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DP/57/2007

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Tsvetan Tsalinski

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March 2007

ISBN: 978-954-8579-05-6

Printed in BNB Printing Center.

Views expressed in materials are those of the authors and do not necessarily reflect BNB policy.

Elements of the 1999 banknote with a nominal value of 50 levs are used in cover design.

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Publications Division
Bulgarian National Bank
1. Alexander Battenberg Square
1000 Sofia. Bulgaria
Tel.: (+359 2) 9145 1351, 9145 1978, 981 1391
Fax: (+359 2) 980 2425
e-mail: Dimova.L@bnbank.org
Website: www.bnb.bg

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SUMMARY*. The discussion paper presented applies two approaches to estimating potential output. One of them is based on Kuttner's unobserved component model. We propose using unit labour costs as a measure of inflation and a signal of overheating in the Phillips curve. The model specifications tested do not show significant deviations from trend of annual GDP. The other approach applied in the paper is growth accounting based on a Cobb-Douglas-like specification of the production function. The most important result is a quantitative measure of the evolution of the capital stock and total factor productivity of non-financial enterprises.

Acknowledgments

The author would like to thank Messrs. Statty Statev, PhD, a member of the Governing Council of the Bulgarian National Bank and Vice Rector of the University of National and World Economy, Sofia; Werner Roeger of DG ECFIN's Research Directorate; Cristophe Planas of the Joint Research Centre of the European Commission at Ispra, Italy; Kaloyan Ganev of the Agency for Economic Analysis and Forecasting for the stimulating discussion and helpful comments.

*Tsvetan Tsalinski is an economist at the Economic Research and Forecasting Directorate of the Bulgarian National Bank and a teaching assistant at Sofia University's Faculty of Economics and Business Administration. He is a member of the Bulgarian Macroeconomics Association. E-mail: Tsalinski.T@bnbank.org

Theoretical Background

Formulating a unified definition of an economy's potential output is not an easy task. Potential output is not directly observable because it depends on a number of factors whose influence on production is difficult to measure and not unambiguous. When exploring an individual production process or a single firm, it is relatively easy to evaluate the indefinitely sustainable level of output at full capacity. This would give a fairly accurate idea of what potential output stands for in the context of an individual firm. It is beyond discussion that the supply capacity of firms is a major determinant of the economy-wide potential level of output.

However, national income is generated in the process of interaction between economic agents, hence it depends not only on supply capacity, but also on factors influencing demand, as well as the functioning of markets. It should also be borne in mind that production is a dynamic process affected by factors, such as technology, skills, preferences, institutions *etc.*, that evolve over time. That is why potential output, in its macroeconomic sense, is a highly complex concept. Working definitions employed by empirical approaches to estimation of potential output reflect its numerous determinants to a varying, mostly partial, degree and hence should be interpreted cautiously.

The macroeconomic production function is the economic model that encompasses the various aspects of the concept most exhaustively, thus helping to grasp the meaning of potential output.

The production function relates economy-wide income (or output) to the resources employed in generating it; hence potential output depends on the fundamental factors characterizing the respective economy. These fall into several categories: human resources (labour), means of production (capital) and total factor productivity, which is a catch-all for the remaining, often immeasurable, characteristics of the economy. These categories are not always easily set apart and the distinction between them depends on the choice of specification of the model.

Constructing and estimating a production function at a highly aggregated level poses serious theoretical and practical problems. On one hand, they consist in the choice of a functional form[1] and measures of the quantity (man hours, machine hours, etc.) and the quality of the actually utilized labour and capital. On the other hand, there comes the issue of estimating potential output, i.e. adjusting for the cyclical fluctuations of input variables. More

[1]See Growth Accounting, p.14.

specifically, it is related to establishing the level and evolution of full employment and the long term trend of *TFP*.

