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Estimating Romania's potential GDP: a production function and multivariate approach

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Abstract. *This research assesses Romania's potential GDP and its variances employing the production function methodology and a multivariate approach. The Cobb-Douglas function measures potential production by integrating labor, capital, and total factor productivity (TFP), utilizing Kalman filtering for labor and the perpetual inventory approach for capital. TFP trends are derived using the Hodrick-Prescott filter. A multivariate filter enhances potential GDP estimates by correlating output gaps with inflation, unemployment, and capacity utilization. Bayesian methodologies guarantee reliable parameter estimate. The results indicate cyclical variations, with recessions and crises exerting enduring impacts on potential output. Structural changes and EU entry foster long-term resilience, although inflation and labor dynamics are crucial factors. This work enhances the precision of potential GDP calculation in a growing economy by integrating various estimation methodologies. It presents empirical information regarding the enduring impacts of economic shocks and furnishes insights for policymakers in formulating efficient fiscal and monetary responses to macroeconomic volatility.*

Keywords: potential GDP, production, multivariate, TFP.

JEL Classification: E32, E37, E52, C32, C53.

1. Introduction

This study enhances the literature by combining production function methods with a multivariate filtering strategy to estimate Romania's potential GDP, thereby filling a notable gap in current research. Previous studies on potential output estimation have predominantly utilized univariate statistical filters or simple production functions, frequently neglecting the dynamic interrelationships among economic variables such as inflation, unemployment, and capacity utilization. This research improves estimation accuracy by integrating the Phillips curve, Okun's law, and capacity utilization equations, optimized using Bayesian methods. Furthermore, although analogous approaches have been widely utilized in industrialized economies, their application in Romania is still constrained, rendering this study one of the first efforts to implement a full multivariate framework in a developing economy characterized by significant structural transformations and external vulnerabilities.

Precise calculation of potential GDP is crucial for comprehending an economy's sustained growth potential and formulating appropriate macroeconomic strategies. Potential output is a crucial benchmark for recognizing business cycle variations, evaluating inflationary dynamics, and adjusting monetary and fiscal strategies. This is especially pertinent in Romania, where economic instability has been shaped by many crises, including the 2008 financial collapse, the COVID-19 pandemic, and geopolitical conflicts.

The results demonstrate the enduring impact of economic shocks on potential output, emphasizing the significance of structural reforms and EU accession in influencing Romania's long-term economic path. This study enhances the precision of potential GDP measurement and output gap evaluation, offering policymakers a more dependable instrument for economic forecasting, inflation targeting, and fiscal planning. The findings provide significant insights for developing economies encountering analogous macroeconomic issues, highlighting the necessity of employing various estimation methods for a more thorough comprehension of economic variations.

2. Literature Review

Estimating potential GDP is a pivotal subject in macroeconomic study due to its significance in informing monetary policy, analyzing inflationary pressures, and determining long-term economic viability. The literature presents several ways for estimating potential output, which can be broadly classified into statistical filtering methods, production function approaches, and multivariate models. Every strategy possesses distinct advantages and drawbacks, especially within the framework of growing economies like Romania.

A prevalent method involves the utilization of statistical filters, such the Hodrick-Prescott (HP) filter (Hodrick & Prescott, 1997) and the Band-Pass filter (Baxter & King, 1999). These methods partition real GDP into trend and cyclical components, presuming a gradual progression of potential output. Nonetheless, they lack a clear connection to economic

fundamentals, frequently yielding skewed estimates that are susceptible to parameter selection (Hamilton, 2018). Research utilizing these filters in Romania (Lupu & Asandului, 2020) has shown inconclusive outcomes, especially during economic shocks, when statistical filters often exaggerate volatility.

A structural approach utilizes the production function methodology to breakdown potential output into its essential supply-side components: capital, labor, and total factor productivity (TFP). This approach is extensively utilized by organizations such the European Commission (Denis et al., 2006) and the OECD (Girouard & André, 2003). The Cobb-Douglas production function, under the assumption of constant returns to scale, has been extensively utilized in empirical research (Borio et al., 2013), although its implementation in Romania is still constrained. Certain studies (Altar et al., 2010) have assessed Romania's potential GDP through production functions, predominantly utilizing deterministic trends for labor and capital, but neglecting a stochastic framework for the underlying dynamics.

Recent research has shifted towards multivariate filtering models, which improve potential GDP estimation by integrating macroeconomic linkages. These methodologies, frequently grounded in the Kalman filter (Laubach & Williams, 2003), amalgamate economic variables such as inflation, unemployment, and capacity utilization to enhance output gap estimations. The European Central Bank (Havik et al., 2014) has implemented a multivariate methodology for euro area nations, showcasing its efficacy in enhancing GDP trend estimations. In Romania, limited research has systematically integrated multivariate filtering with the production function approach, resulting in a gap in the literature.

