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ESTIMATE OF POTENTIAL GROSS DOMESTIC PRODUCT USING THE PRODUCTION FUNCTION METHOD

CONTENTS

SUMMARY

This study is concerned with the calculation of potential GDP using the production function. The production function method is a structural approach to calculation of potential output and it is based on economic theory. The Cobb-Douglas function has been selected as the production function model. Potential GDP has been calculated by two methods. In the first, potential GDP has been calculated using estimated elasticity of labour and capital, while in the second approach potential GDP was calculated using the income-based share of labour and capital in gross value added. In both cases, potential GDP was obtained as the sum of potential technology (Solow residual trend), potential employment level and actual gross capital stock.

The basic outcome of this research is estimated elasticity of GDP with reference to labour and capital. The difference between the estimated models is the result of the assumed technological development over time and restriction of parameters. Under both models, labour elasticity of approximately 0.80 was obtained both under the assumption of constant returns on scale and when no such assumption was applied. We therefore conclude that the selected series in the production function model for Croatia will generate precisely this result, until a theoretically more justified series of labour and capital inputs is constructed. The estimated elasticity of labour has been overvalued in comparison to our national accounts, where the income-based share of labour during the 1997-2003 period was 0.64, and 0.36 for capital.

The level of potential GDP obtained using the production function approach was compared to actual GDP so that an analysis of cyclical economic trends could be conducted and the status of macroeconomic policy in the preceding period could be assessed. The GDP gap—defined as the difference between actual and potential GDP—that resulted from the production function was compared with the gap obtained using certain simple statistical techniques.

1. INTRODUCTION

There are a number of definitions of potential output, and an equally number of methods to quantify it. According to the so-called technical definition, potential output is the level of production where factors of production are completely utilised at the given level of technology. Over the long run, potential output reflects the optimum potential supply of an economy and facilitates an estimate of non-inflationary growth. Over the short run, the difference between actual and potential output is reflected in the balance between supply and demand and the potential impact of economic growth on macroeconomic stability indicators, including inflation.

From the purely statistical point of view, potential output can be viewed as a trend or a smoothed component of actual production series. Alternatively, if we wish to bring economic reason into the definition, potential output reflects the possibilities of an economy's aggregate supply that are determined by the level of technology and available inputs (European Central Bank, 2000). According to the definition of the OECD, for example, potential output means the level of production that is consistent with stable inflation over the medium term[1]. This concept of potential output is linked to the emphasis on controlling inflation that is a key priority over the medium term.

The objective of monetary policy in many countries is to maintain a low and stable inflation rate. In this context, measurement of potential output and its growth rate is vital. Growth of potential output and the output gap can be very useful indicators in assessing inflationary pressures over the short and medium term. For those formulating economic policy, it is crucial to be able to observe on time whether potential output growth rate has changed. If capital and labour force trends are relatively stable, the variability of potential output growth will be small (European Central Bank, 2000).

Potential output is not a directly measurable variable and it must therefore be estimated using statistical and theoretical methods. There is a wide range of empirical methods for measuring potential production, beginning with analysis of time-series data and trend-based analysis to more complex assessments based on the production function and production-factor demand equations. In this study, potential output is calculated on the basis of the production function. The most common structural method to estimate the production function is the Cobb-Douglas function[2]. Since the Cobb-Douglas production function is easily expressed in linear form, which is then easy to estimate, the use of this function is still very popular.

This study is structured so that in the second section GDP is explicitly modelled in factor input terms, i.e. with regard to technology, labour and capital. Among the several models assessed, the most acceptable were selected and their elasticity has been employed to calculate potential GDP. Additionally, potential GDP was also calculated using the income-based share of labour and capital in gross value added derived from the national accounts. In the fourth section a comparison is made between the GDP gap obtained using the two preceding methods and the GDP gap obtained using some simple statistical detrending techniques. The principal results are subject to comment in the conclusion.

The motive underlying this research is the need to model the Croatian economy's supply side and the need to forecast GDP values for increasingly longer periods. There is also a better

[1] Torres and Martin (1990), p. 129.
[2] Cobb C. W. and P. H. Douglas (1928).

statistical basis for factor inputs, particularly capital, than there was in previous years. Measurement of potential output plays a vital role in various economic models because it is useful in distinguishing between medium-term trends and short-term cyclical trends in the economy. The output gap is, for example, used to obtain estimates of a cyclically adjusted state budget. It is also used to monitor the progress of international competitiveness, where the output gap is employed to calculate the real exchange rate based on cyclically adjusted labour unit costs. Additionally, much research dealing with the impact of the GDP gap on the national economies of industrial countries responds to the question of how inflation responds to the GDP gap.

2. ESTIMATE OF THE PRODUCTION FUNCTION FOR CROATIA

2.1. Method

There are a number of methods to estimate potential output that are normally categorised into two groups: statistical and structural. In the first group, the production series is divided into the trend and cyclical components. The structural method constitutes an attempt to create an explicit supply model for a given economy relying on economic theory. Among the structural methods, the production function method has a special place. The production function can assume different forms, but most often the Cobb-Douglas functional specification is used.

The Cobb-Douglas functional formula represents a link between output and production inputs:

$$Y_t = A_t L_t^{\alpha} K_t^{\beta}, \qquad (2.1.1)$$

where Y is aggregate output, L is labour input, K is capital input, A is the level of technology and efficiency of its use, α and β represent production factor elasticity given labour and capital, while t stands for time. If the sum of elasticities is one, $\alpha + \beta = 1$, the production function generates constant returns on scale. Or, stated mathematically, the production function should be linearly homogenous. This is the standard production function case, so instead of parameter β, the parameter $1-\alpha$ is written. If the sum of elasticities is less than one, $\alpha + \beta \langle 1$, the production function generates decreasing returns on scale, while if this sum is greater than 1, returns are increasing.

Logarithmic linearization simplifies the function and provides for clear separation of coefficients. Using logarithmic transformation, the Cobb-Douglas function assumes this form:

$$\ln Y_t = \ln A_t + \alpha \ln L_t + \beta \ln K_t. \qquad (2.1.2)$$

Total factor productivity, also known as the “Solow residual”, is obtained directly from equation (2.1.2)

$$tfp = \ln(A_t) = \ln Y_t - \alpha \ln L_t - \beta \ln K_t. \qquad (2.1.3)$$

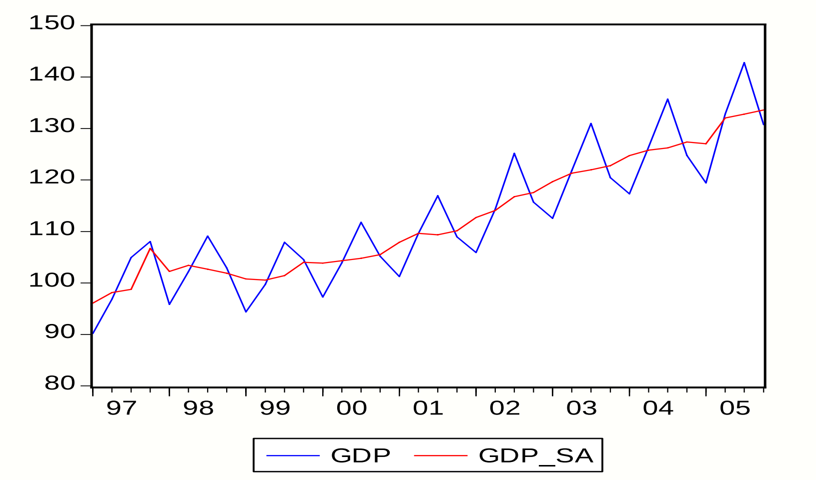
This means that total factor productivity is determined by the difference between actual output and the weighted average of production factors. To obtain the most accurate possible estimate of total factor productivity, correct measurement of labour and capital inputs is required.

