BANKA SLOVENIJE

EVROSISTEM

OUTPUT GAP IN SLOVENIA

WHAT CAN WE LEARN FROM DIFFERENT METHODS?

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PRIKAZI IN ANALIZE
4/2012

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http://www.bsi.si/iskalniki/raziskave.asp?MapaId=234

Številka 4, Letnik XVIII

ISSN 1581-2316

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ABSTRACT

The aim of this paper is to estimate the output gap in Slovenia with a variety of different methods. We employ the following statistical methods: the linear and quadratic trend, the Hodrick-Prescott filter, the extended HP filter, the band-pass filter, the univariate and bivariate unobserved components model and finally the quasy-theoretical production function approach. Compared to other studies made for Slovenia, our period of estimation is extended to 2012, which means that we also include the last, most prominent cycle in our sample.

We find that the dynamics of the output gap is fairly similar among all methods. The output gap was positive in the periods of 1996-1997, 1999-2001 and especially 2006-2008, and negative otherwise. The production function approach also allows us to calculate contributions of different determinants to potential output growth. TFP was a leading source of growth on average in the period 1996-2008. However, in the crisis its contribution fell most notably in absolute terms. Also the contribution of capital has been relatively high prior the crisis and has decreased a lot during the crisis. The labour contribution has been the lowest of all, and even turned negative in the current crisis.

POVZETEK

Namen raziskave je oceniti proizvodno vrzel v Sloveniji z uporabo različnih metod. Uporabili smo sledeče statistične metode: linearni in kvadratni trend, Hodrick-Prescott filter, razširjeni HP filter, pasovno prepustni filter, univariatni in bivariatni model neopazovanih komponent ter kvazi-teoretično metodo produkcijske funkcije. V primerjavi z drugimi študijami narejenimi za Slovenijo je naše obdobje ocenjevanja razširjeno do leta 2012, kar pomeni, da vključuje tudi zadnji in hkrati največji cikel v našem vzorcu.

Ugotovili smo, da je dinamika gibanj proizvodne vrzeli med vsemi metodami precej podobna. Proizvodna vrzel je bila pozitivna v obdobjih 1996-1997, 1999-2001 in še posebej v 2006-2008, sicer pa je bila negativna. Metoda produkcijske funkcije nam omogoča tudi izračun prispevkov proizvodnih dejavnikov k rasti potencialnega proizvoda. Skupna faktorska produktivnost je bila glavni vir rasti v povprečju obdobja 1996-2008. V krizi pa se je njen prispevek v absolutnem smislu najbolj zmanjšal. Tudi prispevek kapitala je bil razmeroma visok pred krizo in se je v času krize močno zmanjšal. Prispevek dela pa je bil najnižji med vsemi in je v času krize postal negativen.

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Corresponding author: natasa.jemec@bsi.si. I am very grateful to Matija Lozej and all the participants of the internal Bank of Slovenia seminar for very useful comments and suggestions. All views expressed herein are those of author and do not necessarily reflect the views of the Bank of Slovenia or of the Eurosystem. All remaining errors in this paper are the sole responsibility of the author.

1. Introduction

Potential output is defined as a measure of non-inflationary level of supply in the economy. It reflects the maximum sustainable level of output which can be attained using available production factors without creating inflationary pressures (ECB Monthly Bulletin 2009). Demand determines the actual output. The output gap is determined as the percentage deviation of the actual level of output from its potential.

Neither potential output nor the output gap are observed directly, but have to be inferred from existing data. Their estimates are therefore surrounded by uncertainty. This is particularly relevant in the current environment, since the long-term economic implications of the financial and economic crisis are still unclear.

Concepts of potential output and the output gap are important indicators for the stability-oriented monetary policy strategy, for example, of the ECB for two reasons: they use a measure of potential output growth in the derivation of the reference value for monetary growth and to assess the outlook for future price developments. Furthermore, these measures are used to produce estimates of cyclically adjusted and structural fiscal balance in the case of fiscal policy, and cyclically adjusted unit labour costs to calculate real exchange rates to monitor developments in international competitiveness (ECB Monthly Bulletin, October 2000). The estimations of cyclically adjusted and structural fiscal aggregates are especially relevant in these times due to the current debate about the golden fiscal rule. The size and the sign of the output gap may influence the central bank's acting on economic activity via adjustment of interest rates and other measures. Therefore, reliable and timely estimations of potential output and the output gap are of crucial importance for the central bank.

For Slovenia several estimates of potential output and the output gap have already been made. For example, Bovha Padilla and Padilla Mayer (2002) have done these estimates with the linear trend, split-time trend, the Hodrick-Prescott filter (HP filter) and with the production function approach for the period 1992-2000. Jongen (2004) did them with the production function approach for the period from 1993 to 2002. Miklič (2007) has estimated these variables with the production function approach for the period 1992-2006 and Jemec (2008) with the HP filter and the production function approach for the period from 1992 until 2007. Finally, Masten and Brezigar Masten (2006) did those estimations for the period 1993-2003 with a variety of methods: linear trend, the HP filter, Nadaraya-Watson kernel regression, unobserved components model, Beveridge-Nelson decomposition, VECM model and the production function approach. We also use a variety of different methods, namely: the linear and quadratic trend, the HP filter, the extended HP filter, the band-pass filter, univariate and bivariate unobserved components model and the production function approach. Furthermore, compared to other authors, our period of estimation is extended to year 2012, which means that we also include the last, most prominent cycle in our sample. We find out that the growth of potential output has declined considerably in recent years and therefore structural reforms in combination with supportive macroeconomic policies are needed in order to maintain the higher growth rate of potential output than the euro area average until the catching-up process is complete.

We find that the dynamics of the output gap is fairly similar among all employed methods. The output gap was positive in the periods of 1996-1997, 1999-2001 and 2006-2008 and negative otherwise. The production function approach also allows us to calculate contributions of different determinants to potential output growth. TFP turns out to be a leading source of potential GDP growth on average in the period 1996-2008. In the crisis, its contribution fell considerably. Also the contribution of capital has been relatively high prior the crisis and has decreased notably in the years of the crisis. While the labour contribution has been the lowest of all factors and even turned negative in the last years.

The remainder of the paper is organized as follows. The concepts of potential output and the output gap and their use are described in section 2. Section 3 provides the description of different methods of estimation. Section 4 includes a description of the data. Results are presented section 5. Section 6 concludes.

2. Concepts of potential output and the output gap and their use

Potential output is defined as a measure of non-inflationary level of supply side in the economy. It reflects the maximum sustainable level of output which can be accomplished using available production factors without creating inflationary pressures (ECB Monthly Bulletin 2009). It is important to note that potential output is lower than the level of output which can be achieved with the maximum utilisation of the factors of production, which is neither sustainable nor efficient (Don, 2001). The level of potential output and its rate of growth are affected by many factors, among which the institutions and structures play an important role (ECB Monthly Bulletin, October 2000).

The output gap is defined as the percentage deviation of the actual level of output from its potential. There are various explanations why the output gap emerges. The first one is that if actual output exceeds its potential level, then constraints on capacity start becoming binding, which restrains further growth and contributes to inflationary pressures. While if actual output falls below its potential, then resources are idle and inflation tends to fall (CBO, 2004). In that case, the output gap represents an important information on price pressures.

Another definition of the output gap exists, according to this one economy is best characterised by real business cycle models, where actual output differs from its potential level due to random productivity shocks. In that case the output gap reflects temporary disturbances caused by the adjustment of the production process to technological changes and unexpected developments on the supply side (ECB Monthly Bulletin, October 2000).

Concepts of potential output and the output gap are important indicators for the stability-oriented monetary policy strategy of the ECB. There the maintenance of price stability is maintained on two pillars. The reference growth rate of monetary aggregate M3, which central bank is supposed to follow to ensure price stability, presents the first pillar. Potential growth helps to derive this reference value. Under the second pillar potential output growth and the output gap may help to assess the potential for inflationary pressures in the short to medium term (ECB Monthly Bulletin, October 2000).

Another important application of these measures arises in the cyclical adjustment of the macroeconomic series. For example, in fiscal policy assessment the output gap is used, together with measures of the sensitivity of government revenue and expenditure to cyclical movements in output, to produce an estimate of cyclically adjusted and structural fiscal balance. Business cycles influence different parts of public finance, therefore, we need cyclically adjusted and structural fiscal aggregates to get more proper picture about the fiscal situation in the country. This is especially relevant in these times due to the current debate about the golden fiscal rule. Also, for monitoring developments in international competitiveness, the output gap is used to estimate real exchange rates based on cyclically adjusted unit labour costs (ECB Monthly Bulletin, October 2000).

Next to the maintenance of price stability, central banks can also influence economic activity. If the economy is estimated to be below its potential level, then the central bank can use monetary policy to speed up the growth of output without incurring the risk of significantly higher inflation (CBO, 2004). It can lower interest rates to ease credit conditions and encourage the economy. In that case, reliable and timely estimates of potential output that tell us in which part of the business cycle economy is in, are of crucial importance (Orphanides, van Norden, 1999).

3. Two basic modelling approaches

Neither potential output nor the output gap are observed directly, but have to be inferred from the data using different techniques. Therefore, estimates of potential output might be surrounded by uncertainty[2] (ECB Monthly Bulletin, November 2011).

Due to that, this paper presents several statistical and econometric approaches available for the estimation of potential output and the output gap. We group these methods into two broad categories: “statistical” approaches and the “production function”. Statistical approaches decompose the real GDP series directly into a trend and a cyclical component, while the production function approach attempts to create an explicit model of the supply side of the economy using economic theory (ECB Monthly Bulletin, October 2000).

[2] This can come from different sources, including model uncertainty, parameter instability and data revisions (ECB Monthly Bulletin, November 2011).

3.1. Statistical methods

These methods are essentially based on the idea of extracting the trend and cycle from the output series using statistical techniques. We divide them into two categories. “Univariate approaches” represent the first category. They include methods that extract the trend and cycle only from the information contained in the output series, so without using the additional information from other variables. “Multivariate approaches” from the second category, attempt to extract the trend and cycle using the information in the output series together with information contained in other variables (ECB Monthly Bulletin, October 2000).

In this analysis we present the linear and quadratic trend, the HP filter, the band-pass filter and the univariate Kalman filter from the category of “univariate approaches”, and the extended HP filter and the multivariate Kalman filter from the category of “multivariate approaches”.

3.1.1. Deterministic trends

Here we assume that the trend in actual output is well approximated as a simple deterministic function of time. We employ two such functions, namely the linear and quadratic trend.

The linear trend is the oldest and the simplest of these methods. It assumes that GDP is decomposed into a deterministic trend and cyclical component:

$$y_t = \alpha + \beta t + \varepsilon_t \tag{1}$$

here y_t represents the logarithm of GDP, trend output is presented by βt corrected for the constant term (α) and the residual, ε_t, represents the business cycle. The quadratic term adds a second term in the deterministic component:

$$y_t = \alpha + \beta t + \gamma t^2 + \varepsilon_t \tag{2}$$

This allows the flexibility to detect a slowly changing trend in a simple way. Furthermore, this method can be adapted, so that breaks in the trend can be allowed. But it is necessary to apply this method to full economic cycle[3] to get a reliable estimate of trend output growth, because this estimate can be heavily influenced by cyclical developments.