This work fills the gap by combining a production function approach with a multivariate model that includes the Phillips curve, Okun's law, and capacity utilization equations to enhance potential GDP estimations. This study employs Bayesian estimating techniques to enhance model precision, in contrast to prior research that concentrated on statistical filters or production functions independently. Furthermore, although multivariate filtering has been extensively utilized in industrialized economies (Benes et al., 2010), its implementation in Romania is limited, despite the nation's susceptibility to significant economic volatility.

This study offers a more robust evaluation of Romania's potential output by integrating structural and multivariate methodologies. The results enhance the current discourse on output gap assessment in emerging economies, providing novel perspectives on the enduring impacts of crises and structural transformations on economic capacity.

3. Data and methodology

The assessment of potential GDP relies on macroeconomic data for Romania from the third quarter of 2003 to the fourth quarter of 2023. The primary data sources comprise Eurostat, which offers real GDP series (seasonally adjusted and adjusted for working days) and Gross Fixed Capital Formation (GFCF); the International Labour Organization (ILO), which furnishes labor force data; the National Bank of Romania (BNR), which supplies Core

Inflation data; and the National Institute of Statistics (INS), which presents data on the Consumer Price Index (CPI). The real GDP series is utilized to ascertain prospective GDP, whilst the capital stock is calculated via the perpetual inventory approach, modified with a quarterly depreciation rate of 1.23% (as per Altar et al., 2010).

The estimation of potential GDP is conducted using two complementary methodologies:

1. The Cobb-Douglas Production Function with constant returns to scale, expressed as:

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

where:
Y_t represents real GDP,
K_t is the capital stock,
L_t is the labor force,
TFP_t denotes total factor productivity,
The output elasticities are α=0.35 for capital and $1-\alpha$=0.651 for labor, following the European Commission's methodology.

The TFP estimation is derived as a Solow residual, while its trend is determined using the Hodrick-Prescott filter (λ=1600).

2. The Multivariate Model, which extends the estimation of potential GDP by integrating economic relationships through the Phillips Curve, Okun's Law, and capacity utilization equations. This approach refines potential output estimation by explicitly incorporating macroeconomic dynamics rather than relying solely on statistical filtering.

The model specification includes the following key equations:

Output gap estimation:

$$gap_{Y,t} = 100 \cdot log\left(\frac{Y_t}{Y_t^*}\right)$$

where Y_t is actual GDP and Y_t^* is potential GDP.

NAIRU and equilibrium unemployment rate:

$$u_t - u_t^* = \beta_1 gap_{Y,t} + \beta_2(u_{t-1} - u_{t-1}^*) + \epsilon_t$$

where u_t is the actual unemployment rate, u_t^* is the non-accelerating inflation rate of unemployment (NAIRU), and ϵ_t is the error term.

a) Inflation and output gap relationship (Phillips Curve):

$$\pi_t = \gamma_1 \pi_{t-1} + \gamma_2 gap_{Y,t} + \epsilon_t$$

where π_t represents core inflation.

b) NAIRU estimation using the Kalman filter to extract the equilibrium component of the unemployment rate.

c) Capacity utilization dynamics:

$$cap_t - cap_t^* = \delta_1 gap_{Y,t} + \delta_2 (cap_{t-1} - cap_{t-1}^*) + \epsilon_t$$

where cap_t is actual capacity utilization and cap_t^* is its equilibrium level.

The model parameters are estimated using Bayesian techniques, ensuring a robust identification of potential GDP by integrating prior information on macroeconomic relationships. This approach enhances accuracy compared to purely statistical filtering methods by explicitly modeling the interactions between GDP, inflation, unemployment, and capacity utilization.