Information on the deviations from potential or the output gap, i.e. the cyclical position of the economy is of prime importance to policy makers, including the central bank, when interpreting macroeconomic indicators, especially the ones related to government revenues and expenditures, money and credit and, not least, prices. That is why the methods for estimating potential output need to be practicable in terms of obtaining the estimates and reliable in terms of the signals they give to policy makers (Butler 1996, Kuttner 1994).

The output gap figures eminently in models of inflation based on the Phillips curve, whose basic intuition is that stretching output beyond potential boosts inflation while disinflation requires that output come down below potential. This is the rationale behind Okun's (1970) definition of potential output as "the maximum output at which no inflationary pressures arise". Based on these models, Kuttner (1994) proposes an approach to estimating potential output based on inflation dynamics. He admits that the microeconomics of the Phillips curve is somewhat ambiguous but quotes Lucas (1972) who deems the "systematic relationship between inflation and real output" one of the main features of the modern business cycle. Variations in inflation are commonly perceived as signalling deviations from potential (De Masi, 1997)[2] while Kuttner's model is one of the most widely used approaches for estimating the output gap.

The paper uses two approaches to estimating potential output. One of them is based on Kuttner's unobserved components model. The other is effectively a growth accounting exercise. They differ in both the quantitative techniques and the definition of "potential output" they employ. The unobserved components method (potential output is an unobserved variable) makes assumptions about the stochastic properties of the observed output series and decomposes it into a trend and a cyclical component, interpreted as potential output and output gap, respectively. If no other economic information is taken into account, the approach reduces to a purely statistical filter and interpreting the two components as potential output and output gap is entirely speculative. Its advantage, however, consists in the fact that the filter allows for incorporating structural information. A

[2]A number of analysts suggest that a widening CA deficit may be signalling overheating of the economy. Such a proposition belittles the fact that GDP is not only the sum of all (domestically produced) final uses but also the amount of total value added. Imports of goods and services for final use (consumption and investment) help wholesalers and retailers generate their output and value added and, thus, are not a pure sign of excess demand.

famous example is Kuttner's model where a Phillips curve equation is added to the specification thereby linking the estimated output gap to inflation (see Kuttner 1994, Curl et al. 2004, Gerlach and Smets 1997). Alternatively, one can verify the estimate from the statistical filter by plugging it into a Phillips curve equation and estimating it (Faal 2005). This is how the unobserved components method relies on the relationship between inflation and the output gap. In this paper we propose a modified specification of Kuttner's model, where instead of price inflation we use unit labour costs as an indicator of deviation from potential.

The other approach we use is based on growth accounting. We assume the functional form of the aggregate production function and try to evaluate the contributions of labour, capital and total factor productivity, measured as a residual. The practical application demonstrates the problems of constructing and estimating a production function for Bulgaria. The most important result is the estimation of the growth rate of the capital stock of non-financial enterprises as well as their total factor productivity. These are only crude illustrative estimates, as the methodology is extremely unsophisticated. Nevertheless, the data examined suggest that the economy is undergoing a process of rapid capacity creation which will necessarily boost the potential growth rate.

An Application of the Modified Watson-Clark-Kuttner Model

The output gap literature repeatedly expresses unambiguous preference of structural approaches to purely statistical ones. There is hardly a paper on the topic that forgoes a critical mention of the famous Hodrick-Prescott filter. Univariate filtering seems inevitable, though. Even with more structural approaches, e. g. based on a production function, it is not uncommon that some of the input variables be transformed/smoothed *via* some univariate routine. Quite often this turns out to be the widely criticized Hodrick-Prescott filter itself (see Bolt, van Els 1998, St. Amant, van Norden 1997). An exhaustive review of univariate filters with applications for the Bulgarian economy can be found in Ganev (2004).

Kuttner's model belongs to the so-called mixed approaches to estimating potential output and comprises a combination of a univariate filter (the unobserved component method developed by Watson (1986) and Clark (1987) based on the Kalman-Bucy filter) and some elements of economic structure, i.e. a Phillips curve equation. Another notable example is the Laxton-Tetlow (1992) model, which combines the Hodrick-Prescott filter with the Phillips curve and Okun's law (see Butler 1996 for an application).