[3] The cycle is defined as the period between peaks in economic growth (Chouraqui et al (1990)). Since the estimated changes in the trend growth can only happen between cycles and not within the cycle, we can not yet incorporate the split-time trend in our data for the last crisis period. Since the linear trend method assumes that potential output grows at a constant rate and other methods indicate that the growth of potential output has changed during the crisis, we use the linear trend method to estimate potential output only in the pre-crisis period. We assume that the crisis hit the economy in the 4th quarter of 2008, after the bankruptcy of the investment bank Lehman Brothers.

Deterministic trends remain appealing due to their simplicity. Therefore, they are used when simplicity is highly appreciated. For example, in monetary policy evaluation Taylor (1993) used the linear trend method and Clarida, Gali and Gertler (1998) used the quadratic trend. However, deterministic trends have been criticized by Nelson and Plosser (1982), who argue that output is better modelled as containing a stochastic rather than a deterministic trend. This has initiated two decades of research and debate and there is still no consensus reached. The possibility that output contained a unit root suggested a variety of other detrending methods which are presented in the rest of the paper (Orphanides, van Norden, 1999).

3.1.2. Hodrick-Prescott Filter

The Hodrick-Prescott filter (HP filter) is a very common approach to estimating potential output. We get trend output by minimizing a combination of the gap between actual output and trend output and the growth rate of trend output

$$min \sum_{t=0}^{T}(y_t - y_t^T)^2 + \lambda \sum_{t=2}^{T-1}[(y_{t+1}^T - y_t^T) - (y_t^T - y_{t-1}^T)]^2 \tag{3}$$

where y_t^T is the logarithm of trend output, y_t is the logarithm of actual output and λ is the degree of smoothness of the trend.

In other words, we need to select the trend values Y^T which solve the following minimisation problem (in matrix notation):

$$\begin{aligned} \nabla^2 Y^T &\equiv \eta \\ Y - Y^T &\equiv \varepsilon \\ \lambda\eta'\eta + \varepsilon'\varepsilon &\rightarrow \underset{Y^T}{Min} \end{aligned} \tag{4}$$

where Y and Y^T denote $Nx1$ vectors of the output and the trend output, respectively, ∇^2 denotes the difference operator in matrix form transforming the series to its second difference. And η and ε stand for vectors of unexplained residuals. In economic applications, the residual $\varepsilon = Y-Y^T$ is typically regarded as the cyclical component, in our case, it stands for the cyclical component of GDP. The objective function can be understood as a weighted sum of the squared trend deviations and the squared second differences of the trend, with λ denoting the pre-defined weight penalising movements in the trend. The solution to the above minimisation problem gives the following first order condition (Mohr, 2005):

$$(I + \lambda\nabla^{2'}\nabla^2)Y^T = Y \quad \text{or} \qquad Y^T = (I + \lambda\nabla^{2'}\nabla^2)^{-1}Y \tag{5}$$

Here, the symbol I denotes the NxN identity matrix (Mohr, 2005).

A key parameter of the filter, λ, determines the weight that controls how smooth the resulting trend line is. If λ is infinite, then all the weight will be on a high degree of smoothness leading to a linear trend. If λ is zero, then all the weight will be on goodness of fit to the original series and, hence, the estimated trend will always be the same as actual output. Lambda is higher (1600 for the USA for quarterly data) for more stable economies and lower for less stable ones (Cerra, Chaman Saxena, 2000). We use standard values of 1600 for quarterly and 100 for annual data. The average length of the cycle implied by this parameter is between five and eight years (Bovha Padilla, Padilla Mayer, 2002).

A few points should be mentioned here regarding the model. First of all, the cyclical component is derived implicitly, but the underlying trend can be interpreted as a second order random walk. Second, by equation 5 it is implied that the cycle is proportional to the fourth difference of the trend, shifted forwards by two periods[4], with lambda being the factor of proportionality. This particular property gives rise to cyclical patterns in the rate of change of the trend component. Third, there is no residual component capturing non-cyclical random impacts since the trend and the cycle add up to the original series[5]. Finally, the trend is computed as a data independent transformation rule since all the elements of the transformation matrix $(I + \lambda\nabla^{2'}\nabla^{2})^{-1}$ are predefined (Mohr, 2005).

The main advantages of the HP filter, when estimating potential output, are:

- It is relatively straightforward to implement.
- It only requires data on actual real GDP (Bovha Padilla, Padilla Mayer, 2002).
- It does not require any judgements about when trend growth changes during the sample.

The main shortcomings are the following:

- End-of-sample problem: to calculate the trend both past and future values are needed to get the average. This can be problematic at the end of the sample, when less and less future values are available to include in the average. Recent history is, however, the period that policy makers are most interested in (CBO, 2004). A possible solution how to deal with this problem is to extend the GDP series by incorporating forecasts. But doing this, the current estimate of potential output becomes sensitive to the quality of the macroeconomic forecasts (ECB Monthly Bulletin, October 2000).
- The choice of the smoothing parameter λ is critical, but ultimately arbitrary. Usually, we use a fixed value of λ across countries, but this is not particularly satisfactory, as the speed of adjustment to shocks tends to differ (ECB Monthly Bulletin, October 2000).
- The filter can mistakenly identify a cycle when there is none (Mohr, 2005). This could arise, for example, in the case of break in the trend.
- In the case of extraordinary situations it rarely delivers plausible results as it tends to smoothen out structural changes and estimates of trend growth tends to be rather pro-cyclical in real-time (Mohr, 2005).

[4] This can be shown by rewriting (3) as $\lambda\nabla^{2'}\nabla^{2} Y^{T} = Y - Y^{T}$. This is equivalent to $\lambda L^{2'}\nabla^{4} Y^{T} = Y - Y^{T}$, with $L^{2'}$ denoting the second lead operator, shifting forward a time series by 2 periods (Mohr, 2005).
[5] This is one of the reasons why we have to use seasonally adjusted data.

- It does not allow to incorporate relevant pieces of information to obtain more plausible trend and cyclical components, which is particularly relevant in the case of large shocks (Mohr, 2005).
- It is a black box—for example, we do not know why the growth of potential output has changed (CBO, 2004).
- Finally, since the trend and the cycle add up to the original series, there is no residual component capturing non-cyclical random impacts (Mohr, 2005).

3.1.3. Extended HP filter

In his paper, Mohr (2005) introduces the extended HP filter. He shows that ordinary HP filter can be extended in several dimensions. First of all, it is possible to add additional exogenous variables, which help to extract the cyclical component from the time series. In other words, an explicit model of the cycle can be introduced to the filter and also residual component capturing noncyclical random impacts is now part of the model. Second, the trend model of the filter can be extended by the incorporation of exogenous variables that are assumed to be highly correlated with the trend. Third, the extended HP filter allows to incorporate one or more (pre-defined) structural breaks in the trend series, while the standard HP filter would smoothen out sharp structural breaks in the trend. Finally, the order of the stochastic trend process can be changed: from two to one, giving rise to the exponential smoothing filter[6].

In our analysis we follow Mohr (2005) and use only the first extension of the filter: we include additional cyclical indicators that help us with the trend-cycle decomposition[7]. This can be derived by solving the following minimisation problem:

$$\begin{gathered} \nabla^2 Y^T \equiv \eta \\ Y^2 - Z\beta \equiv \xi \\ Y - Y^T - Y^C \equiv \varepsilon \\ \lambda\eta'\eta + \xi'\xi + \varepsilon'\varepsilon \rightarrow \underset{Y^T, Y^C, \beta}{Min} \end{gathered} \tag{6}$$

Here the *Nxp* matrix *Z* denotes p exogenous variables which are assumed to be correlated with the cyclical component, and β denotes the *px1* vector of loadings of the indicators on the cyclical component which are to be estimated. *Z* can also contain leads or lags of the indicator series. Y^C stands for the cyclical component and ξ stands for another residual component.

From this minimisation problem, we get the following first order conditions for Y^T, Y^C, and β:

$$\begin{gathered} (I + \lambda\nabla^{2'}\nabla^2)Y^T \equiv Y - Y^C \\ (I + M)Y^C \equiv Y - Y^T \end{gathered} \tag{7}$$

[6] This filter was used by Lucas (1980) in an empirical analysis of the quantity theory of money and has been developed further by Tödter (2002).
[7] Further extensions incorporating also trend indicators, structural breaks and for the discussion of the exponential smoothing procedure can be found in Mohr (2005) and Tödter (2002).

$$\beta \equiv Z(Z'Z)^{-1}Z'Y^C$$
$$M \equiv I - Z(Z'Z)^{-1}Z'$$

We introduce the auxiliary matrix M to shorten notation. It is the residual-maker projection matrix of regression analysis: pre-multiplying Y^C, i.e. the expression $M\,Y^C$, gives the residuals of a regression of Y^C on Z. From the third line in (5), $MY^C \equiv Y - Y^T - Y^C$ can be derived, implying that the residuals ε are equal to those components of Y which can be explained neither by the trend, nor by the cycle model. We estimate the vector of loadings β using the least-squares regression of Y^C on Z. Finally, (5) implies that the residuals of the regression of indicators, ξ, are equal to the noise residuals, ε. This reflects the fact that the residuals of the Z-regression are not explicitly penalised and therefore not weighted such as the residuals of the trend equation which go into the optimisation procedure with the weight λ. From (5) we derive solutions for the trend and the cycle processes:

$$Y^T \equiv (M + M\lambda\nabla^{2'}\nabla^2 + \lambda\nabla^{2'}\nabla^2)^{-1}MY$$
$$Y^C \equiv (M + \lambda\nabla^{2'}\nabla^2 M + \lambda\nabla^{2'}\nabla^2)^{-1}\lambda\nabla^{2'}\nabla^2 Y \qquad (8)$$

Several points should be mentioned here. First, the properties of the trend and cycle series generated with the extended HP filter depend much on the indicator series selected. This requires the indicator series to be selected carefully[8], usually in line with some strong theoretical priors. In our case, we used capacity utilization, and two sentiment indicators, the shortage of demand and confidence indicator in manufacturing, but also inflation indices may be used. Second, both Y^C and the loading vector β are simultaneously estimated, so the level of the cycle is undetermined, meaning that indicator variables should be demeaned before applying the extended HP filter. Third, formally there is no constraint on p, the number of variables in Z, but the selection should be kept as sparse as possible as the identification of the loadings may be difficult when many variables are used (Mohr, 2005).

Compared to the standard HP filter, the extended HP filter possesses some more advantages[9]. Assuming cyclical indicators are well selected, it has better within and end-of-sample properties than the standard HP filter and potentially gives rise to more plausible patterns in the cyclical component. This makes the real-time estimates more plausible and is particularly relevant in the case of large shocks (Mohr, 2005).

[8] One obvious minimum requirement for the indicator variables is that they should be stationary.
[9] More detailed comparison of HP filter to extended HP filter can be found in Annex 1.