4. Results and discussion

4.A. Labour Function

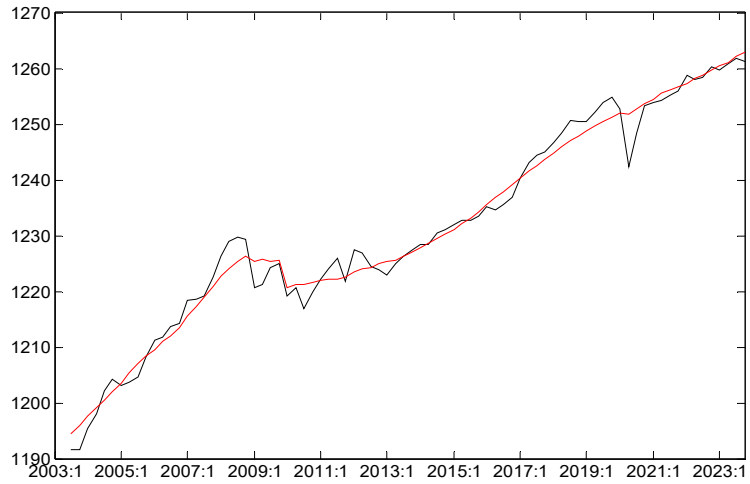
The outcomes derived from the production function methodology establish a robust basis for evaluating potential GDP. This approach predominantly emphasizes supply-side factors and fails to explicitly consider macroeconomic linkages, including inflationary dynamics and labor market rigidities. To mitigate these constraints and improve the reliability of potential GDP calculation, we expand our study through a multivariate approach that incorporates supplementary macroeconomic linkages.

Figure 1 illustrates the correlation between actual GDP and projected potential GDP derived from the production function. Although the overarching trend corresponds with existing work (e.g., Altar et al., 2010; Denis et al., 2006), our findings underscore the significance of structural determinants in influencing the trajectory of potential output. Throughout the reviewed period, the real quarterly GDP exhibited a consistent rising trajectory. Concurrently, its trajectory, assessed through the production function, exhibited analogous patterns, including throughout the financial crisis, a phase of quasi-stagnation in the growth rate of potential GDP (2009-2013). Subsequently, the trend reverses, but at a diminished slope relative to the pre-crisis period, highlighting the repercussions of the recession, referred to in the literature as the scarring effects of production (Larch et al. 2022).

The scarring effects of the 2009 financial crisis are evident in our calculations, akin to those reported by Larch et al. (2022), underscoring the enduring influence of economic downturns on supply-side factors.

It is important to acknowledge the inflationary pressures associated with the financial crisis from 2008 to 2011, stemming from GDP growth exceeding potential levels, alongside its decline during the recessionary period. The substantial increase in potential GDP is attributed to the contributions of production factors, particularly the capital stock and factor productivity, following Romania's entrance to the European Union. Similar to the previously employed statistical filters (HP and Band-Pass), the potential GDP maintained its growth trajectory during the COVID-19 pandemic, with the decline in production during the quarantine reflecting a deviation rather than impacting the economy's potential level.

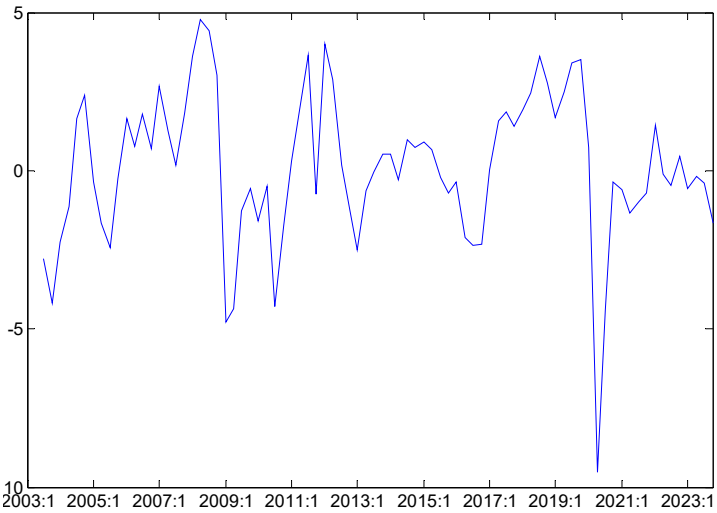
Figure 1. *GDP and potential GDP in the period 2003 Q3 – 2023 Q4*



Source: Own research.

Figure 2 illustrates the GDP gap derived from the production function. The inflationary pressures preceding the financial crisis, marked by a positive production gap, are significant. During the crisis, the GDP gap contracted by about 10 percentage points, shifting from +5% above potential to -5% below potential.

Figure 2. *GDP deviation Results corresponding to the production function*

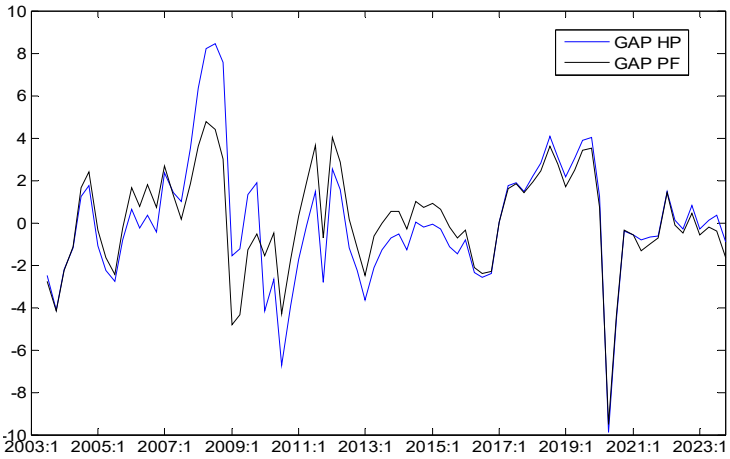


Source: Own research.