2.2. Data

The production function has been estimated for the 1997-2005 period based on quarterly data. The shortcomings in the completed research refer to first and foremost to the short period in which the link between overall output in a given economy and the most important production inputs are determined. Normally, such an analysis is applied to a much longer period and data with annual frequency. Output variable has been approximated using gross domestic product, labour input is shown through a series of employment figures, and capital input was obtained using a series of gross capital stock figures.

Chart 1 shows trends in original and seasonally adjusted real GDP values. The gross domestic product series has existed since 1997 and it has been revised on several occasions. Data revision raised GDP growth rates in period from 2001 to 2003[3]. Data for 2004 and 2005 are still preliminary.

Chart 1. Gross domestic product
Base index, 1997 = 100



Legend:
GDP – gross domestic product, original data
GDP_SA – gross domestic product, seasonally adjusted data

It is not possible to note any remarkable cyclical regularity in Croatian overall economic activity. Nevertheless, analytical and descriptive purposes required time series division into three parts. An upward trend in economic activity during 1997 and first three quarter of 1998 was followed by depression in 1999. Second part, from the last quarter of 1999 to the third quarter of 2004, was characterized by continual and positive GDP trend. The last part was signed by deceleration of GDP movement.

Croatian economic activity was very dynamic from 1994 to 1997 having growth rates between 5.9 and 6.8 percent. In 1997, GDP grew by 6.8 percent. Due to strong credit activity, main growth contributions came from personal consumption and investment. Exports were supported by growing demand on main foreign trade markets. According to the supply side, growth in 1997 was a result of continual and dynamic positive trends in construction and trade. Tourism, also strongly contributed to GDP growth in 1997.
GDP growth rate slowed down to only 2.5 percent in 1998. Recession tendencies started in the last quarter of 1998. Such reverse developments was a consequence of structural problems in the economy, from privatization and corporate restructuring to inadequate public consumption structure, banking crises, Kosovo' crises and relatively weak economic growth in main foreign trade partners.

[3] Growth rate was increased by one percent point in 2003.

Economic recovery registered in the last quarter of 1999. It was determined by strong personal consumption growth and a slower growth of exports and public consumption. Economic activity in trade, financial and commercial-service sector were strong while it had a negative trend in construction and transport. From 2000 to the end of observed period, growth trend of economic activity continued. Supported by credit activity, remarkable contribution to growth came from personal consumption. Public infrastructure investment improved GDP growth in 2002, 2003 and the first half of 2004. Exports of goods and non-factor services were among major sources of growth as well.

Reduction of investment caused a slowdown in overall economic activity in the second half of 2004. Faster GDP growth in 2005 compared with the previous year was a result of decreased negative contribution of net exports. Weaker personal consumption and investment slowed down domestic demand moderately.

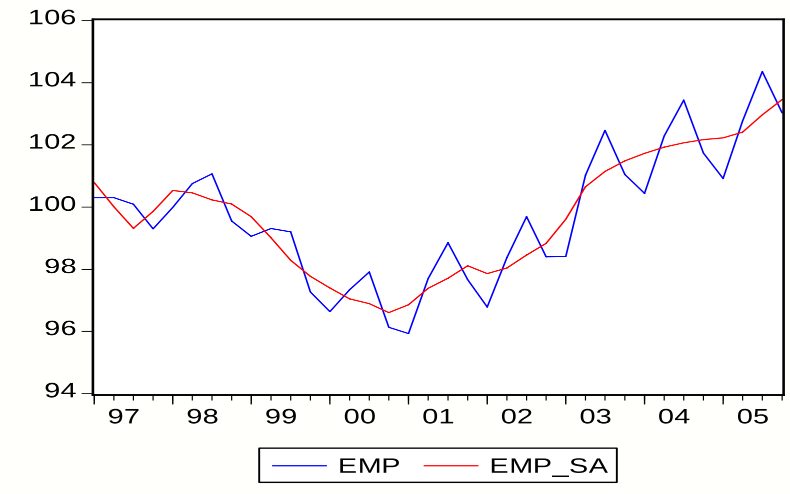
Table 1. GDP growth rates (%)

1997	1998	1999	2000	2001	2002	2003	2004	2005
6.8	**2.5**	**-0.9**	**2.9**	**4.4**	**5.6**	**5.3**	**3.8***	**4.3***

Source: National Bureau of Statistics
* Preliminary data

In this study, data on total employment released by the National Bureau of Statistics was used for labour input. These data include those employed in legal entities, those employed in crafts and trades and free lances and insured persons - private farmers[4].
The economic recession only intensified the declining trend in employment present even earlier. The negative trend was only stopped at the end of 2000.

Chart 2. Employment
Base index, 1997 = 100



Legend:
EMP – total number of employed, original data
EMP_SA – total number of employed, seasonally adjusted data

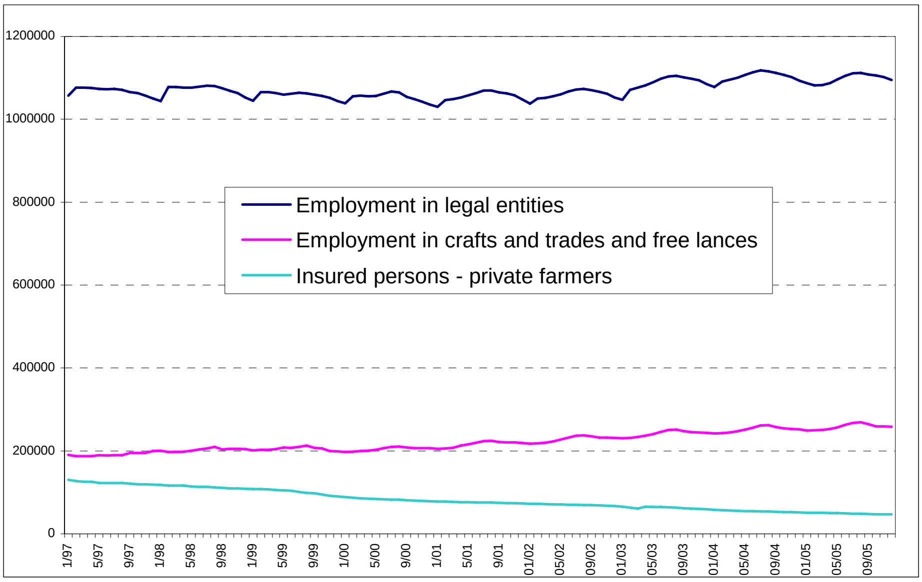
[4] From the standpoint of output analysis, labour input is best measured by total hours worked. This must be a measure that allows for changes in the composition and quality of labour over time. The least recommended labour input measure is the number of employed. However, we only have annual data on hours worked in legal entities, and these data are released with a two-year delay. Monitoring the labour market based on The Labour Force Survey began in 1996, and it has a semi-annual frequency.