3.1.4. Band-pass filters

Band-pass filters isolate the cyclical component of a trend by specifying a range for its duration. They are linear filters that take a two sided moving average of the data where cycles in a "band" are extracted, given a specified lower and upper bound.

The 'ideal' band-pass filter comes from the theory of the spectral analysis of the time series, and relies on the Spectral Representation Theorem, according to which any time series within a broad class can be decomposed into different frequency components. The ideal band-pass filter serves as a tool for extracting those components. It is a linear transformation of the data, which leaves intact the components of the data within a specified band of frequencies and eliminates all other components. The adjective 'ideal' means, that it requires an infinite amount of data. Therefore in practice, when we deal with finite data, certain approximation is required (Chistiano, Fitzgerald, 1999).

In our analysis we use the most general band-pass filter, which is the Christiano-Fitzgerald (CF) asymmetric filter. To calculate it, we first need to explain what an optimal linear approximation is. Let $\hat{y}_t^c$ denote the data generated by applying the ideal, though infeasible, band-pass filter to the raw data, y_t. We then approximate $\hat{y}_t^c$ by y_t^c a linear function, or filter, of the observed sample y_t's. After that we select filter weights to make y_t^c as close as possible to the object of interest, $\hat{y}_t^c$. We select them in the sense of minimizing the mean square error criterion:

$$E[(\hat{y}_t^c - y_t^c|y], y \equiv [y_1, \dots, y_T], \qquad (9)$$

Here, the expectation operator is evaluated using the time series properties of y_t. Thus, y_t^c is the linear projection of $\hat{y}_t^c$ onto every element in the data set, *y*, and there is a different projection problem for each date *t*. In these projections we derive closed form formulas for filter weights.

As already mentioned, the optimal approximation to the band-pass filter requires knowing the true time series representation of y_t, which is not known in practice and must be estimated. We use the approach of Chistiano and Fitzgerald (1999), which uses the assumption that the data are generated by a pure random walk. This filter can be calculated as follows:

$$y_t^c = B_0 y_t + B_1 y_{t+1} + .. + B_{T-1-t} y_{T-1} + \tilde{B}_{T-t} y_T + B_1 y_{t-1} + \cdots + B_{t-2} y_2 + \tilde{B}_{t-1} y_1, \ for \ t=3,4,..,T\text{-}2 \qquad (10)$$

$$where\ B_j = \frac{sin(jb) - sin\,(ja)}{\pi j}, j \geq 1,\ B_0 = \frac{b-a}{\pi}, a = \frac{2\pi}{p_u}, b = \frac{2\pi}{p_l}\ and\ \tilde{B}_k = -\frac{1}{2} B_0 - \sum_{j=1}^{k-1} B_j$$

Here, the parameters p_u and p_l are the cut-off cycle length[10]. Cycles longer than p_l and shorter than p_u are preserved in the cyclical term y_t^c. From the formula (8) it can be seen that this filter varies with time and that it is not symmetric in terms of future and past y_t's. For more details see Christiano-Fitzgerald (1999).

The advantages of the band-pass filter compared to the HP filter are the following: the gap is smoother compared to the HP filter, since band-pass filter extracts the gap directly, while the HP filter gap also contains an irregular component. It does not have an end-of-sample bias as the HP filter (IMF, 2011).

3.1.5. Unobserved components model

The unobserved components method is an approach to estimating unobserved variables using information from observed variables and economic structure (Cerra, Chaman Saxena, 2000).

We write the model in the so-called state-space form. This is a general way of representing dynamic systems. In the first equation observed variables are specified as a function of the unobserved state variables. This equation is also called measurement or observation equation. The second equation, also called the transition equation, specifies how state variables evolve over time (Cerra, Chaman Saxena, 2000).

$$\begin{aligned} a_t &= T b_t + \rho_t \\ b_t &= Z b_{t-1} + \theta_t \end{aligned} \tag{11}$$

Here a_t is vector of observed (signal) variables and b_t is vector of unobserved (state) variables. T and Z are matrices, ρ is vector of measurement errors related to observed variables and θ is a vector of shocks related to the unobserved variables (IMF, 2011).

Once we write a dynamic time series model in a state-space form, we can estimate the unobserved state vector using the Kalman filter.

We use univariate and bivariate filter to estimate potential output and the output gap for Slovenia.

Simple univariate filter is composed as follows:

$$\begin{aligned} y_{t=} y_t^c &+ y_t^T \\ y_t^c &= \vartheta y_{t-1}^c + \mu_t && \vartheta < 1, \mu_t \approx N(0, \sigma_\mu^2) \\ y_t^T &= y_{t-1}^T + \Delta\, y^T + \eta_t && \eta_t \approx N(0, \sigma_\eta^2) \end{aligned} \tag{12}$$

[10] The typical upper and lower bounds for GDP correspond to the NBER definition of business cycles in the U.S., so they are between 6 and 32 quarters (1.5 and 8 years).

here y_t stands for the logarithm of original GDP series, y_t^c is its cyclical component and y_t^T is its trend component. μ_t is a shock affecting cyclical component and η_t is a shock affecting trend component. All the shocks affecting the components are assumed to be independently and identically distributed with zero mean. The first equation tells that output is split into "gap" and "trend", the second equation shows that the cycle component is assumed to follow an AR(1) process, while from the third equation we can see that trend grows on average.

In the case of bivariate filter we include inflation, π_t, as an additional source of information. In doing this, we use a well-known economic relationship - the Phillips curve. In this approach a common cyclical component for output and inflation is assumed[11]:

$$\begin{aligned} & y_t = y_t^c + y_t^T \\ & \pi_t = \alpha\pi_{t-1} + \kappa y_{t-1}^c + \varepsilon_t \qquad 0 < \alpha < 1, \varepsilon_t \approx N(0, \sigma_\varepsilon^2) \\ & y_t^c = \vartheta y_{t-1}^c + \mu_t \qquad \vartheta < 1, \mu_t \approx N(0, \sigma_\mu^2) \\ & y_t^T = y_{t-1}^T + \Delta\, y^T + \eta_t \qquad \eta_t \approx N(0, \sigma_\eta^2) \end{aligned} \tag{13}$$

Of all these variables, only GDP and inflation are observable and all the others need to be estimated (potential output, the output gap, parameters and variances).

The main advantages of the bivariate Kalman filter is that it takes into account the information contained in the other economic series and incorporates some elements of economic theory. The relationship between relevant macroeconomic variables makes it less arbitrary and potentially more robust- to the extent the relationship is supported by the data. While the main disadvantage is that it requires considerable programming and making certain assumptions. For example, with regard to the underlying trend and the cyclical component of a series (ECB Monthly Bulletin, October 2000).

3.2. Quasi-theoretical methods: Production function approach

The production function approach[12] provides a comprehensive economic framework for estimating potential output, which makes a clear link between output and the level of technology and factor inputs, usually labour and capital. It can thus be used to explain the most important economic forces underlying developments in output and its growth and to assess the impact of structural changes and policies on the components of output and its potential (ECB Monthly Bulletin, October 2000).

[11] Sign and the size of the output gap is assumed to imply the direction and the size of inflationary pressures. However, due to nominal rigidities, there are supposed to be significant asymmetries in response of prices to changes in activity. This is because firms are more reluctant to move prices down than up, and also workers resist reductions in nominal wages. Those rigidities mute the disinflationary response to a slowdown in economic activity. The muted disinflationary response can also be the result of well-anchored inflation expectations in the euro area countries and of the uncertainty in the measurement of potential output and the output gap (ECB Monthly Bulletin, January 2011).

[12] This method is regularly used by international organizations, for example, by the European Commission (Denis et al., 2006) and by the OECD (Beffy et al., 2006) to assess the productive potential of countries.

There are many possible functional forms of production functions, but the one used the most is the Cobb-Douglas production function. We follow Giorno et al. (1995) and use the two factor Cobb-Douglas production function with Hicks-neutral technology:

$$Y_t = A_t {K_t}^{\alpha} {L_t}^{(1-\alpha)} \qquad 0< \alpha<1 \qquad (14)$$

where Y_t stands for GDP, L_t for labour input, K_t for capital input, A_t for the total factor productivity (TFP) level, *1-*α is the elasticity of output with respect to labour and α is the elasticity of output with respect to capital. The most important assumption of this production function is that of constant returns to scale, meaning that both elasticities sum up to 1. It also satisfies other properties of a neoclassical production function: it has positive and diminishing marginal products of each input and satifies Inada conditions. Under the assumption of perfect competition elasticities can be represented by the shares of income earned by capital and labour, respectively, and can be estimated from the labour income share[13] (Romer, 2006).

The capital income share is around 0.33 in industrialized countries, so many researches use this value and, therefore, we use it as well[14].

3.2.1. Labour

The measure of quantity of labour is actual employment (including self-employment), which is a standard measure of labour inputs in industrialized countries. This measure is, however, less accurate than hours worked. However, the times series on hours worked for Slovenia is not long enough[15], so we need to use the head count data instead (Bovha Padilla, Padilla Mayer, 2003).

We can decompose the labour component as shown below:

$$L_t = LF_t(1-U_t) = POP_t PR_t (1-U_t) \qquad (15)$$

here L_t presents labour in the number of people, ${LF_t}$[16] stands for labour force, U_t for unemployment rate, POP_t for working-age population and PR_t for participation rate (Barwell et al., 2007).

[13] However, ECB reports that direct estimation of the production function can yield values for 1-α which differ markedly from the labour share, as measured by the national accounts. This can possibly reflect the fact that an assumption of perfect competition does not hold in reality (ECB Monthly Bulletin, 2000).
[14] Mrkaić (2002), for example, uses the value of 0.3.
[15] Available only from 2004 on.
[16] The labour force is represented by the economically active population, which means all persons aged between 15 and 64 years who are classified as employed or unemployed according to the ILO methodology.

3.2.2. Capital

No official series on physical capital for Slovenia[17] exists. Therefore, we construct our own series for capital stock[18]. We base our estimate on Mrkaić`s (2002) approach. There the level of capital is estimated using optimality condition where the marginal product of capital equals its user cost (the real interest rate plus the rate of depreciation). If we assume that the marginal product of capital equals the user cost of capital, then the capital-output ratio equals the capital income share over the user cost of capital:

$$K_0 = \frac{\alpha Y_0}{(r_0 + \delta)} \tag{16}$$

here α stands for the capital income share, r_0 denotes the real interest rate[19] in the base year, δ stands for depreciation, Y_0 represents the real GDP in the base year and K_0 represents the real stock levels of capital in the base year. The base year[20] is 1999 and the assumed annual depreciation is 5%.

To estimate the rest of the series we use the perpetual inventory method[21], where gross fixed capital formation as a proxy for a change in capital stock is used:

$$K_t = (1 - \delta_{t-1})\, K_{t-1} + I_t \tag{17}$$

here K_t represent the real stock levels of capital, I_t stands for gross fixed capital formation and δ_{t-1} is depreciation.

