estimating potential output and the output gap in Slovakia. Eastern European Economics, 48(2), 39-55. *European Comission, Ispra*, 15(1), 19-20

[10] Nardo M., Saisana M., Saltelli A. and Tarantola S. 2005 *Tools for composite indicators building*