The Watson-Clark model (see Planas, Rossi 2004) assumes that observed output, X_{1t}, consists of a long term component (trend) X_{1t}^{N}, perceived as potential output and a short term (cyclical) component X_{1t}^{S}, representing deviations from potential:

$$X_{1t} = X_{1t}^{N} + X_{1t}^{S} \quad (1).$$

Potential output evolves as a second order random walk:

$$(1-L)X_{1t}^{N} = \mu_{1t-1} + a_t^{N} \quad (2),$$

$$(1-L)\mu_{1t} = a_t^{\mu} \quad (3),$$

where L is the lag operator.

The cyclical component is AR(2):

$$(1-\phi_1 L - \phi_2 L^2)X_{1t}^{S} = a_t^{S} \quad (4).$$

a_t^{S}, a_t^{N} and a_t^{μ} are white noise innovations with variances V_S, V_N and V_μ. This type of model has a state space representation and can be estimated via the Kalman-Bucy filter. Equation (1) is the observation equation while (2), (3) and (4) are the transition equations. A Phillips curve equation, modelling the theoretical relationship between inflation (X_{2t}) and the deviation from potential output, can serve as an additional transition equation, this incorporating economic structure into the model. Most generally, the Phillips curve equation has the following form:

$$X_{2t} = \mu_2 + \sum_{i=1}^{M_2} \alpha_{2i} Z_{2it} + \gamma(1-L)^d X_{1t-1} + \sum_{i=0}^{r} \beta_i X_{1t-i}^{S} + \sum_{i=1}^{p} \phi_i^{*} X_{2t-i} + \sum_{i=0}^{q} \theta_i a_{t-i}^{\pi} \quad (5),$$

Where $Z_{2.t}$ is a vector of M exogenous variables, *and* a_t^{π} is a white noise innovation with variance V_π. It can be correlated with the innovation a_t^{S} in the AR(2) process generating the cyclical component X_{1t}^{S} only if the coefficient of the contemporaneous value of the cyclical component $\beta_0 = 0$.

Kuttner's approach is well established in this field of research. The Joint Research Centre at Ispra, Italy, a division of the European Commission, has developed the specialized program GAP which has convenient interface for specifying and estimating various modifications of the Watson-Clark-Kuttner model set out in equations (1)–(5). Program GAP was also used for the estimations presented in the remainder of this chapter.

For the application at hand, we choose a bivariate specification a-la Kuttner and try to establish the validity of the Phillips curve for the Bulgarian economy, i.e. whether variations of inflation are informative of the cyclical position of the economy. We assume that potential output is a second order random walk as per equations (2) and (3). We deem this specification appropriate, as the economy is undergoing structural changes and the potential growth rate μ_t is most likely variable and, hopefully, with an upward trend in the medium term. We choose to specify the short term component as AR(2), which under certain conditions could give the estimated output gap a cyclical pattern.

We estimate three models featuring different measures of inflation in the Phillips curve. Model 1 uses the **consumer price index**. It is unrivalled in terms of timeliness of publication. Model 2 uses the **GDP deflator** – the most comprehensive measure of the price level of domestically produced goods and services. Last, but not least, model 3 uses unit **labour costs**.[3] We believe that unit labour costs are a straightforward measure of both costs and performance and thus are closely related to potential output and the cyclical position of the economy. They are also more informative with respect to market tightness and production bottlenecks than wages alone, a variable that features prominently in many versions of the Phillips curve. We refrain from testing a specification with the producer price index as it only covers mining, manufacturing and the distribution utilities, but not the rapidly growing services sector.