3.2.3. TFP

TFP is the key variable that determines long-run economic growth (Solow, 1957), but also business cycles (Kydland, Prescott, 1982). The TFP level cannot be measured directly. Therefore we estimate it by rewriting equation 13:

$$A_t = \left[\frac{Y_t}{L_t^{1-\alpha} K_t^{\alpha}}\right] \tag{18}$$

[17] In Rapid Report No. 107 (2002) the SORS published preliminary estimates for the capital stock in 1999. But since then, no updates on the official capital stock have been published. However, the reported capital-output ratio of more than 3 seems to be relatively high (Jongen, 2004).
[18] For more details and arguments on this capital series see Jemec (2008).
[19] Long-term real interest rate on capital investment.
[20] Errors captured in initial position diminish in significance over time.
[21] Perpetual inventory method represents only one part of the solution to the problem of data quality, especially due to the fact that the relevant time series in post-communist economies are quite short (Mrkaić, 2002)

Since TFP is generally measured by the Solow residual, it heavily depends on the specification of the production function and on the measurement of capital and labour (ECB Monthly Bulletin, October 2000).

3.2.4. Potential output

Finally, we obtain potential output, Y_t^T, by taking into account the trend total factor productivity, A_t^T, and potential employment, ${L_t}^T$[22] and the measure of capital, K_t[23]:

$$Y_t^T = A_t^T {K_t}^{\alpha} {L_t}^{T(1-\alpha)} \tag{19}$$

Since we use the same filtering techniques to obtain potential output through its components in the production function approach as in the direct de-trending of output, the production function does not give us a very useful estimation of potential output estimation per se. What really matters for the analysis of the supply side is the decomposition of the potential output into the contribution of its determinants, which is done by growth accounting exercise.

3.2.5. Growth accounting

Growth accounting exercise makes it possible to decompose the change in actual or potential output into components, which are changes in factor inputs and a measure of technological progress. To obtain the growth rate of potential GDP and its components, we use the fact that the growth rate of variable equals the time derivative of its logarithm (Romer, 2006) and transform equation (18) in this way to get:

$$y_t^T = a_t^T + \alpha k_t + (1-\alpha) l_t^T \tag{20}$$

here y_t^T stands for the growth rate of potential output, k_t for the growth rate of capital, l_t^T for the growth rate of potential employment and a_t^T for growth in the trend total factor productivity. We decompose potential labour component even further by taking the time derivative of the logarithm of the equation (15)[24]:

$$l_t^T = pop_t^T + pr_t^T - \frac{U_t^T}{1-U_t^T} u_t^T \tag{21}$$

[22] We obtain potential labour and TFP using the HP-filter method (where lambda is 100 for yearly data and 1600 for quarterly data).

[23] Unlike the labour input and TFP, the capital input does not need to be cyclically adjusted, in other words the unadjusted capital input already represents its potential contribution to output. This is due to the fact that even though the use of the capital stock varies greatly during the business cycle, the potential flow of capital services will always be related to the total size of the capital stock and not to the amount currently being used (CBO, 2004).

[24] For the details of this derivation see Musso and Westermann (2005).

here pop_t^T presents the growth rate of potential working-age population, pr_t^T stands for growth of the potential participation rate, U_t^T presents potential unemployment[25] and u_t^T potential unemployment growth rate.

This decomposition allows us to comment on changes in the long-run supply-side performance. For example, if an increase in the growth rate of capital is accompanied by a rise in trend total factor productivity, this may signalize some improvement in the supply-side performance. On the other hand, if an increase in the growth rate of capital is accompanied by stagnating trend total factor productivity, that may signalize that supply side is functioning ineffectively (Hajkova, Hurnik, 2007). Results we get from the growth accounting exercise are also an important indicator when proposing policies that could enhance the growth potential.

The main advantages of production function method are the following:

- It reveals more insights about the economy than a more aggregated model, since it looks explicitly at the supply side of the economy or in other words, it allows a transparent accounting for the sources of growth (CBO, 2004).
- Decomposition into sources of growth makes it easier to forecast potential output, since forecasts of important components (employment, unemployment, investment and therefore capital stock) are usually available (ECB Monthly Bulletin, October 2000).
- Because the production function approach is guided by views on the relationships between relevant macroeconomic variables, its estimates of potential output are less arbitrary and potentially more robust. This holds to the extent that the macroeconomic relationships are supported by the data (ECB Monthly Bulletin, October 2000).

There are also certain disadvantages associated with this approach:

- Assumptions about the weights of labour and capital may not be consistent with data (CBO, 2004).
- Detrending of the specific variables with the HP filter leads us to similar results as from direct de-trending of output and also to similar problems, for example, end-of-sample bias (Cerra, Chaman Saxena, 2000).
- Estimates of potential output may be affected by measurement errors in factor inputs, particularly in the capital stock (Cerra, Chaman Saxena, 2000). Data availability is an issue here. Since there is often no reliable measure of physical capital stock (Bovha Padilla, Padilla Mayer, 2002), the measures of capital stock are not very reliable (ECB Monthly Bulletin, October 2000).
- An important assumption about perfectly competitive markets may not hold in practice.

[25] Potential unemployment has been estimated from the unemployment rate based on ILO definition.

- There are also some problems with the labour component, for instance, in case of labour-hoarding hypothesis. This emphasises transaction costs of adjustments in the labour force and says that firms may find it profitable to substitute labour utilization rates for measured labour input when the labour force cannot be modified without costs. As a result effort levels may change over the business cycle instead of measured inputs (Cerra, Chaman Saxena, 2000). Data on hours worked would to some extent capture the effort levels, but they are often not available (ECB Monthly Bulletin, October 2000). Additionally, large fluctuations in the labour supply make it very difficult to disentangle the trend labour force. Obtaining the trend levels of the effective labour supply also, to some extent, depends on the presence of rigidities in the labour market. Therefore, different assumptions of this will lead to very different estimates of potential output (ECB Monthly Bulletin, October 2000; CBO, 2004; Cerra, Chaman Saxena, 2000).
- Regarding decomposition into the trend and cyclical component also productivity levels are problematic due to large fluctuations. Different ways of detrending TFP, again lead to very different estimates of potential output (ECB Monthly Bulletin, October 2000).

4. Data

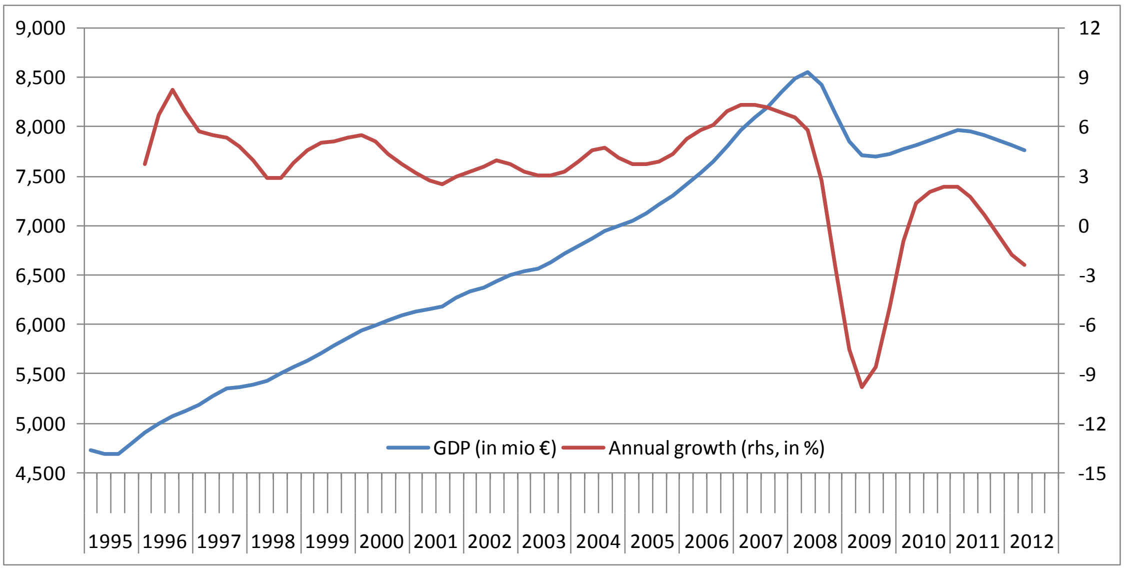
In our analysis we use data on a quarterly frequency[26]. We seasonally adjust them with U.S. Consensus Bureau´s X12 seasonal adjustment program[27]. Compared to the TRAMO/SEATS method, X12 is more accurate for most series, X12 works better for short series (4 to 7 years) and for longer series (over 15 years) and finally X12 has better diagnostics (Catherine Hood Consulting, 2007). GDP, labour and capital series are available from 1995:1, other cyclical indicators from 1995:2 and the harmonized index of consumer prices, which is available from 1996:1. Data are available until the 2012:2. For growth accounting exercise we transform data to annual level and use projections up to 2014.

4.1. GDP

In Figure 1, the level of seasonally adjusted quarterly GDP in prices from 2005 and its growth rate are presented. The average annual growth rate of GDP in the observed period was 3.2%, with a considerable decline in the current crisis (average before 2008:4 was 4.7%).

[26] When we are dealing with monthly data, we transform them to quarterly level.
[27] Within this method we use final trend-cycle decomposition.

Figure 1: Real quarterly GDP and its annual growth in Slovenia from 1995 until 2012, seasonally adjusted in constant prices from 2005



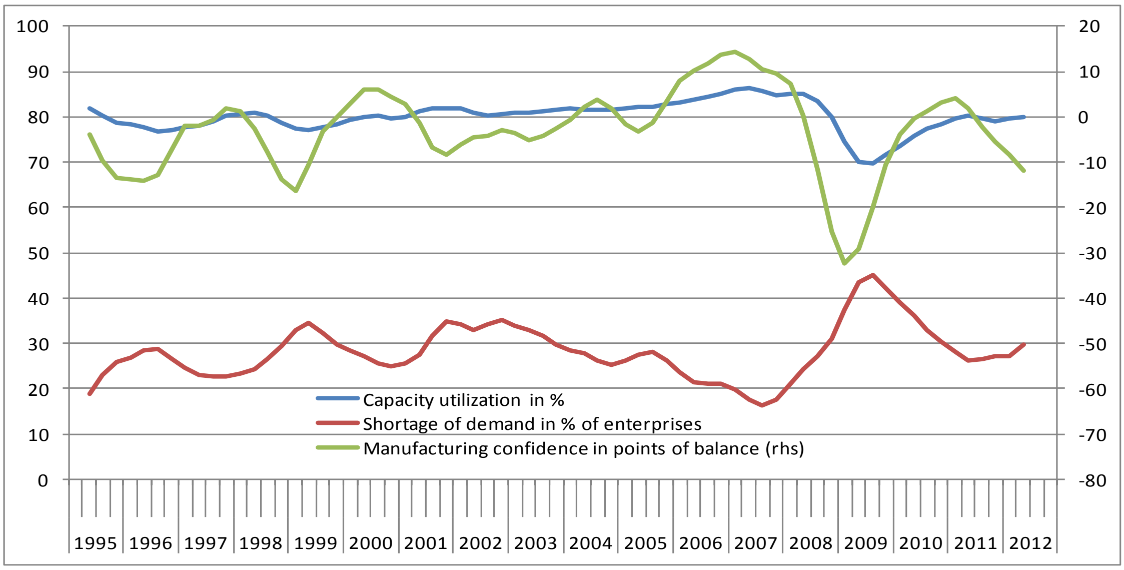
Source: Statistical Office of the Republic of Slovenia, author's calculations.