Economic recovery leaded to positive trends on labor market just in 2001. After several years of its decline, employment started positive trends towards the end of observed period. Employment growth especially accelerated in 2003. Due to deceleration of overall economic activity as well as some methodological changes employment growth retarded in 2004. Insured persons - private farmers decreased severe during 2004 contributing total employment growth deceleration. Total employment increased 0.8 percent in 2005 compared with the previous year.

Employment in legal entities, with its stable average share of 78 percent, mainly determined development of total employment, but it could not be ignored positive movements of employment in crafts and trades and free lances which increased its share from 13 to 18 percent in observed period. At the same time, permanent declining of insured persons - private farmers was registered.

Employment reduction in agriculture resulted from persons' exclusion from pension insured register due to contribution unpaid, but not necessary from activity failure. In that way, insured persons - private farmers became unreliable indicator of change in total employment. It can be assumed that reduction in share of insured persons - private farmers contributed to average productivity level. Such people are usually less educated and have a low level of productivity.

Chart 3. Total employment components



In Croatia there still are no officially released data on capital stock. A preliminary estimate of capital stock levels for the 1999-2003 period was made by the National Bureau of Statistics. The calculation contains data on gross and net capital stock, gross fixed investments and depreciation. The data were calculated yearly and shown in current prices and in 2003 prices. These data are subject to further adjustment. Gross capital stock in constant prices was taken as the capital input series.[5]

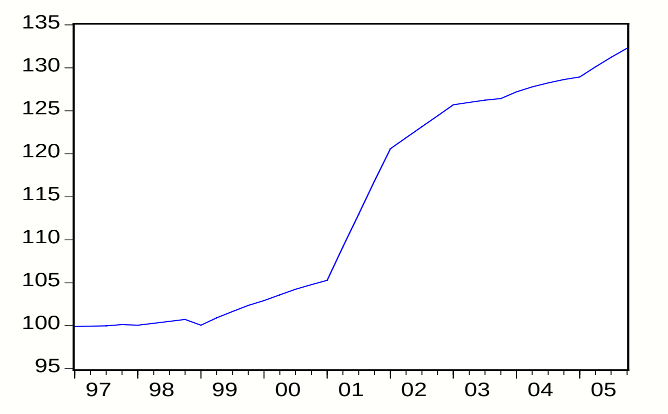
[5] In the context of output theory, it is correct to use the flow of capital services for capital input. Some statistics agencies release the index of capital service volume as aggregate capital services.

Since the production function for the years from 1997 to 2005 is being estimated, the PIM (Perpetual Inventory Method) was used to estimate capital stock in the years in which there is no data. The dynamics of capital stock was updated using this formula:

$$K_t = I_t + (1-\delta)K_{t-1}, \qquad (2.2.1)$$

where K_t is capital stock, I_t is investment in fixed assets and δ is the depreciation rate. Data on investments were taken from the national accounts, while the depreciation rate is equal to the average weighted rate from the capital stock estimate for the 1999-2003 period, which was 3.1%[6]. The depreciation rate is low, regardless of whether it is compared with international numbers or theory[7].

Chart 4. Gross capital stock in constant prices
Base index, 1997 = 100



Due to extremely high road building investment in 2002 and 2003, capital stock level grew very quickly. The series of annual data for capital stock was interpolated into a series with quarterly frequency using the Chow-Lin interpolation method[8]. The fast upward trend of that series started earlier, in 2001. The usefulness of Chow-Lin method in practice depends on the quality of the assumed regression model and the possible finding of a reference series that forms a regression model with a good approximation of reality. The reference series in our case was constructed using cumulated quarterly investment series.

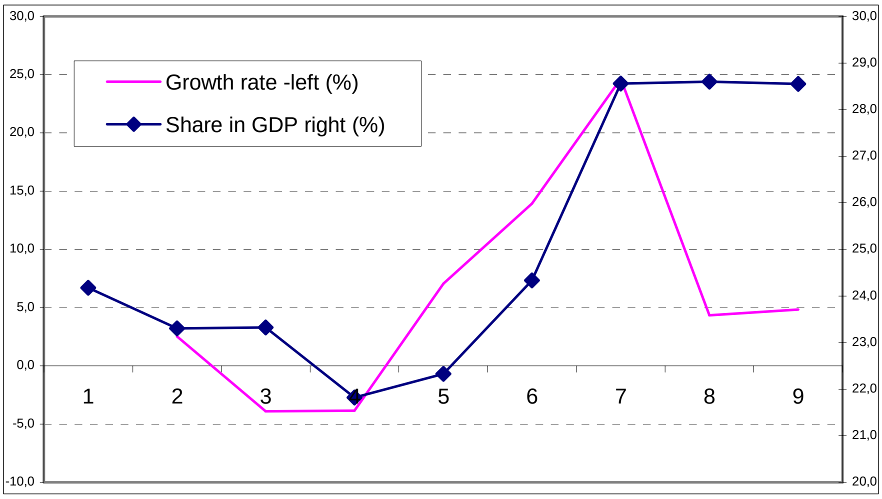
Chart 5 shows the share of investment in GDP and the growth rate in the period under analysis.

Chart 5. Growth rate and share of fixed investment in GDP

[6] The depreciation rate for Croatia is low due to the large share of buildings with low depreciation rates. In research related to Poland, for example, covering roughly the same period, the depreciation rate was 5.5%, and 6.0% for the Czech Republic and 10% for Estonia.

[7] For example, according to Nadiri and Prucha (1993), the depreciation rate of capital stock in the US manufacturing sector was 5.9%.

[8] Chow, G. C. and A.-l. Lin (1971).



In 1999, the positive investment trend that acted as a strong impulse for GDP growth during the post-war recovery years was interrupted. This trend was only reversed at the end of 2000. Positive trends on the demand side and financing conditions encouraged investment in the subsequent years. One of the prime sources of financing for corporate investment was bank loans. Extremely high investment growth rates were achieved in 2002 and 2003. Besides private sector activities, public investment in infrastructure, i.e. highway construction, also increased considerably. Investments declined in the second half of 2004 after the completion of primary works on the Zagreb-Split motorway. Since then their quarterly growth stayed at approximately 5%.

2.3. Estimate

The problem that exists in the original formulation of the Cobb-Douglas function (equation 2.1.1) is the impossibility of change in technology. The standard procedure of incorporating the possibility of technological change is to include the time trend (T). Technological change is encompassed in this manner, even though it is assumed to be exogenous in the specification being estimated.

The Cobb-Douglas function can be reformulated as

$$Y = A(t)L^{\alpha}K^{\beta}, \qquad (2.3.1)$$

where $A(t) = Ae^{\gamma}$. A and γ are constants. γ is the measure of proportional change per period when the input level remains constant (i.e. proportional change in output which occurs as a result of technical progress).