The estimation period spans Q1[4] 1998 – Q4 2005. Prior to that data are subject to unwieldy fluctuations under totally different economic policy, wage and price setting frameworks (Minassian, Nenova, Yotzov 1998). This implies a break in the data generating process of trend output and the output gap as well as the other variables discussed. The data for the first two quarters of 2006, available at the time of submission of the paper, are still preliminary.

The X12 ANOVA test finds stable seasonality in all the series discussed so all the series were adjusted accordingly.[5] The three price indices (CPI, PGDP and ULC) were smoothed additionally by removing the irregular component estimated by the X12 routine. These preliminary transformations were carried out in order to facilitate the model estimations in view of the limited number of data points.

The estimation output for the bivariate models is presented in the following tables.

[3]The indices in models 2 and 3 were constructed from National Accounts data.

[4]Q3, rather, as two cases are consumed by differencing.

[5]Seasonal adjustment models, such as X12-ARIMA, decompose time series into a trend-cycle, a seasonal factor and an irregular component.

Table 1

MODEL 1

X_{1t}: log GDP at prices of 2004
X_{2t}: second logarithmic difference of CPI
Estimation period: Q3 1998 – Q4 2005
Maximum likelihood estimates and stats

		coefficient	standard error	t-statistic
Equation 1				
	f_1	0.0159	0.217	0.0732
	f_2	-0.4508	0.185	-2.4363
	V_N	5.80E-02		
	V_μ	5.26E-02		
	V_S	5.80E-02		
Ljung-Box Q Stat.		2.0051	p-value:	0.7348
Equation 2				
	μ_2	0.0929	0.082	1.1322
	b_0	-1.2828	0.3028	-4.237
	b_1	-0.0348	0.4744	-0.0734
	f^*_1	0.2872	0.1924	1.493
	V_p	1.28E-01		
Ljung-Box Q Stat.		7.1835	p-value:	0.1265
R2(uncentered) 0.204				

-2*log-likelihood:73.9182

Table 2

MODEL 2

X_{1t}: log GDP at prices of 2004
X_{2t}: second logarithmic difference of the GDP deflator, base year[6] – 2004
Estimation period: Q3 1998 – Q4 2005
Maximum likelihood estimates and stats

		coefficient	standard error	t-statistic
Equation 1				
	ϕ_1	0.5027	0.1193	4.2148
	ϕ_2	-0.8014	0.1124	-7.1322
	V_N	5.79E-02		
	V_μ	5.81E-02		
	V_S	2.84E-02		
Ljung-Box Q Stat.		6.2097	p-value:	0.184
Equation 2				
	μ_2	0.0357	0.0787	0.4535
	β_0	-1.9356	0.3404	-5.6857
	β_1	-0.883	0.5274	-1.6742
	ϕ^*_1	-0.1692	0.1654	-1.0226
	V_π	4.14E-02		
Ljung-Box Q Stat.		5.5551	p-value:	0.2349
R^2(uncentered) 0.642				

-2*log-likelihood:102.7742

[6]When constructing constant base volume and price indices from chain-linked data, the choice of base year influences the results, more specifically the pattern of seasonality.

Table 3

MODEL 3

X_{1t}: log GDP at prices of 2004
X_{2t}: second logarithmic difference of the Unit Labour Costs index, base year – 2004
Estimation period: Q3 1998 – Q4 2005
Maximum likelihood estimates and stats

		coefficient	standard error	t-statistic
Equation 1				
	ϕ_1	-0.3986	0.1384	-2.8799
	ϕ_2	-0.9057	0.1427	-6.3483
	V_N	5.80E-02		
	V_μ	5.75E-02		
	V_S	2.72E-02		
Ljung-Box Q Stat.		4.6781	p-value:	0.3219
Equation 2				
	μ_2	-0.0318	0.1197	-0.2659
	β_0	4.3468	0.4999	8.6947
	β_1	4.6237	0.5019	9.2120
	ϕ^*_1	0.446	0.1431	3.1175
	V_π	2.65E-05		
Ljung-Box Q Stat.		6.4715	p-value:	0.1666
R2(uncentered) 0.693				
-2*log-likelihood: 104.7261				

The estimated coefficients of models 1 and 2 establish a negative relationship between price inflation and the output gap. This is a puzzling result, as it implies that when output growth overshoots trend (potential), CPI inflation and the price inflation of domestically produced final use output tend to decelerate and *vice versa*. While a recovery of output may go hand in hand with disinflation, it hardly stands to reason that if demand or output hit the supply constraints, product and factor markets will respond with a slowdown of price growth.