4.2. Other cyclical indicators

The main use of other cyclical indicators in our paper is their inclusion in the extended HP filter, where they serve as an additional source of information, which helps to decompose GDP into the trend and cyclical component. They can, however, be also used to cross-check the validity of the output gap estimates. There has been significant uncertainty regarding the magnitude of the output gap since the economic and financial crisis and in these times cyclical indicators prove especially useful.

Cyclical indicators that we use in our paper are capacity utilization rate, the shortage of demand and confidence in manufacturing, all seasonally adjusted. They are collected in the European Commission business survey for the manufacturing sector. Capacity utilization rate and the shortage of demand are collected on a quarterly basis, while confidence in manufacturing is collected on a monthly frequency. For more information about the chosen indicators see The Joint Harmonised EU Programme of Business and Consumer Surveys (European Commission, 2007).

Figure 2: Other cyclical indicators of the output gap, seasonally adjusted



Source: European Commission.

One useful feature of the cyclical indicators is that they, like most opinion surveys, are normally not revised, while on the other hand, the degree of uncertainty surrounding real-time estimates of the output gap is usually high and they are frequently revised. However, the use of above mentioned cyclical indicators has several limitations. One of them is that they are based only on the manufacturing sector, which represents less than one-third of the Slovenian GDP, while estimates of the output gap are based on the whole economy. Regardless of that, there appears to be a strong empirical link between developments in these cyclical indicators and in estimates of the output gap (ECB Monthly Bulletin, June 2011).

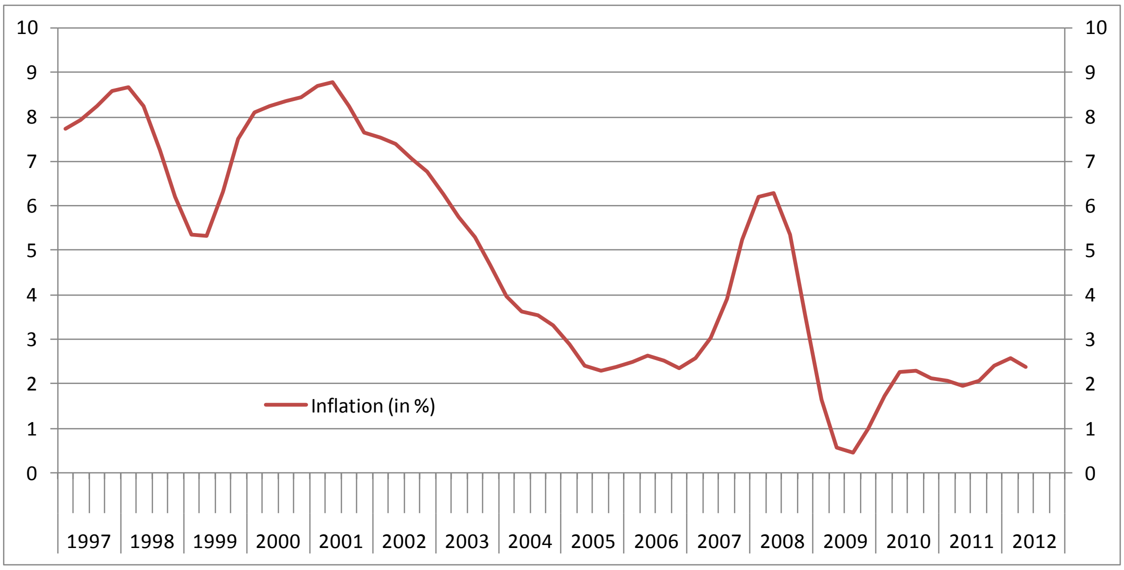
Together with estimates of the output gap, the capacity utilisation rate and confidence indicator in manufacturing declined sharply during the latest recession, reaching a historical low in 2009. The shortage of demand indicators has also increased a lot during the last crisis, reaching historically high levels in 2009.

In contrast to the various estimates of the output gap, the cyclical indicators subsequently recovered strongly to virtually "normal" levels, suggesting a sharper decrease in the slack in the euro area economy than signalled by the various output gap estimates from international institutions. This could point to an overestimation of potential output. In 2011 and 2012 those indicators point to another deterioration of the economic situation.

4.3. Inflation

In Figure 3, seasonally adjusted annual inflation rate in Slovenia from 1997[28] to 2012 is presented. We can see a clear disinflation trend after inflationary shocks in 1999, from 2001 until 2005, when inflation reached levels close to 2%. Inflation rose again in 2007 and 2008, partly due to the booming domestic macroeconomic environment and party due to incraesing commodity prices. At the end of 2008, the crisis hit the economy, which was also reflected in the annual inflation rate, falling below 1%. After that it was moving around 2%[29] and increased over 2.5% in 2012, mostly due to higher food and energy prices.

Figure 3: The annual inflation rate in Slovenia from 1997 to 2012, seasonally adjusted



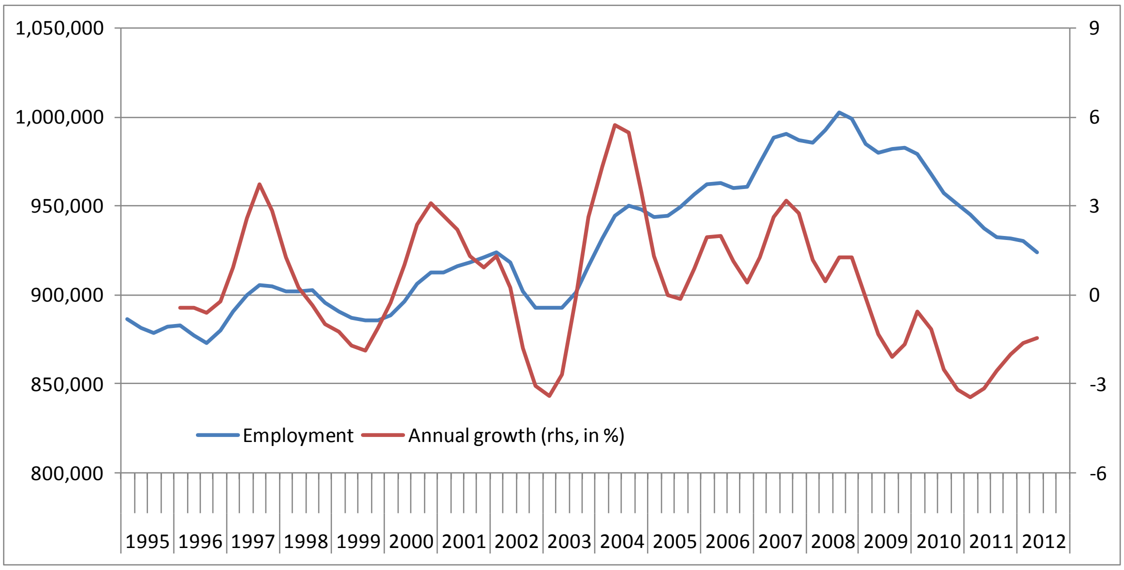
Source: Statistical Office of the Republic of Slovenia, author's calculations.

4.4. Labour

In Figure 4, the level of seasonally adjusted employment[30] and employment growth rates in Slovenia are shown. Due to the restructuring of the economy, employment in Slovenia was falling up until 1996, it has steadily increased after that up to 2008, followed by a fall in the crisis. Drop in employment prior 1996 can be partially explained by the rise in unemployment[31] and partially by the fall of the gross participation rate due to early retirement schemes (Jongen, 2004).

[28] HICP is only available from the beginning of 1996, therefore we get inflation only from 1997 on.
[29] The main ECB's objective is to keep medium-term inflation below but close to 2%. Slovenia is part of euro area since the beginning of 2007.
[30] According to the ILO methodology.
[31] During socialist times, unemployment was kept (presumably artificially) low (Jongen, 2004).

Figure 4: the level of employment and employment growth rates in Slovenia from 1995 to 2012, seasonally adjusted

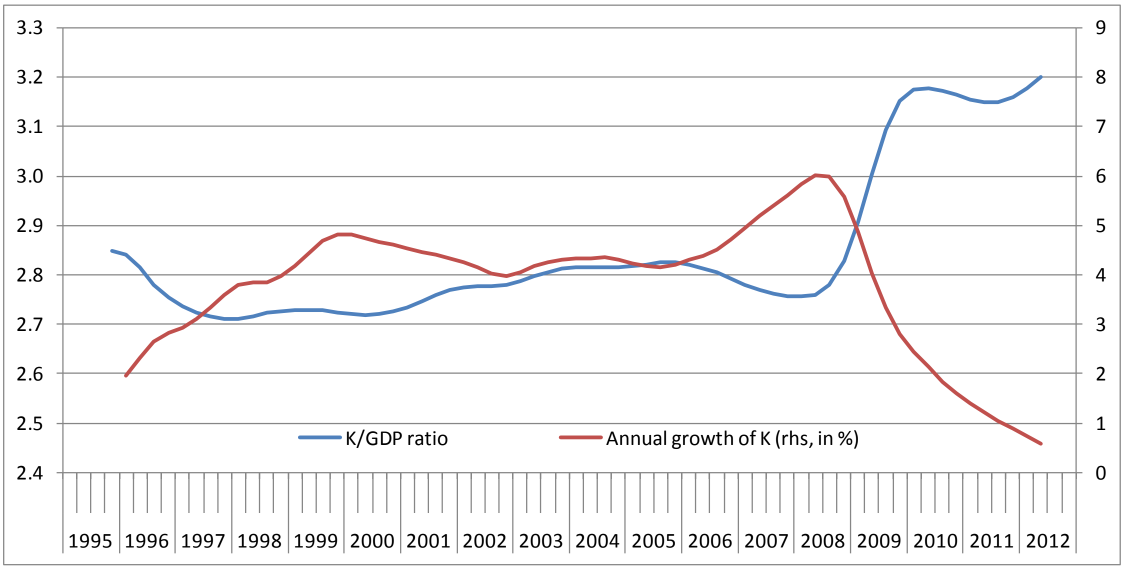


Source: Statistical Office of the Republic of Slovenia, author's calculations.

4.5. Capital

In Figure 5, we present the physical capital stock estimate as a share of GDP and the growth rate of capital stock. The average annual growth rate of the estimated capital in the observed period is 3.8%, with a considerable decline in growth in the current crisis (before that it amounted to 4.3%). We see that the stock of capital as a proportion of GDP in Slovenia was mostly increasing in the observed period, from 2.8 to 3.2, which indicates the capital deepening in a catching-up economy. Nevertheless, the largest increase occurred during the last crisis, because of the sharp fall in GDP at the beginning of the crisis. This ratio is, however, still below the euro area average, at 3.4, according to the Area-Wide Model (AWM) database. This is in line with the theory that transition countries have, due to the larger depreciation of capital in the transition, lower K/GDP ratios than developed countries (Jongen, 2004).