The GDP deviation projected by the production function indicates a "overheating" of the economy prior to the financial crisis, a phenomenon previously emphasized by statistical filters. The pandemic era is marked by a significant decrease in deviation to 10% below the potential level.

The economy's recovery is strong, resulting in the GDP gap being eliminated swiftly by 2021Q4. However, it is expected to diminish and subsequently enter negative territory in 2022 due to the onset of the war in Ukraine and the implementation of tighter monetary policy to address inflationary pressures.

Figure 3. *Comparison of the gap obtained by the HP statistical filter and the FP filter*



Source: Own research.

It can be seen from Figure 3 that the deviation estimated by the HP filter is much more volatile than that of the production function, although during the pandemic the decrease in the output gap is similar in magnitude in both cases.

4.B. Multivariate method

To enhance the production function estimations, we utilize a multivariate filtering method that considers demand-side effects on potential output. This method, unlike univariate statistical filters (e.g., HP filter) that lack economic grounding, incorporates relationships such as the Phillips curve and Okun's law, hence improving the interpretability of the predicted output gap.

The Bayesian methodology, namely the maximum regularized probability, is employed to estimate the model (Ljung 1999). The presence of non-informative data across several parameters enables the establishment of a priori distributions that prevent parameters from being entrenched in irrelevant regions. Additional details regarding this strategy are available in Annex 2. Considering the model, its parameters, and the data creation procedure, analytical estimations of the confidence intervals derived from the sample information are given. The analysis period for Romania extends from the third quarter of 2003 to the fourth quarter of 2023, with a further forecast period extending to 2027. Integrate the following equation into the model to guarantee that the rise in potential output remains closely aligned with its steady-state value.

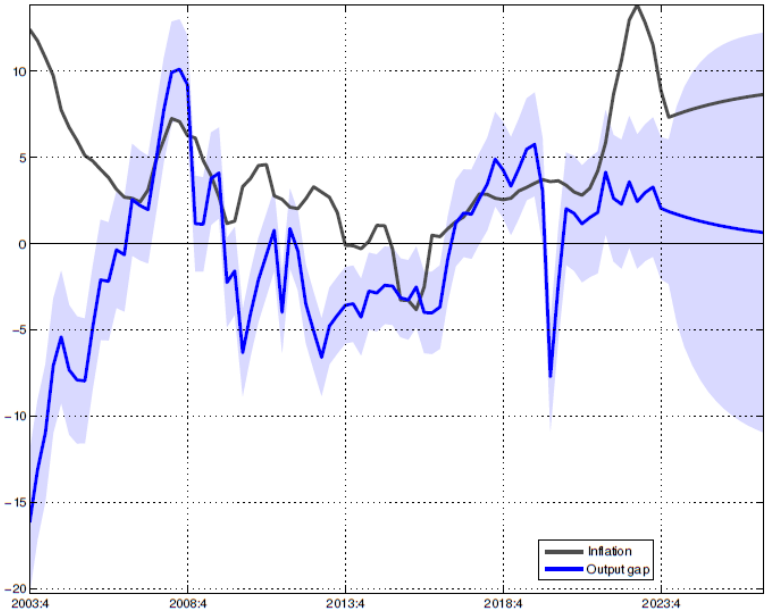
4.B.1. GDP gap and core inflation

Given that the interaction between these two variables encapsulates the essential elements of the model and the resultant estimates, it is prudent to initially report the findings of the multivariate filter concerning the GDP gap and inflation. Alongside the central estimate for the GDP gap, Figure 4 presents a confidence interval of +/- 2 standard deviations. The inflation rate is defined as the percentage change in the core consumer price index.

A monetary policy framework focused on direct inflation targeting must consider the correlation between inflation and the GDP gap. Prior to 2005, there was no significant association between GDP and inflation, coinciding with the NBR's adoption of a direct inflation targeting method. Nonetheless, the graph displayed clearly demonstrated a link between the two variables. Despite the GDP gap remaining negative in 2005 and 2006, inflation persisted in its decrease, reaching nearly zero in the first quarter of 2007 at -0.57% of GDP.