The equation (2.3.1) is generally assessed as

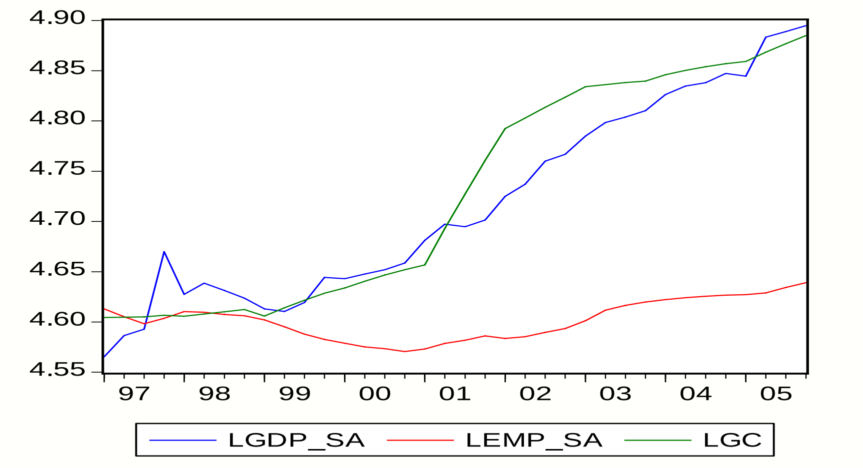
$$\ln Y = a + \gamma T + \alpha \ln L + \beta \ln K + \varepsilon, \qquad (2.3.2)$$

where ε is the error term. To estimate constant returns on scale, it is simply necessary to test the hypothesis on the sum of parameters α and β.

The form of the production function was estimated based on equation 2.3.2. The objective of estimation was to determine the production function parameters, i.e. GDP elasticity with reference to labour and capital. The data related to the 1997-2005 period, with a quarterly frequency. The dependent variable in the model is real gross domestic product, while the independent variables are the number of employed according to administrative sources and the gross capital stock expressed in constant prices. All three variables are expressed in base indices, where the base is the 1997 average.

Estimation was conducted with variables expressed in levels. From the theoretical point of view, cointegration literature indicates the superiority of econometric estimation at levels in comparison to estimation of first differences if the series are not stationary. The seasonal component present in gross domestic product and employment has been eliminated prior to modelling. A natural logarithm was then applied to all series. The logarithmic values of variables in the production function model are shown in chart 6.

Chart 6. Gross domestic product, employment and gross capital stock
Logarithm of seasonally adjusted data[9], 1997 = 100



Legend:
LGDP_SA – logarithm of seasonally adjusted GDP series
LEMP_SA – logarithm of seasonally adjusted employment series
LGC – gross capital stock logarithm

Results of estimates of several alternative production function models for Croatia are shown in Table 2.

Table 2. Estimated production function for Croatia

	Model 1 (linear T, const. returns on scale)	**Model 2 (T^1.5, const. returns on scale)**	**Model 3 (T^0.56, const. returns on scale)**	**Model 4 (linear T, no restrictions)**	**Model 5 (T^1.1, no restrictions)**
Constant	-0.0269 (0.0067)	0.0013 (0.0047)	-0.0657 (0.0158)	-0.7198 (0.7492)	-0.2469 (0.7760)
T	0.0064 (0.0009)	0.0009 (0.0001)	0.0280 (0.0055)	0.0061 (0.0009)	0.0043 (0.0007)
LEMP_SA	0.8023 (0.0908)	0.6940 (0.0806)	0.6399 (0.0988)	0.9341 (0.1691)	0.8385 (0.1668)
LGC				0.2171 (0.0934)	0.2111 (0.0939)
R^2	0.9746	0.9730	0.9626	0.9753	0.9754
$\overline{R}^2$	0.9731	0.9714	0.9603	0.9730	0.9731
Wald test $(\alpha+\beta=1)$				$F_{(1,32)} = 0.8553^*$	$F_{(1,32)} = 0.0860^*$

[9] The X12 method was used for seasonally adjustment and a multiplicative model was selected.

D.W.	1.2630	1.2241	0.8317	1.3110	1.3173

The values in parenthesis relate to the standard errors.
* The null hypothesis on the unit sum of elasticity of labour and capital with significance of 5% cannot be rejected.

The first three models were estimated based on the assumption of constant returns on scale, while there are no restrictions to parameters in the last two models. Furthermore, the models differ in terms of intensity of growth in technological progress over time. In model 1, a constant growth rate was assumed. In model 2 the technology growth rate accelerates with time, while in model 3 this rate slows down with time. The trend exponent in model 2 was selected so that labour elasticity generally corresponds to the practice of developed countries (approximately 2/3). The trend exponent in model 3 was selected so that labour elasticity is equal to the income-based share of labour from the national accounts for Croatia.[10] The average value of this share in the 1997-2003 period was 0.64.
Model 4 resulted in increasing returns on scale and it has the highest labour elasticity. The Wald test of parameter restrictions showed that the null hypothesis on the unit sum of labour and capital elasticity with significance of 5% cannot be rejected. Model 5 is the most similar to model 1, the only difference being the slightly accelerating growth of technology over time. In model 5 one cannot particularly reject the null hypothesis on the unit sum of labour and capital elasticity with significance of 5%.

The trend variable is statistically significant in all models. The Durbin-Watson statistic is lowest in model 3, indicating that residuals are positively autocorrelated or that perhaps considerable explanatory variables in the model were omitted. A positive autocorrelation of residuals is also present in other models, but in lesser extent.

The results of the estimate have shown that direct estimation of the production function can produce α values that greatly differ from the income-based share of labour in gross value added according to national accounts, probably reflecting the fact that the assumption of perfect competition does not apply at the level of a given economy[11].

Model 1 and model 2 were selected to calculate potential GDP in the subsequent section. The values of parameters in model 1 are confirmed by model 5, in which there are no parameter restrictions with a slight variance in the intensity of trend. Model 2 was selected due to the labour elasticity which is present in a large number of countries.
Technology in model 1 assumes the form of a straight line and constant growth rate. The average quarterly growth of technology was 0.64%, and 2.56% annually. Technology in model 2 developed “exponentially” with average quarterly growth of 0.52% and annual growth of 2.09%.

3. CALCULATION OF POTENTIAL GDP

3.1. Calculation of potential GDP using estimated labour and capital elasticity

[10] See section 3.2.
[11] For example, most research shows that the value of labour elasticity in developed countries is approximately 2/3, while capital elasticity is approximately 1/3. In the euro zone, from 1991 to 1997 the contribution of capital growth to output growth was 67%, -13% to employment growth, while the contribution of the factor that relates to productivity, including technology, was 45%.

If inputs are at their potential levels, then the production function provides an estimate of potential output and the output gap. With the Cobb-Douglas specification of the production function, it is essential to estimate the trend of components of individual production factors, except capital. Since capital stock is an indicator of total capacity, there is no justification for smoothing out this series in the production function approach. The maximum contribution of capital to potential GDP is provided with the full use of existing capital stock in the economy. By contrast, it would not be desirable to incorporate current employment into the definition of potential output, because labour input is subject to powerful cyclical fluctuations. Estimation of potential GDP thus requires the elimination of cyclical components from the labour factor and the total factor productivity

Potential GDP can be calculated using the equation:

$$\ln Y_t^{POT} = \ln A_t^{POT} + \alpha \ln L_t^{POT} + (1-\alpha) \ln K_t \,. \qquad (3.1.1)$$

Total factor productivity is obtained using equation (2.1.3) or, alternatively, through the equality

$tfp = c(1) + c(2) * T + e$.