A likely explanation of the sign of the estimates is that the deviation of output from trend is not the only determinant of price inflation. The specification omits other important factors, such as import prices, adjustments in administered prices, *etc.*[7] Their incorporation into the model will probably change the signs of β_0 and β_1.

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[7]One-off irregular factors were eliminated by the smoothing procedure applied.

The estimation of the version of Kuttner's model that we propose (Model 3) suggests that there is a relationship between unit labour costs and the output gap. The respective coefficients in the Phillips curve equation have the expected positive signs and are statistically significant. Unit labour costs are inherently linked to the dynamics of potential output and the output gap. By construction, they should be capturing productivity and cost developments. The results of the estimation are quite important as they indicate that unit labour costs can actually be informative of the cyclical position of the economy.

For comparison, we present the estimation results for a univariate specification after Watson and Clark.

Table 4

MODEL 4

X_{1t}: log GDP at prices of 2004
Estimation period: Q3 1998 – Q4 2005
Maximum likelihood estimates and stats

		coefficient	standard error	t-statistic
Equation 1				
	ϕ_1	-0.2306	0.2181	-1.0573
	ϕ_2	-0.6018	0.1556	-3.8675
	V_N	5.80E-02		
	$V\mu$	2.69E-02		
	V_S	5.80E-02		
Ljung-Box Q Stat.		3.9388	p-value:	0.4144
-2*log-likelihood:		67.9787		

What the four models have in common is that the deviations from trend are quite small when computed on an annual basis. Practical experience has shown that an output gap of less than 0.2 per cent is not robust to revisions of data and subsequent reestimations of models (Denis et al., 2006).