Demand has been positive and the economy has grown faster than expected in the years before the financial crisis. Consequent to the financial crisis, GDP commenced its decrease, and the disparity began to diminish. The model indicates that the GDP gap transitioned into positive territory toward the end of 2015 and the beginning of 2016, signifying a gradual and sustained return to equilibrium.

Figure 4. *GDP Gap and Inflation*



Source: Own research.

The narrowing of the GDP gap between 2014 and 2015 suggests that inflation is steadily nearing equilibrium, and inflationary pressures will ultimately dissipate when actual output reaches its potential. The output gap experiences a little increase from 2016 onward,

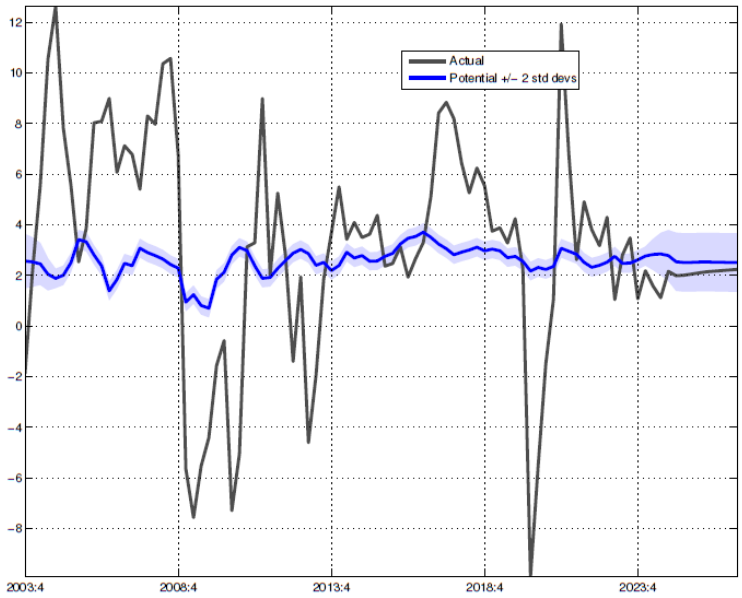
thereafter narrowing progressively; however, from 2017, GDP exhibits substantial growth, maintaining the output gap in a favorable condition. The COVID-19 pandemic and the deceleration of economic activity are resulting in a significant and quick decline in GDP. Consequently, the GDP gap expands to -7.5% of GDP, marking the most significant negative level within the investigated timeframe, excluding the period prior to the implementation of the NBR's direct inflation targeting method. By the end of 2023, a recovery is evident, and predictions suggest that real GDP is nearing its potential, with an output gap of approximately 1%.

The estimated GDP gap derived from the multivariate filter (Figure 4) indicates a pronounced cyclical component, aligning with theoretical expectations regarding inflation-output dynamics. The findings validate that during phases of economic overheating (2007–2008), inflationary pressures escalated, a trend similarly documented by Havik et al. (2014) for euro area nations. Our estimates indicate a significant reduction in the output gap following the 2008 financial crisis, consistent with other research (Benes et al., 2010).

4.B.2. Potential Gross Domestic Product

Figure 5 juxtaposes the growth rate of actual GDP against potential GDP. The reduction in potential GDP growth after the 2008 crisis is more significant than the initial drop in actual GDP, indicating a lasting impact on supply-side circumstances. This observation aligns with Borio et al. (2013), who underscore the significance of financial cycles in shaping long-term output trends. Our calculations indicate that the COVID-19 pandemic exerted a less effect on potential GDP growth than the financial crisis, a trend also evident in other rising economies.

Figure 5. *Growth rate of actual and potential GDP*



Source: Own research.

The graphic above illustrates the impact of the 2008 economic recession on actual and projected GDP growth rates. The recession adversely affected potential GDP growth more significantly than actual growth, which plummeted precipitously after the onset of the COVID-19 pandemic. The economy has been profoundly impacted by the recession, resulting in a diminished prospective growth rate. Given the advancements in each sector, the growth rate reverts marginally to its prior level. The forecast suggests that, in the forthcoming term, the economy will stabilize and align with the potential growth rate.

4.B.3. Unemployment Rate and NAIRU Trend

With rare exceptions, when the unemployment rate was in a positive although minimal range, the divergence was primarily negative. The rise in the unemployment rate during the 2008 financial crisis and the hysteresis effect are primarily responsible for this predicament. From 2007 to 2008, the negative correlation between inflation and unemployment was evident: as inflationary pressures rose, both effective and equilibrium unemployment rates decreased.