The Hodrick-Prescott filter is applied to a series so calculated to obtain the potential total factor productivity.

When calculating potential employment, a smoothed labour force series was used corrected by the balanced rate of unemployment. The non-accelerating wage rate of unemployment (NAWRU) was selected for the equilibrium rate of unemployment once, while the average rate of unemployment in the analyzed period was selected a second time.
Research has shown that the equilibrium growth rate changes over time, i.e. that it is not constant, although it generally follows the actual rate of unemployment (due to hysteresis and labour market inelasticity). The method specified by Elmeskov and Scarpetta (1999) was used to measure the NAWRU that varies over time. Torres and Martin (1990) showed that the NAWRU approach provides better consistency between the labour market and the commodities market than the non-accelerating inflation rate of unemployment (NAIRU) approach[12].

Potential employment is calculated using this equation

$$L_t^{POT} = LF_t \; (1 - u_t^N) \qquad (3.1.2)$$

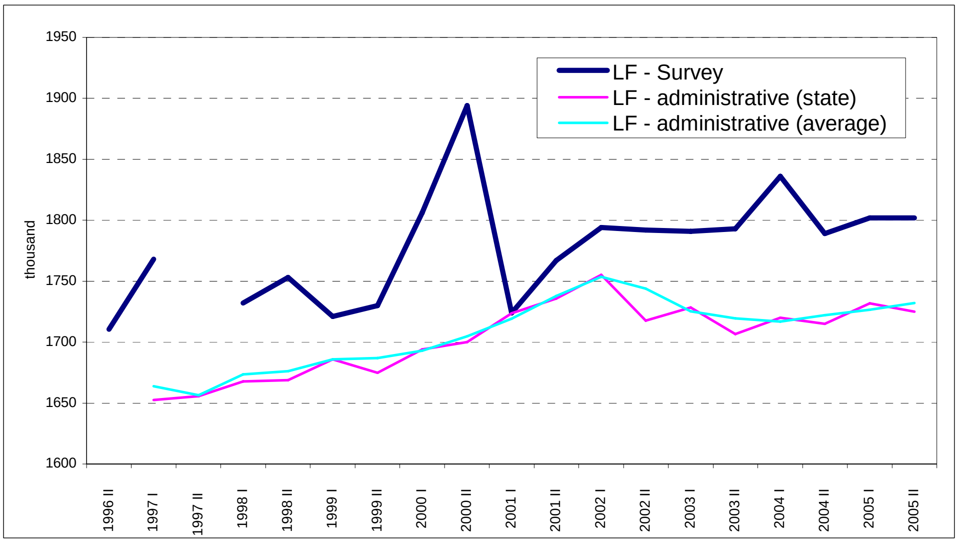
where LF_t is the smoothed labour force (labour supply) series, while u_t^N is the smoothed NAWRU.

The average level of labor force in Croatia according to The Labor Force Survey data was 4.1 percent higher than the level from administrative source data in observed period. Thus, potential labor force from The Survey data was higher compared with the administrative

[12] In the European Commission approach, Denis, McMorrow and Roeger (2002), the definition of the maximum contribution of employment to potential GDP is the employment level consistent with stable inflation (NAIRU) or wages (NAWRU). Potential employment can be obtained from smoothed labour force series derived through use of the HP filtered rate of participation in relation to the working age population. Using a smoothed participation rate that leads to a less volatile labour supply series, potential employment is equal to labour supply minus the NAIRU estimate. One of the great advantages of this approach is that it generates a series of potential employment that is relatively stable, while at the same time it also ensures that year-to-year changes in series are closely linked to long-term demographic trends and labour market trends.

source data. However, it could not be possible to use The Survey data because of its semiannual frequency.

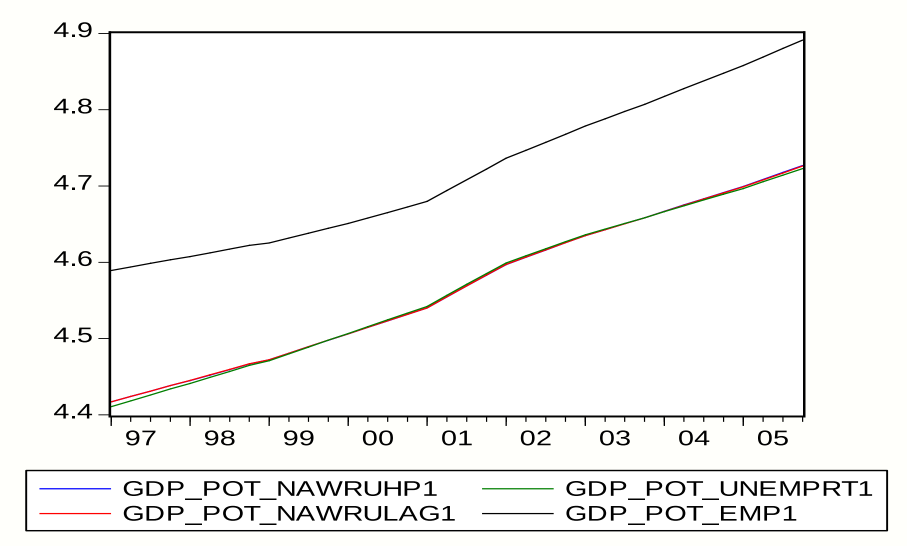
Chart 7. The Labor force according to The Survey and administrative source data



Labor force administrative data was calculated as a sum of total employment and registered unemployment. That series was growing by middle of 2002 even in period of recession. The growth was encouraged by unemployment reaching the highest level in first half of 2002. Employment growth started in the second half of 2001 could not overcome negative tendencies of unemployment up to 2004[13].

Chart 8. Potential GDP based on model 1 structure.