Figure 5: the K/GDP ratio and capital growth rates in Slovenia from 1996 to 2012



Source: Statistical Office of the Republic of Slovenia, author's calculations.

5. Results

5.1. Unobserved components models

The estimation of all parameters of the unobserved components models described in section 3.1.5. prove difficult, as the parameters are unstable. Therefore we use the pre-crisis data to estimate the majority of parameters:

Table 1: Estimations of uni- and bivariate models

	Uni-	bivariate	
	ϑ	α	ϑ
Coefficient	1	0.99	0.85
std. dev.	*0.15*	*0.14*	*0.4*

Source: Author's calculations.
Note: Coefficients are estimated using the pre-crisis period. Due to the availability of the series the estimation for the univatiate model starts in 1995 and for the bivariate model in 1997.

In addition we use the grid search method to obtain parameter κ that was not significant when estimated with Kalman filter. Since the correlation between inflation and the lagged output gap is around 0.5, we check the interval of values between 0.3 and 0.7 and find that 0.3 is the value that gives us the highest maximum likelihood estimation.

Furthermore, we use gird search to get parameter $\Delta\, y^T$ that proved to be difficult to estimate. We take an interval of sensible values between 0.75 and 1.25 and find that 1 gives us the highest maximum likelihood value.

Finally, we use the grid search method to find the relations between variances. We assume that the cycle is at least 50% more volatile as a trend up to 2.5 as volatile as a trend (the relation between 1.5 and 2.5). With grid search we find that gap is 50% more volatile than a trend (relation is 1.5). Grid search also gives us an indication that relation between σ_ε^2 and σ_η^2 is 1.5, which has a different interpretation than before-mentioned result. In this case, if we restrict σ_ε^2 to 0, it means that inflation must be fully explained by the Phillips curve and the output gap. The more volatile the inflation is, the higher should σ_ε^2 be, so that the inflation's volatility does not directly translate to the output gap volatility. However, this variance should not be too high, because that would mean that all the information from the inflation would end in σ_ε^2 and there would be no impact of inflation on the output gap. With this in mind we restricted the σ_ε^2 to be between 1.5 and 3.

For the univariate filter we only present the results for the pre-crisis period, because the model does not manage to incorporate the changes the crisis brought due to its simplicity. In case of the bivariate filter we insert the estimated values and relations from the pre-crisis period in the model for the whole sample to get the final results.

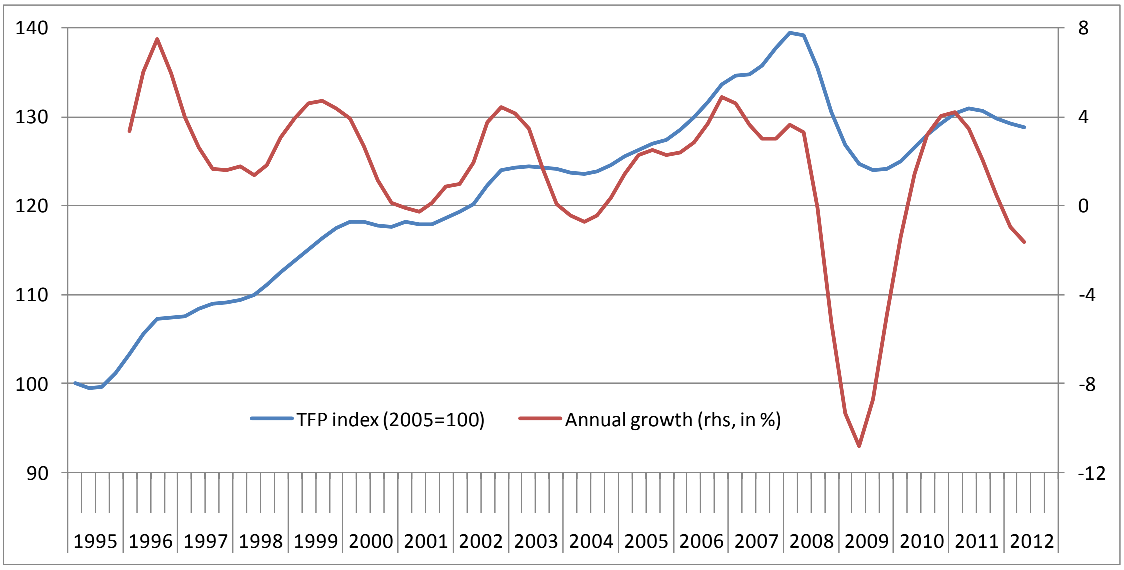
5.2. TFP

We also present the results of TFP fluctuations, which is the missing component of GDP according to the production function approach, that needs to be estimated with Equation 19. In Figure 7 below we present its level expressed as an index, where 1995=100, together with its annual growth rates.

We can observe an upward trend in the TFP level, while its annual growth rates indicate a cyclical movement of TFP. We detect five periods when TFP growth dropped significantly. In 1998 it reached 2%, in 2001 it fell to 0.2%, in 2004 to -0.3, in 2009 to -8.5 and finally in 2012 to -1.3. Between those drops, TFP has grown on average by 4.1% in 1996- 997, followed by 3.2 percent in 1999-2000, in the period 2002-2003 it grew by 2.6%, between 2005 and 2008 by 2.4% and finally by 2.2% in the period 2010-2011.

We can see that TFP growth varies a lot, which comes from the fact that it is calculated as a residual from the production function and as such reflects movements in GDP, physical capital stock and employment. We can also observe that TFP growth has slowed down throughout the observed period. Higher growth at the beginning of the period was probably the result of higher GDP growth, which was the consequence of fast restructuring after the country became independent. TFP growth was also affected by the chosen capital series, according to which the contribution of capital grows due to the capital deepening process, and consequently the contribution of TFP as a residual falls.

Figure 7: TFP level expressed as an index (1995=100) and TFP annual growth rates in Slovenia from 1995 to 2012



Source: Author's calculations.

5.3. Potential output and the output gap

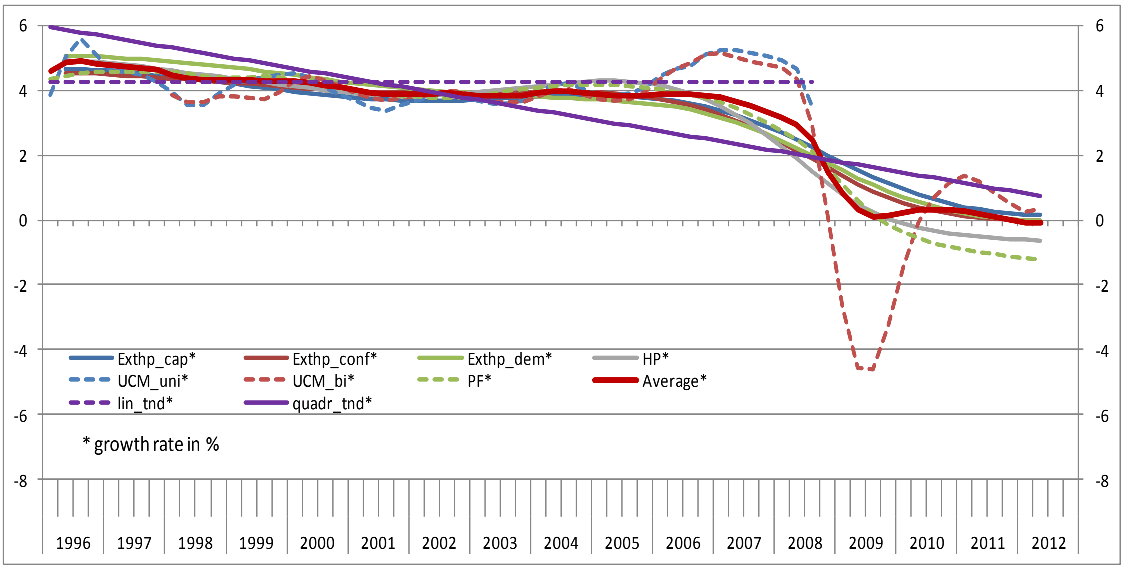
Figures 8 and 9 show the results of nine different estimates of the growth rates of potential output and ten[32] different estimates of the output gap and their average for Slovenia for the period from 1995 to 2012[33].

From Figure 8 we can see that growth rates of potential output estimated with different methods do not diverge significantly. The average potential output growth was around 4% before the crisis has hit the economy at the end of 2008. It turned negative in 2009 and then stabilized at around 0%.

[32] In the case of the band-pass filter we only get cyclical series as an output. What the band-pass filter does is that it eliminates higher and lower frequencies than specified from the data and therefore, the difference between original series and the cycle does not give us the potential output.

[33] Estimates of linear trend and univariate unobserved components model are only sensible for the pre-crisis period due to reasons mentioned above.

Figure 8: Potential output annual growth rates, estimated with eight different methods and their average, in Slovenia from 1996 to 2012



Notes: Exthp_cap, Exthp_conf and Exthp_dem stand for the extended HP filter with capacity utilization, manufacturing confidence and the shortage of demand, respectively. HP stands for the HP filter. UCM_uni and UCM_bi stand for the univariate and bivariate unobserved components models, respectively. PF stands for the production function method, lin_tnd stands for the linear trend, quadr_tnd for the quadratic trend and average represents the average of growth rates of potential output from nine methods

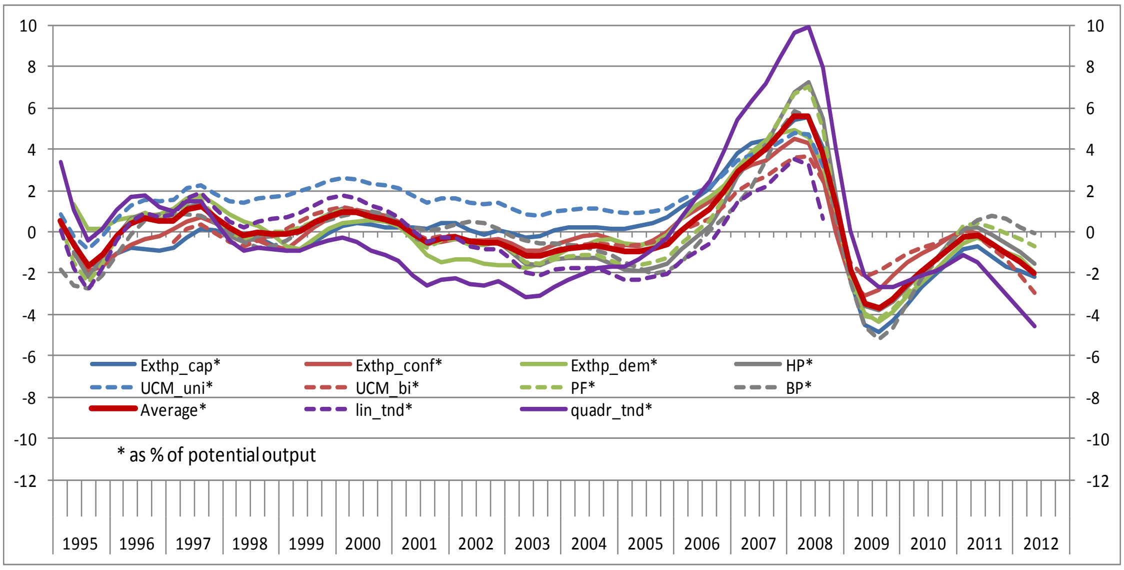
Source: Author's calculations.