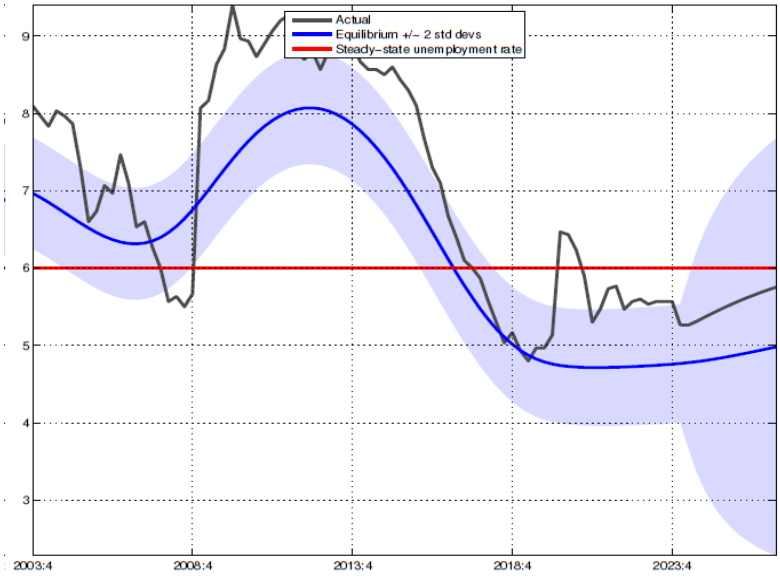
The unemployment rate mostly exhibits a negative deviation, primarily reflecting the effects of the financial crisis. Nonetheless, given the economy has rebounded and advanced more rapidly than anticipated (particularly in the latter half of 2015 and the initial quarter of 2016, as illustrated in Figure 1.9), the model forecasts that the unemployment rate will ascend to equilibrium in the forthcoming period. This can be elucidated by the implementation of fiscal policies aimed at augmenting both the demand and supply of labor, the incorporation of the jobless into the workforce, and the provision of subsidies to employers.

The NAIRU and the unemployment rate align with the long-term equilibrium value within the same timeframe (Figure 6). In 2018, a gain in GDP and growth rate corresponds with a significant decline in the unemployment rate; but, as shown in prior instances, the pandemic in 2020 leads to a temporary surge in unemployment, confined to the duration of the quarantine.

The health issue has adversely affected the progression of the labor market. This is logical considering the quarantine limits that have been implemented, resulting in the technical unemployment of numerous employees. Since 2021, the unemployment rate has consistently stayed below the equilibrium threshold of 6%. The projections suggest that the unemployment rate and the NAIRU will exhibit a comparable trajectory aligned with the equilibrium level in the forthcoming future.

The unemployment rate decreased consistently throughout the examined period. The unemployment rate decreased from 8% to 5.5% by the conclusion of the fourth quarter of 2023. The drop was mostly attributable to the enhancement of structural reforms and fiscal measures enacted to bolster the market, particularly in pursuit of this goal after the 2009 financial crisis.

Figure 6. *Unemployment rate, NAIRU, equilibrium level of the unemployment rate*



Source: Own processing.

A primary imbalance is the inactivity of the 55-64 age demographic. The financial crisis has significantly elevated the jobless rate. In contrast to the pandemic crisis, which was characterized by a temporary shock, the shock associated with the global financial crisis was enduring, with significant repercussions for economic activity.

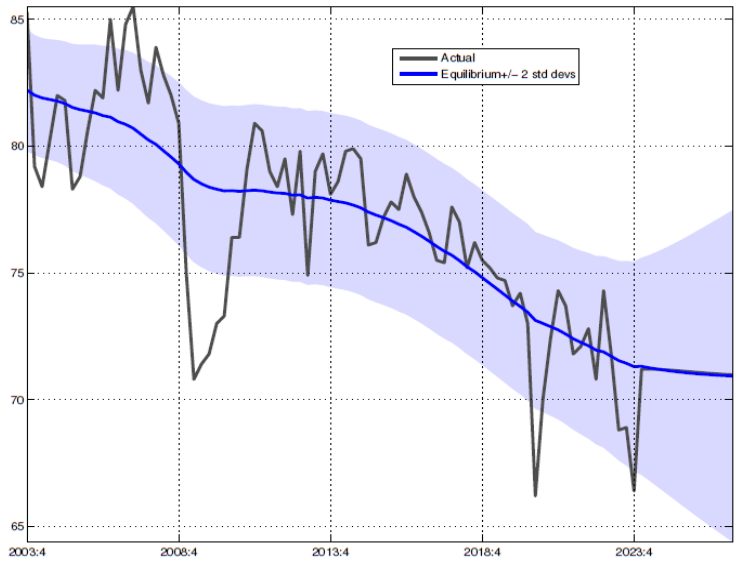
4.B.4. Usability

The subsequent section will provide the evolution of usability and its trend component, which illustrates the relationship between the output generated with available resources and the potential output achievable if this capacity were fully utilized.