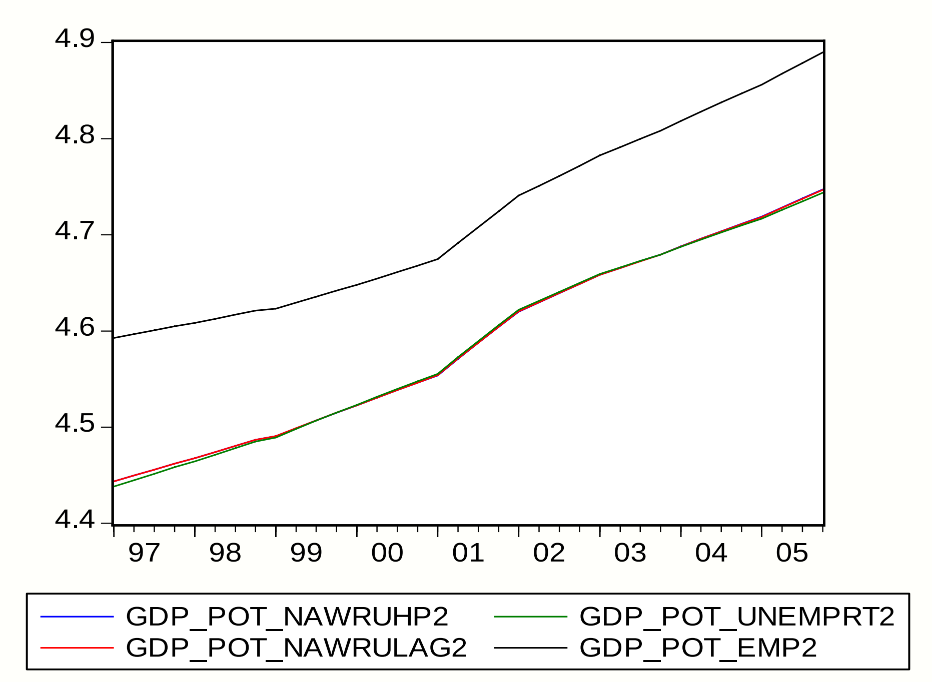
[13] The upward unemployment trend was stimulated by economic activity deceleration, crowded problems in some companies as well as activation of some necessary restructuring processes. Growing trend of unemployment continued despite of recovery of the overall economic activity. The main cause of that attributed to fast companies' restructuring as well as the Croatian legislation for defenders registration in the Croatian Employment Service. A reversed trend of unemployment concured with start of employment intermediation reform carried out in the second half of 2002. Persons who did not satisfy the new criteria were already removed from the register. A quick reduction in unemployment happened during 2003. Such unemployment trend was also a result of positive employment movements, i.e. labor demand reinforcement. A slowdown of economic activity at the end of 2004, connected with investment growth deceleration in transport infrastructure, caused a weak decrease of unemployment. But, downward trend of unemployment continued in 2005. The impact of employment intermediation reform disappeared by the end of 2004.



Legend:
GDP_POT-NAWRUHP1 – Potential GDP where potential employment is calculated with the NAWRU, and where expected wages are derived using the HP filter on real wages
GDP_POT_NAWRULAG1 – Potential GDP where potential employment is calculated with the NAWRU, and where expected wages are shifted real wages
GDP_POT_UNEMPRT1 – Potential GDP where potential employment is calculated with the average rate of unemployment
GDP_POT_EMP1 – Potential GDP where potential employment is calculated using the HP filter on overall employment

The chart shows that the series of potential GDP calculated using the NAWRU concept and the “natural” rate of unemployment almost overlap and that their levels are below potential GDP, the potential employment of which is calculated using an HP filter on overall employment.

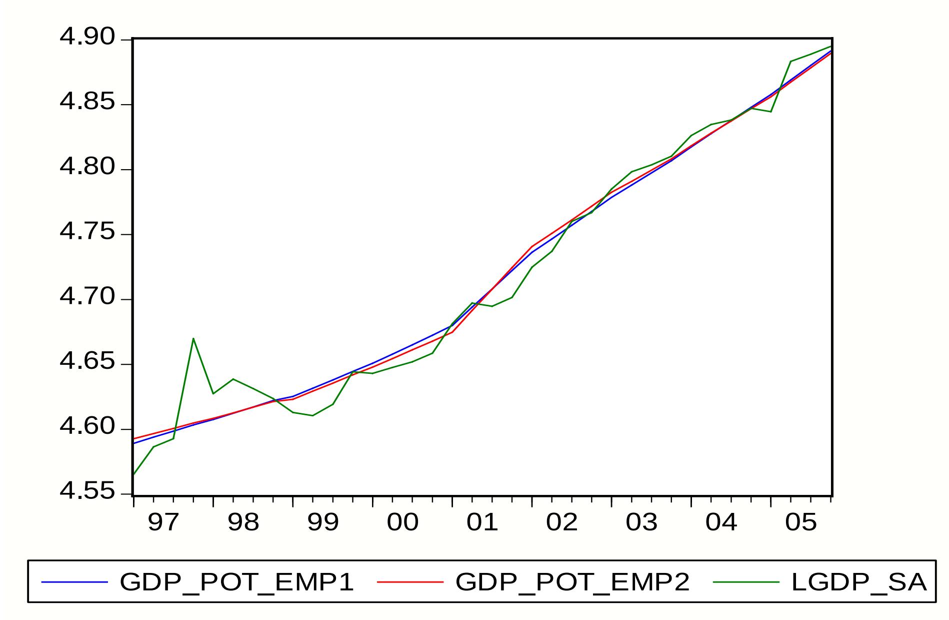
Chart 9. Potential GDP based on model 2 structure.



Legend:
GDP_POT-NAWRUHP2 – Potential GDP where potential employment is calculated with the NAWRU, and where expected wages are derived using the HP filter on real wages
GDP_POT_NAWRULAG2 – Potential GDP where potential employment is calculated with the NAWRU, and where expected wages are shifted real wages
GDP_POT_UNEMPRT2 – Potential GDP where potential employment is calculated with the average rate of unemployment
GDP_POT_EMP2 – Potential GDP where potential employment is calculated using the HP filter on overall employment

The next chart finally shows actual and potential GDP trends according to the different methods.

Chart 10. Actual and potential GDP



Legend:
GDP_POT_EMP1 – Potential GDP where potential employment is the HP filtered number of employed, according to model 1.
GDP_POT_EMP2 – Potential GDP where potential employment is the HP filtered number of employed, according to model 2
LGDP_SA – actual GDP

The potential GDP series where potential employment is a smoothed labour supply series adjusted by the unemployment rate is not shown in the chart because these lines are constantly below the level of actual GDP. Potential GDP calculated using model 1 and 2 is very similar. They show that a cycle with a positive GDP gap can be observed in Croatia at the beginning of the analyzed period, in 1997 and 1998, and negative during the recession period, in 1999 and 2000. During the subsequent period, in fact, the regularity of a cycle cannot be detected, and actual GDP is very close to its potential.

We shall now specify some of the advantages and drawbacks to the production function method in the estimation of potential output. One of the advantages lies in the fact that it is possible to forecast potential output by forecasting its components, which are normally at our disposal. The production function is quite flexible, because it can take into account different assumptions about technology and it can encompass several of the advantages of the new growth theory, such as change in the quality of production inputs.

The basic drawbacks of the production function approach to estimating potential output relate to the data and trends of its input component. Capital stock is normally not quite reliable or there are no data on effective work hours. Major fluctuations in productivity levels and the labour supply make it difficult to liberate total factor productivity and labour supply trends. For example, there are different views of how to model technical progress. Similarly, there are alternative views given the trend level of effective labour supply that depend on resistance on the labour market. Different assumptions about these trend components will lead to very different estimates of potential output.
The Cobb-Douglas production function represents a great simplification of economic reality. Furthermore, it assumes perfect competition on the production inputs market, i.e. the factors are homogenous. When potential output is defined as maximum possible output, the situation

in which actual output exceeds potential output does not exist. This shows that use of capital stock in its entirety is impossible. The Solow residual is a considerable component of the production function, which is computed as the estimated residual and as such it is economically inexplicable and is thus freely interpreted.