In Figure 9, we see that the output gap was on average positive in the periods: 1996Q2-1998Q2, 1999Q2-2001Q1 and 2006Q1-2008Q4 and negative otherwise. This corresponds to inflationary movements: during periods of a negative output gap inflation was decreasing while during the periods of the positive output gap, inflation was increasing. For some years there has been some variation in the magnitude of the output gap estimates generated by different methods. However, most of the time majority of estimates follow the same cyclical movements.

If we comment more carefully on the most recent period, we can observe that the gap was the highest in the last expansion (2006-2008), and its fall is the deepest in the period following it. For the last recession, the majority of methods[34] show that the output gap has a shape of "W", in a sense that the output gap was already closing in 2010, but then started to widen again in 2011 and 2012.

[34] The exceptions is the output gap estimated with the band-pass filter, which shows closing of the output gap after 2009.

Figure 9: The output gap in Slovenia, estimated with nine different methods and their average, from 1995 to 2012



Notes: Exthp_cap, Exthp_conf and Exthp_dem stand for the extended HP filter with capacity utilization, manufacturing confidence and the shortage of demand, respectively. HP stands for the HP filter. UCM_uni and UCM_bi stand for the univariate and bivariate unobserved components models, respectively. PF stands for the production function method, BP stands for the band-pass filter, lin_tnd stands for the linear trend, quadr_tnd for the quadratic trend and average represents the average of output gaps estimated with ten methods
Source: Author's calculations.

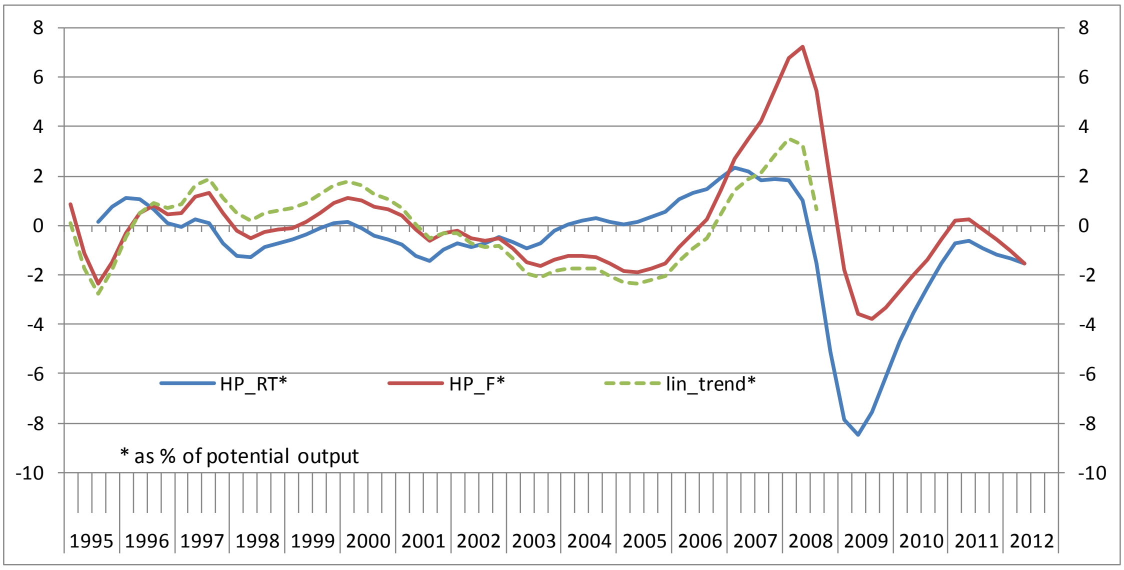
Estimates of potential output and the output gap in the period of the crisis may change substantially over time as additional data become available. This is clearly seen in Figure 10, where final and real-time estimates of HP filter are presented. One of the main drawbacks of the HP filter is the well- known end-of-sample bias and therefore also the linear trend estimation is included in the graph for comparison[35]. The biggest difference between the final and real-time estimate can be observed in the year 2008 and in the beginning of 2009. In real time output gap was estimated to be positive in the period from 2006 until the first half of 2008 with the peak a little over 2%, while linear trend estimates suggest the peak of 3.5%. Real-time estimates thus did not suggest such a large overheating of the economy as indicated by final estimates.

An insightful illustration of how misleading output gap methods may be is the 2008 episode. In Figure 11, we present changes in the size of the output gap for the second quarter of 2008 estimated with HP filter. For comparison we include European Commission estimates for 2008 from its spring and autumn European economic forecasts[36]. The output gap in the

[35] This estimate is only sensible for the pre-crisis period as mentioned above.
[36] European Commission only estimates output gap on a yearly level and uses the production function as a method of estimation. For more information on the method see Denis et al. (2006).

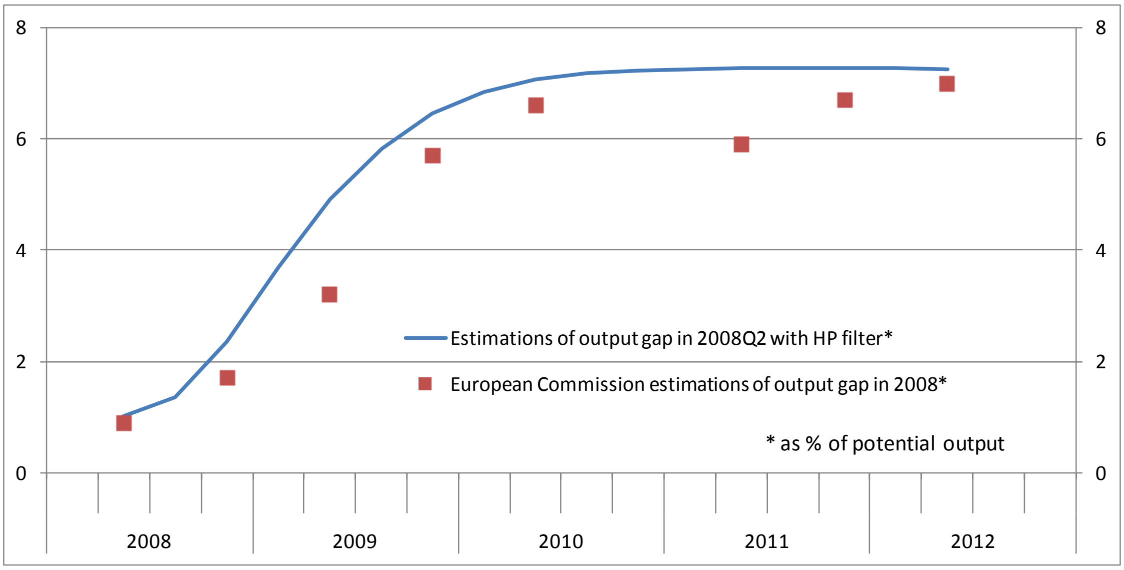
second quarter 2008 measured with the data up to that period amounts to a little over 1%. When data for additional quarters become available, the output gap for that period widens further, exceeds 7% in the second quarter of 2010 and stays above that level until the end of the analysed period. European Commission estimates show a very similar movement. This is expected due to the fact that the HP filter serves as the main de-trending method in the production function approach, used by the Commission. Similarity of the estimates proves that uncertainty is presented on a global level in crisis times.

Figure 10: The output gap in Slovenia, estimated with linear trend and the HP filter real-time and final estimation, from 1995 to 2012



Notes: HP_RT stands for the HP filter estimation in real time, HP_F stands for the final HP filter estimation and lin_trend stands for the estimation with the linear trend method.
Source: Author's calculations.

Figure 11: Estimations of the output gap for the 2nd quarter of 2008 with the HP filter and the European Commission estimates for 2008 estimated in each period, starting in 2008Q2 up to 2012Q2



Source: Author's calculations, the European Commission.

5.4. Growth accounting

In Table 2,[37] the growth rate of potential output from 1996 to 2014 is divided into its contributions, estimated from annual data. We can see that TFP was on average a leading source of potential GDP growth in the period 1996-2008. Development of the trend total factor productivity is seen as critical for the evaluation of the supply-side performance[38]. However, it has to be taken into account that TFP`s contribution is calculated as a residual and it may be therefore incorrect to conclude that real GDP was growing due to improved technological progress. Conversely, in the crisis, TFP was the component, that fell most notably in absolute terms.

An important contributor to a relatively high potential output growth was also the capital. It was growing together with TFP, which signals that the investment activity was effective. The contribution of capital has been relatively stable at around 1.5 until the 2006 and has grown even further by 2008. In the crisis, its contribution fell below 1 percentage point and even approaches 0 in 2014. This downward shift may come about through the adjustment of excess capacity which accumulated before the crisis. In Slovenia that is especially relevant for the

[37] When we report our estimates to ECB, we take these estimates as a base and then adjust them with our expert opinion.

[38] In a growth accounting exercise, the contributions of factors do not identify the ultimate sources of growth. In theory, changes of capital are endogenous to technological change, so the contribution of technology in growth accounting underestimates the full effect of technological change on output. For more details see Barro and Sala-i-Martin (2004).

construction sector. In crisis times, investment fail to substitute the depreciation of existing capital and therefore its contribution started to fall. Investment can stay depressed over the longer run, since the crisis has depressed current and expected profits over a protracted period and led to increases in risk premium. Additionally, the supply of credit has become constrained, which results in tighter lending standards and higher effective borrowing costs (ECB Monthly Bulletin, July 2009, January 2011).

Table 2: Estimates of potential output growth in Slovenia, from 1996 to 2014

	1996-2000	2001-2005	1996-2008	2006	2007	2008	2009	2010	2011	2012*	2013*	2014*
Potential output growth	4.26	3.63	3.68	3.02	2.88	2.51	1.17	0.48	0.07	-0.24	-0.36	-0.41
Contributions												
TFP	2.39	1.66	1.74	1.03	0.78	0.53	0.33	0.22	0.15	0.12	0.10	0.10
Capital	1.40	1.46	1.51	1.61	1.86	1.90	0.95	0.53	0.33	0.14	0.07	0.03
Labour-of which	0.47	0.52	0.43	0.38	0.24	0.07	-0.11	-0.27	-0.40	-0.49	-0.53	-0.55
- working age population				0.06	0.06	0.04	0.03	0.01	-0.01	-0.03	-0.04	-0.04
- labour force part. rate				0.07	0.05	0.02	-0.01	-0.05	-0.08	-0.09	-0.10	-0.10
- unemployment rate	0.14	0.09	0.07	-0.01	-0.07	-0.14	-0.23	-0.33	-0.41	-0.49	-0.56	-0.62
residual**				0.25	0.20	0.15	0.11	0.10	0.10	0.12	0.16	0.21

Source: Author's calculations.
Note: * To calculate potential output growth and its contributions from 2012-2014 we use projections from Price Stability Report (Bank of Slovenia, October 2012). ** Residual comes from the fact that labour sub-component no longer add to labour component, due to the fact they are filtered and of different length.