There exists a positive correlation between GDP and capacity utilization (Figure 7); a decline in the GDP gap is promptly succeeded by a decrease in the capacity utilisation gap. The model demonstrates the impact of the 2008 financial crisis on capacity utilization, indicating a decline in capacity utilization from 2009 to 2013. The extent of the drop throughout the crisis was approximately 10 percentage points, and in contrast to the pandemic crisis or the energy crisis stemming from the Federation's invasion of Ukraine, the disparity in the financial crisis was markedly greater.

The correlation between GDP variations and capacity utilization further substantiates the cyclical characteristics of economic activity. Consistent with Hamilton's (2018) findings, our data demonstrate that the financial crisis resulted in a sustained underutilization of economic potential, while the COVID-19 shock had a more ephemeral impact. This distinction is essential for policy formation, indicating varied recovery strategies based on the type of economic shock.

Figure 7. *Usability and its trend (its equilibrium value)*

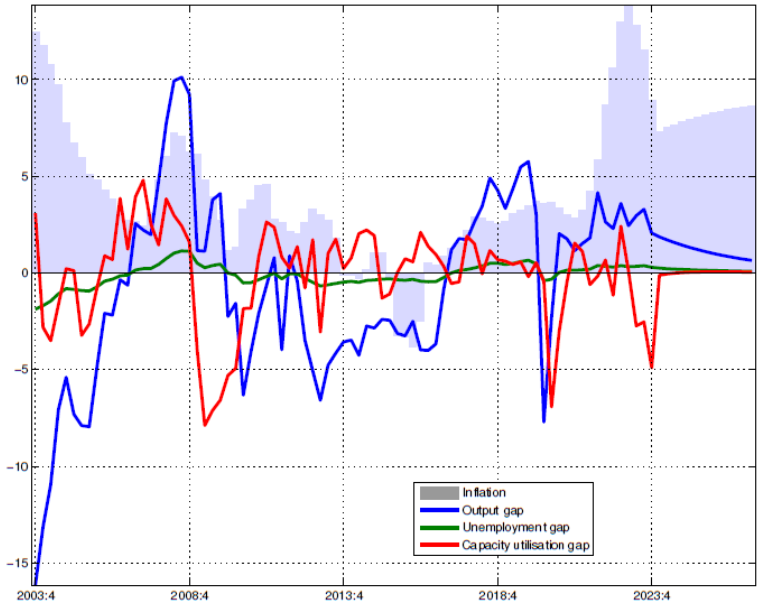


Source: Own processing.

4.B.5. Estimates of deviations

The subsequent section will give the three gaps corresponding to the original equations. i) Deviation of GDP, ii) Deviation of the unemployment rate, iii) Deviation of usability.

Figure 8. *Inflation. GDP deviation. Deviation of the unemployment rate. Usability deviation*



Source: Own processing.

Low productivity and inadequate capacity utilization are the primary causes of the three adverse deviations at the onset of the model sample, resulting in a sustained negative output deficit, as the actual growth rate fell somewhat behind the potential growth rate. The progress observed in 2005-2006 may be attributed to the adoption of the National Bank of Romania's new monetary policy framework, specifically the direct targeting of inflation.

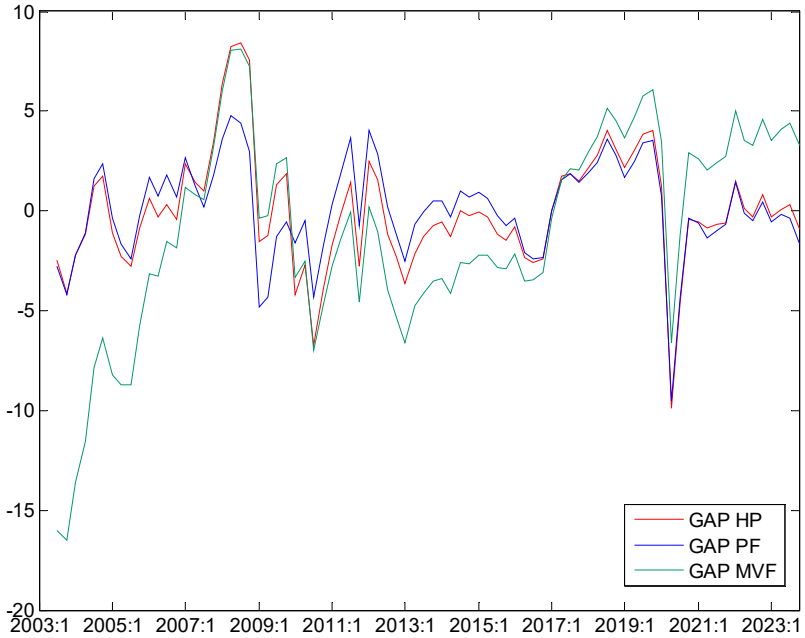
In 2007 and 2008, there was sustained economic growth, primarily attributable to admission to the European Union, with growth rates surpassing potential, a decline in the unemployment rate, and an increase in total factor productivity.