The estimate of potential output includes a high degree of uncertainty. This is because it is a variable that cannot be measured. Additionally, potential output depends on variables that cannot be measured, such as the natural rate of unemployment and the capital stock depreciation rate.

3.2. Calculation of potential GDP using income-based share of labour and capital in gross value added

Under perfect competition, where prices of production factors are equal to their marginal product, parameter α from the Cobb-Douglas production function (formula 2.1.1) should coincide with the income-based share of labour in gross value added from the national accounts. The elasticity of capital is then equal to $1-\alpha$.

Since based on Croatia's national accounts we know the shares of income generated by labour and capital in gross value added according to ex-work prices from the 1997-2003 period, we shall use them to calculate one more series of potential GDP. In the subsequent period the average annual income-based share of labour in gross value added was 0.64, while the share of capital was 0.36[14]. In the literature this approach to calculate potential output is known as the growth accounting framework.

With the given value α, total factor productivity is computed as

$$\ln A = \ln Y - \alpha \ln L - (1-\alpha)\ln K, \qquad (3.2.1)$$

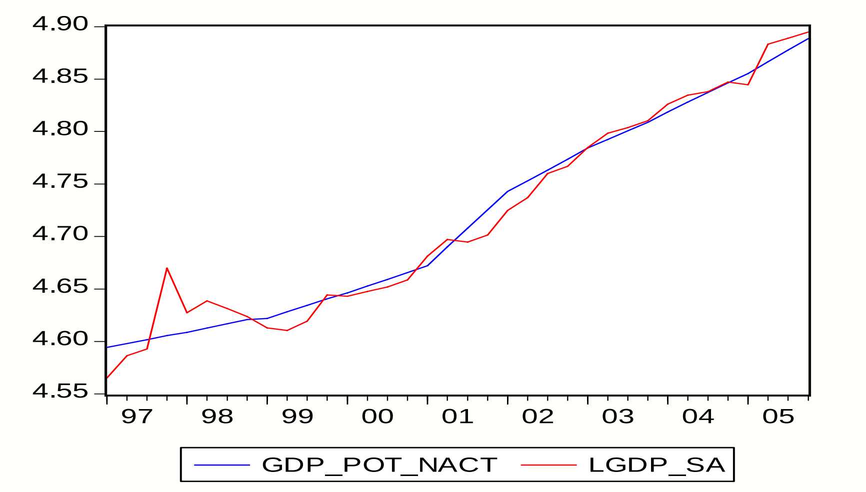
or

$$\ln A = \ln Y - 0.64 \ln L - 0.36 \ln K. \qquad (3.2.2)$$

Potential GDP is once more calculated according to formula 3.1.1. Potential technology is obtained by applying the HP filter to the series (3.2.2), while potential employment is obtained by applying the same filter to the employment figure series.

Chart 11. Potential GDP calculated according to income-based shares of labour and capital in gross value added

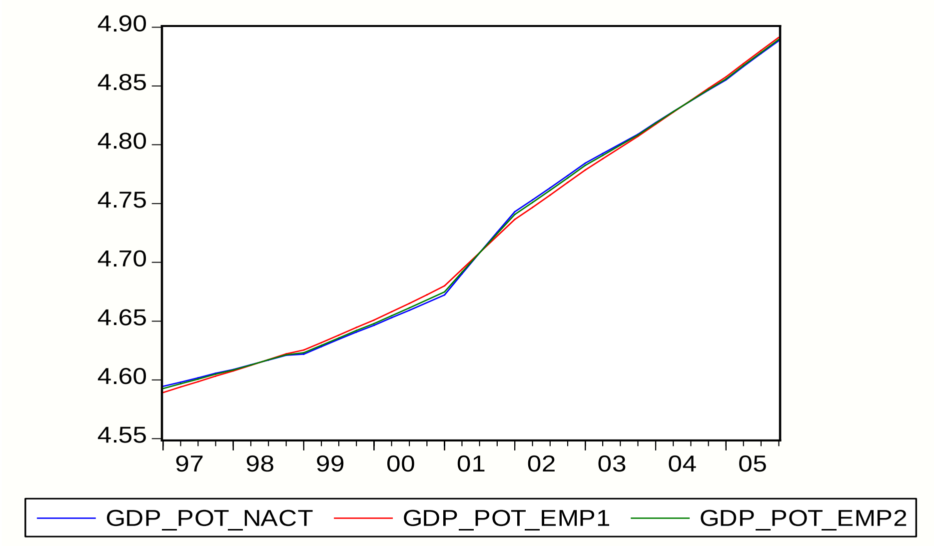
[14] The share of labour income in value added in developed economies is normally about 2/3. It is 68% in the U.S. (Giorno et al., 1995), 67% in Canada (Dion and Kuszczak, 1997), 70% in England, 46% in Argentina (Barro and Sala-i-Martin, 1999), 48% in Chile (Barro and Sala-i-Martin, 1999), etc. According to the European Commission's work (2002a, 2002c), the assumed share of labour income is 0.65 for each country. In the period in which we are estimating potential GDP, the share of labour income in Hungary was 0.65, 0.66 in Poland, and 0.50 in the Czech Republic.



Legend:
LGDP_SA – actual GDP
GDP_POT_NACT – potential GDP calculated according to income-based shares of labour and capital in gross value added (from the national accounts)

Chart 12 shows potential GDP according to model 1, model 2 and according to income-based shares. A considerable overlap between these three lines is notable.

Chart 12. Comparison of potential GDP according to model 1, model 2 and the model with income-based shares



Legend:
GDP_POT_NACT – Potential GDP according to the model with income-based shares
GDP_POT_EMP1 – Potential GDP according to model 1.
GDP_POT_EMP2 – Potential GDP according to model 2.

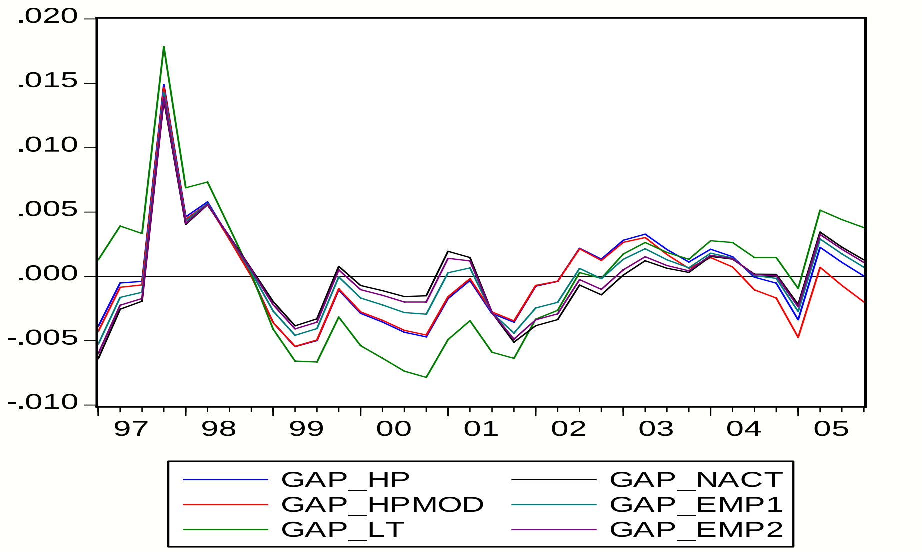
4. COMPARISON OF GDP GAP OBTAINED BY THE PRODUCTION FUNCTION METHOD AND THE UNIVARIATE TECHNIQUES

The output gap is defined as the difference between actual and potential output. The positive gap corresponds to excess demand in the economy, which make cause inflationary pressure. If the gap is negative, then potential output exceeds demand. The output gap cannot be maintained over the long run, because adjustments of wages and prices will be established to reach a balance in which supply and demand are equal.