The contribution of trend labour input to potential GDP growth has been relatively stable around the average 0.5 in 1996-2008. After 2005 it started decreasing faster, and turned negative in 2009. In times of crisis, large increases in unemployment and the downsizing of some sectors may lead to a loss of work-related skills and experience which increase the level of structural unemployment. This is somehow captured in the increasingly negative contribution of potential unemployment rate, and the increasingly negative contribution of participation rate (ECB Monthly Bulletin, July 2009, January 2011). Another component that contributed to the decrease of potential labour component was the lower and from 2011 the negative contribution of the potential working age population, which is the effect of ageing of population.

These results can be an important indicator to be taken into account in the design of policies that could enhance the growth potential of Slovenia. The prediction of sources of potential GDP growth up to 2014 show small contributions of capital stock and even negative contributions of employment. Also the TFP contribution is expected to be depressed until the end of the projection period, which implies very little technological improvement in these years.

The longer-term effects of the crisis very much depend on the flexibility of the economy and the policy reaction to the crisis. If the crisis triggers more structural reforms, making labour and product markets more flexible and competitive, this can strengthen productivity growth in the long run and can be achieved by facilitating appropriate wage-setting and enhancing labour mobility across sectors and regions. Fostering competition and strengthening investment incentives would also speed up the process of restructuring and boost productivity. Structural reforms are supposed to have a positive effect on the output growth in the medium and long run, but could have a negative effect in the short run. Therefore, they have to be combined with supportive macroeconomic policies in order to not depress growth even further, e.g., Barkbu (2012). However, irrespective of the crisis, the ageing population will have a dampening effect on future potential output growth. So in any case structural reforms in combination with supportive macroeconomic policies are needed to maintain the higher growth rate of potential output than the euro area average until the catching-up process is complete (ECB Monthly Bulletin, July 2009, January 2011).

6. Conclusion

In order to analyse the growth potential of Slovenian economy, we estimate potential output and the output gap using several methods. We use two different approaches: statistical methods and the production function approach. We find that the dynamics of the output gap is fairly similar among all employed methods. On average the output gap was positive in the periods of 1996-1997, 1999-2001 and especially 2006-2008, and negative otherwise. The production function approach also allows us to calculate contributions of different determinants to potential output growth. TFP was a leading source of potential GDP growth on average in the period 1996-2008. In the crisis, however, its contribution fell most notably. Also the contribution of capital has been relatively high prior to the crisis and has decreased considerably in the crisis. Meanwhile, the labour contribution has been the lowest of all factors and has even turned negative in the last years. Results we get from the growth accounting exercise are an important indicator when proposing policies that could enhance the growth potential.

Due to uncertainty related to the measure of the output gap, a particular caution is required when drawing policy conclusions based on these estimates. Especially in the case when large structural changes happen, a forward-looking stability-oriented monetary policy has to take into account all available sources of relevant information that indicate the size and the sign of the output gap. In the current financial and economic crisis large downward swings in potential output growth have taken place and if we also take into account the future downward effect on potential output due to demographic developments, structural economic reform efforts are needed more than ever to support a lasting increase in production and employment. Reforms should be complemented by policies to boost demand, since gains from structural reforms take time to materialize.

Annex 1: Assessment of the extended HP filter in "quasi-real" time: comparison to the ordinary HP filter

We apply the extended HP-filter to GDP in combination with the following cyclical indicators: capacity utilisation, the shortage of demand and manufacturing confidence. Then we compare those estimates with the ordinary HP filter by comparing the end-point reliability of trend-cycle decompositions. To do that we need to generate vintages of trend-cycle estimations by cutting the sample artificially at each quarter starting at 1995Q4 and estimating the trend and the cyclical component for each of those samples. At the end we obtain for each period between 1995Q4-2012Q2 one end-point estimation of the cyclical component and the trend, those are so-called quasi[39] real-time estimations.

We compare the quasi real-time results (in the following referred as real-time results) with the quasi-final results (in the following referred as final results), which correspond to the trend and cycle components obtained with the full sample. Several indicators can be calculated to do so.

The first one is the regression of the final on the real-time cyclical component, as proposed by Rünstler (2004). The results from this regression indicate how much are the real-time cyclical components $\bar{Y}^C$ related to the "true" (the final) ones, Y^C:

$$Y^C = const + \bar{Y}^C b + u \qquad \text{(A1)}$$

End point reliability implies b = 1 and const = 0 to hold, which would mean that the real-time cyclical components are broadly in line with the "final" cyclical components (Mohr, 2005).

Table A1 presents the outcomes of this real-time regression applied to the cyclical components obtained with the extended and normal HP filters, together with the p-value for the Wald (F) test of the joint hypothesis b = 1 and const = 0. Also other standard indicators such as the root mean square error (RMSE), the mean absolute percentage error (MAPE), Theil's inequality coefficient and the coefficient of correlation between the real-time and final cyclical component[40] are reported in this table.

Results in Table A1 show that in the case of b parameter, the extended HP filters outperform the standard HP filter (b is closer to 1). If b is lower it means that the GDP gap tends to be underestimated in real-time. It should be noted, however, that the joint hypothesis of b = 1 and const = 0 is rejected for both types of filters. The error measures, in particular Theil's unit free inequality measure, show that the extended HP filters outperform the standard HP filter.

[39] "quasi" because we do not take into account data revisions.

[40] Theil's inequality coefficient is calculated as follows: $\sqrt{(MSE/(\frac{\sum(\bar{Y}^C)^2}{N} + \frac{(Y^C)^2}{N})}$, where MSE denotes the mean squared error. The coefficient takes the value between 0 and 1, with values closer to unity indicating less equality. For further details see Maddala (1977).

Furthermore, in terms of correlation of the real-time with the final cyclical component (ρ), the extended HP filters (with ρ being closer to unity) outperform the standard HP filter, which has the value of ρ of about 0.5.

Table A1: Real-time assessment of the HP filter and the extended HP filters

Filter	Indicators		Regression	
Standard HP-filter	**RMSE**	2.254	**const.**	0.475
	MAPE	1.844	*Std. error*	*0.489*
	THEIL	0.510	**b**	0.519
	Correlation	0.528	*Std. error*	*0.160*
			F-test	#0.000
Extended HP-filter with capacity utilization	**RMSE**	2.149	**const.**	1.137
	MAPE	3.499	*Std. error*	*0.454*
	THEIL	0.449	**b**	0.714
	Correlation	0.776	*Std. error*	*0.118*
			F-test	#0.000
Extended HP-filter with shorage of demand	**RMSE**	1.820	**const.**	0.661
	MAPE	1.888	*Std. error*	*0.384*
	THEIL	0.420	**b**	0.660
	Correlation	0.735	*Std. error*	*0.122*
			F-test	#0.000
Extended HP-filter with manufacturing confidence	**RMSE**	1.440	**const.**	0.436
	MAPE	3.584	*Std. error*	*0.260*
	THEIL	0.395	**b**	0.593
	Correlation	0.782	*Std. error*	*0.116*
			F-test	#0.000

Source: Authors' calculations.

Another important feature of real-time assessments of the cycle is the behaviour around business cycle turning points. Errors in the real-time detection of the ”true” turning points might lead to a misdiagnosis of the current situation. The extent the different approaches to trend-cycle decomposition are prone to errors in the detection of turning points can be assessed by inspecting the number of cases with positive and negative signs of the real-time and the final cyclical components on the basis of the classification shown in Table A2.

Table A2: Reliability of signs of real-time cyclical components

Sign of		final cyclical component +	final cyclical component -	Sum
real-time cyclical component	+	N_{++}	N_{+-}	$N_{+.}$
	-	N_{-+}	N_{--}	$N_{-.}$
Sum		$N_{.+}$	$N_{.-}$	$N_{..}$

Source: (Mohr, 2005).

- First, the relative share of wrong signs $(N_{+-} + N_{-+})/ N_{..}$ is calculated.
- Second, the information content (IC) measure defined as $N_{++} /(N_{++}+ N_{-+})+ N_{--} /(N_{--}+ N_{+-}) – 1$ is computed. It takes values between -1 and 1. Values in the range $0 < IC \leq 1$ indicate a positive information content, IC = 1 means that the signs of cyclical components in real-time and final estimates coincide perfectly. And finally, if $-1 \leq IC < 0$ there is a systematic bias in the sign of the cyclical component in real-time.
- Third, the cell counts can be compared with the expected cell counts under the zero hypothesis that they are random: $E(N_{ij}) = N_{i.} \cdot N_{.j}/N_{..}$. The zero hypothesis can be tested using the following test-statistic $\sum(N_{ij} - E(N_{ij}))^2/E(N_{ij}) \sim \chi^2(1)$ (Mohr, 2005).

Table A3: Sign-test of the cyclical component in real-time derived with the standard and the extended HP filters

Sign real time cycle Sign final cycle	+ +	+ -	- +	- -	Wrong sign	Information content	Test statistic	p-value	Signifi-cance
Standard HP-filter	12	12	15	28	0.40	0.14	1.46	0.23	
Extd. HP-filter with cap.util.	7	3	27	30	0.45	0.12	1.74	0.19	
Extd. HP-filter with short. of dem.	10	4	20	33	0.36	0.23	5.08	0.02	**
Extd. HP-filter with man. conf.	13	8	11	35	0.28	0.36	9.05	0.00	***

Source: Authors' calculations.

In Table A3 results of the abovementioned tests are reported, together with the number of cases of congruent and non-congruent signs as well as the shares of cases in which the real-time cyclical component of GDP gives wrong signs. We can see that none of the filters has a negative value for the information content measure – it is positive for all filters, though relatively low. Therefore, the signs of the real-time cyclical components cannot be regarded as biased. The extended HP filters with the shortage of demand and manufacturing confidence do better than the standard HP filter according to this criterion, since the information content measure is between 0.2-0.4. The extended HP filter with capacity utilization performs similarly as the HP filter, with the value of information content between 0.1 and 0.2. When comparing the share of wrong signs, the extended HP filter with capacity utilization does the worst, with the share of 0.45, the standard HP filter follows with 0.4 and the extended HP filters with the shortage of demand and manufacturing confidence do best in this case, with the share of 0.36 in the former and 0.28 in the latter. Finally, in the case of the standard HP filter and the extended HP filter with capacity utilization zero hypothesis that the expected cell counts are random, cannot be rejected.

All in all, the results confirm that the extended HP filters produce more reliable trend-cycle decompositions than univariate filter approaches. In the case of the extended HP filters with the shortage of demand and manufacturing confidence the pseudo real-time exercise suggests that the trend component is less prone to pro-cyclical bias and that the detection of turning points in the cyclical component is improved. On the other hand, the improvement is not so clear, when we compare the standard HP filter with the extended HP filter with capacity utilization. This suggests that indicators of the shortage of demand and manufacturing confidence should be accounted for when estimating potential output and the output gap, while in the case of capacity utilization the reason for inclusion is less persuasive.

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