The economic slowdown following the financial crisis at the end of 2008 led to a negative output deviation and a diminished potential growth rate. During 2013-2014, GDP approached its potential level, thereby closing the GDP gap. The GDP gap and the capacity gap have developed concurrently across the whole time frame. The realized values are likely to align with the equilibrium state, consistent with projections for the forthcoming three years.

Figure 8 illustrates that the GDP gap and the capacity gap will diminish subsequent to the closure of the unemployment gap.

After estimating the GDP gap using the multivariate filter, we compared it with the two previously calculated GDP deviations (Figure 9), derived from other models, specifically the production function and the HP filter.

Figure 9. *Results corresponding to the GDP deviation obtained by the 3 methods*



Source: Own processing.

Consequently, the distinction between the outcomes of the two multivariate methodologies (Kalman and the Production Function) is evident, as the former considers interconnections among economic data, whereas the HP filter solely accounts for the dataset itself. The Kalman filter exhibits a more pronounced departure at the onset of the data series compared to the other two, resulting in a significantly more volatile series.

The linearity of the HP filter yields unique outcomes. During the pandemic, the reduction in the output gap is nearly uniform across all three specifications (about -10%); but, in the crises preceding the pandemic, the multivariate filter appears to identify a more significant negative deviation compared to the other models. The Kalman filter indicates a return to positive deviation following the pandemic crisis, coinciding with the resurgence in demand and the easing of economic activity conditions.

An examination of GDP gap estimates across various techniques (Figure 9) reveals significant disparities in their sensitivity to economic swings. The HP filter yields a more refined estimate, whereas the production function and multivariate approaches identify more pronounced aberrations, especially during crises. In accordance with prior research (Havik et al., 2014; Lupu & Asandului, 2020), our findings indicate that the incorporation of macroeconomic linkages improves the precision of potential GDP estimations, rendering them more appropriate for policy analysis.

5. Conclusions

This study sought to estimate Romania's potential GDP by a dual approach that integrates the Cobb-Douglas production function with a multivariate filtering technique. The analysis utilized quarterly macroeconomic data from Q3 2003 to Q4 2023, obtained from Eurostat, the International Labour Organization, the National Bank of Romania, and the National Institute of Statistics. The production function technique dissected potential output into its fundamental supply-side elements—capital, labor, and total factor productivity—whereas the multivariate method included interactions like the Phillips curve, Okun’s law, and capacity utilization dynamics. Bayesian estimate methods were utilized to guarantee reliable parameter identification, hence improving the precision of potential GDP assessment.

The results underscore significant cyclical variations in Romania's economy from a statistical standpoint. The production function estimates indicate a consistent rise in potential GDP, accompanied with discernible scarring effects post-2008 financial crisis, akin to conclusions drawn in the literature. The multivariate filter method identified more significant variances, especially during economic downturns, validating the robust correlation among GDP variations, inflationary trends, and unemployment changes. The analysis of estimation techniques indicated that statistical filters, like the HP filter, generally underestimate structural changes, but multivariate methods yield more responsive and economically significant estimates. The output gap study revealed that

Romania's economy faced overheating prior to the financial crisis and had a swift contraction during the COVID-19 epidemic, followed by a rebound propelled by robust fiscal and monetary support measures.

These findings yield various policy recommendations. Policymakers should incorporate several estimation methods when evaluating potential GDP to achieve a more thorough understanding of economic variations. Secondly, structural reforms designed to enhance labor market flexibility and productivity development must be emphasized to alleviate the long-term consequences of economic recessions. Third, considering the inflation-output correlation identified in the analysis, monetary authorities ought to meticulously observe output gaps when formulating inflation-targeting policies. Finally, specific fiscal policies that promote capital accumulation and labor force engagement might aid in maintaining potential GDP growth, especially amid external shocks and economic instability. These ideas furnish essential insights for Romanian policymakers and present a framework relevant to other rising economies encountering analogous macroeconomic issues.

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