In the economics literature there are different explanations of why actual and potential output often diverge. According to one theory, actual output differs from potential output because rigidities in the economy imply a certain period for prices and wages to adjust. In this case, the output gap is an important measure to balance overall demand and supply in the economy and it can provide useful information on price pressures. According to another theory, an economy is best characterised by business cycle models, where actual output differs from tend output because of occasional productivity shocks. In this case, the output gap reflects temporary deviations provoked by adjustment of output through technological changes and unexpected supply-side trends.[15]

This section contains a comparison of the GDP gap obtained by the production function with the GDP gap obtained using the linear trend method, the Hodrick-Prescott filter and a modified Hodrick-Prescott filter.[16] A comparison of these variables can lead to a more credible conclusion on the current position of the economy given its potential, and a conclusion on business cycles in the preceding period.
The GDP gap is calculated as the difference between actual and potential GDP, and it is shown in percentages of actual GDP.

Chart 13. GDP gap according to different potential GDP calculation methods



Legend:
GAP_HP - Potential GDP obtained by applying the HP filter to actual GDP
GAP_HPMOD – Potential GDP obtained by applying the modified HP filter to actual GDP
GAP_LT – Potential GDP is a linear trend of actual GDP
GAP_NACT – Potential GDP calculated according to income-based shares from national accounts
GAP_EMP1 – Potential GDP calculated using the production function, model 1.
GAP_EMP2 – Potential GDP calculated using the production function, model 2.

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15 European Central Bank, 2000.
16 According to Bruchez, P.-A. (2003). The modified Hodrick-Prescott filter solves the problem of bias in final points, which is a shortcoming of standard HP filters.

One can see that the gap lines have a very similar shape, they seem translated and they rarely intersect. According to all methods, the economy move in the same direction with stronger or weaker inflationary pressures.

The statistical features of individual series of GDP gaps are provided in table 3.

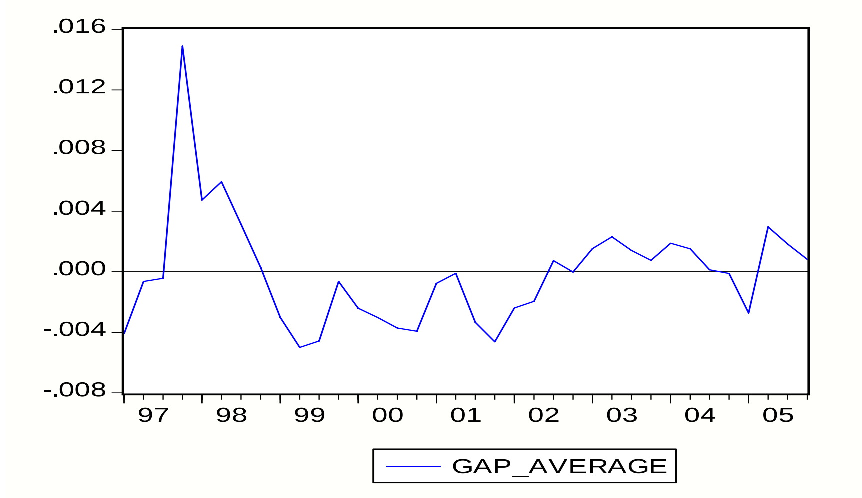
Table 3. Basic GDP gap statistics

	Mean	**Median**	**Maximum**	**Minimum**	**Std. deviation**
GAP_HP	-0.0000174	-0.0003480	0.0148990	-0.0054560	0.0038230
GAP_HPMOD	-0.0003550	-0.0006900	0.0146720	-0.0054280	0.0037700
GAP_LT	-0.0000262	0.0007910	0.0178450	-0.0078420	0.0053050
GAP_NACT	-0.0000135	0.0001340	0.0137540	-0.0063930	0.0035130
GAP_EMP1	-0.0000153	0.0000120	0.0142700	-0.0052590	0.0035290
GAP_EMP2	-0.0000141	0.0000975	0.013925	-0.0060160	0.0034950

The mean is closest to zero, and this also means that the closest proximity between actual and potential GDP is in the GDP gap obtained using the production function method with the income-based share from the national accounts (GAP_NACT). The average deviation of values of the series from its average, standard deviation, is the least for the gap that follows from the production function, model 2, so the oscillations in capacity use are the least in comparison with other methods and inflationary and deflationary pressures are less intense than in other methods.

The next chart shows the average GDP gap calculated as the arithmetic average of the GDP gap series based on all methods.

Chart 14. Arithmetic average of the GDP gap obtained by different methods for calculation of potential GDP



Actual GDP was rather close to potential GDP in the analyzed period, with the exception of 1997 and 1998, when very dynamic economic activity was recorded. The largest negative gap was recorded 1999, 2000 and 2001, which have been characterised as recession or early recovery years. From mid-2002 to the end of the analyzed period, positive gap values were recorded, except in two quarters: the last quarter of 2004 and the first quarter of 2005. In the remainder of 2005, inflationary pressures were somewhat more significant.

5. CONCLUSION

In this work the production function has been selected to estimate potential GDP, since it has one major advantage over other methods, and that is that it creates a relationship between output and production inputs. Two basic procedures were used to calculate potential GDP. In the first, potential GDP was calculated using GDP elasticity obtained by regression with reference to labour and capital, while in the other case potential GDP was calculated using income-based shares of labour and capital in gross value added from the national accounts.

For the selected labour and capital inputs, estimated labour elasticity in Croatia during the period from 1997 to 2005 was approximately 0.80, while according to the national accounts the income-based share of labour was 0.64. Potential GDP was calculated using the total factor productivity trend, the trend in the number of employed and actual gross capital stock. Total factor productivity in both approaches was calculated as the residual of actual GDP and the weighted sum of factor inputs.
Potential GDP obtained using the production function method with the income-based shares from the national accounts were best “adapted” to actual GDP data, and among the three methods it has the lowest gap standard deviation.

The difference between actual and potential GDP is the GDP gap, and it has been compared with the gap from certain univariate techniques. The series of arithmetic GDP gap averages derived from the different methods shows that in 1997 and 1998 very strong economic activity was recorded, and after these years GDP moved not far from its potential, although an increasingly narrower link has been in effect from 2003 to the present. Low-level inflationary pressures have generally been present over the past few years.

Continued research is expected to produce improvements in the series of labour inputs given the educational structure. Attempts will be made to modify potential employment according to aggregates from labour supply surveys. As for capital stock, a revision of data is expected soon in the direction of changes to its structure and increased depreciation rates. In the next phase of research, much more emphasis should be accorded to forecasting potential GDP growth.

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