Figure 1

ESTIMATED OUTPUT GAP,%

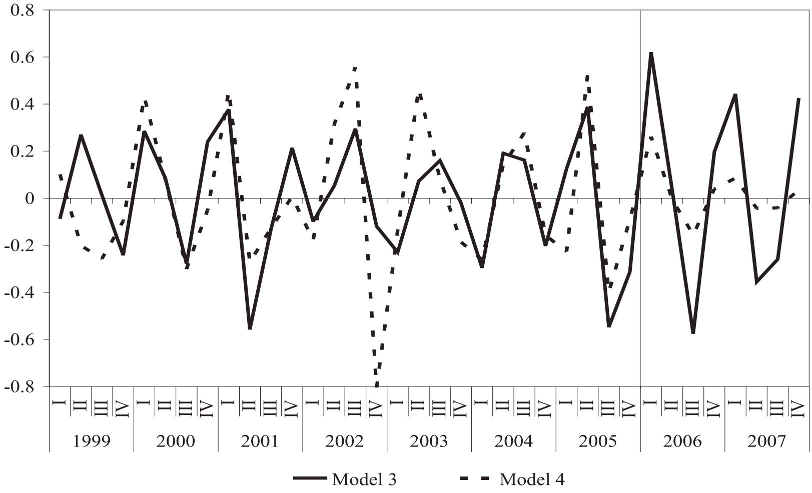

Figure 2

GROWTH RATES OF POTENTIAL AND ACTUAL OUTPUT PER CENT ON THE CORRESPONDING QUARTER OF PRECEDING YEAR,%

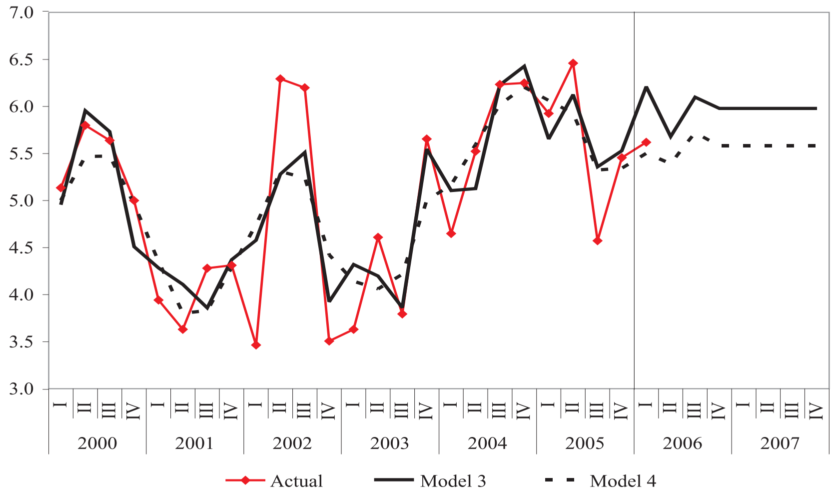

Table 5

ACTUAL AND TREND GDP GROWTH RATE ON PRECEDING YEAR, %

	2000	2001	2002	2003	2004	2005	2006	2007
Actual	**5.4**	**4.1**	**4.9**	**4.5**	**5.7**	**5.5**		
Model 1	5.2	4.1	4.8	4.6	5.5	5.8	5.3	5.4
Model 2	5.2	3.9	5.0	4.6	5.5	5.7	5.3	5.5
Model 3	5.3	4.2	4.8	4.5	5.7	5.7	6.0	6.0
Model 4	5.2	4.1	4.9	4.4	5.8	5.7	5.6	5.6

Growth Accounting

An estimate of potential output can be derived from the trends in the evolution of production factors: labour, capital and total factor productivity, the latter usually measured as a residual. For this purpose one has to assume the form of, and estimate or calibrate a production function. The most commonly used one is the Cobb-Douglas production function which is a special case of the CES[8] production function (see Musso and Westermann, 2005, Bolt and van Els, 1998):

$$Y_t = F(A_t, K_t, L_t \mid \alpha, \rho) = A_t[\alpha L_t^{\rho} + (1-\alpha)K_t^{\rho}]^{\frac{1}{\rho}} = A_t L_t^{\alpha} K_t^{1-\alpha} \text{ , for } \rho \to 0,$$

where K_t is the capital stock at year t, L_t is employment, A_t is total factor productivity, α is the labour intensity parameter, $1/(1-\rho)$ is the elasticity of substitution between factors.

These functional forms have a number of useful properties that facilitate the quantitative illustration of the analysis and econometric estimation. However, they are not exhaustive of the variety of approaches to modelling production (Denis et al., 2006).

Estimating a production function faces a number of difficulties when it comes to quantifying the basic input variables: labour and capital.

Data on the value of the total capital stock of the Bulgarian economy are not available. However, the Bulgarian National Statistical Institute publishes the aggregate balance sheet of non-financial enterprises. It has data on the tangible and intangible fixed assets, which should be a good measure of the sector's capital. The NSI also compiles the Integrated Economic Accounts by institutional sector and they give us data on the formation and consumption

[8] Constant Elasticity of Substitution

of fixed capital. All these data are at current prices, while we are interested in the real growth of capital. Lacking relevant deflators, we take the ratio of net fixed capital formation to the average of the value of capital at the beginning and end of the respective year as the real growth rate of capital.

To measure employment we use the average annual number of persons employed[9] for the whole economy less the persons employed in the financial sector, public administration, healthcare and education. Ideally, one would want to use hours worked. Unfortunately, statistics on these is not readily available and reliable enough. To calculate output (growth) of non-financial enterprises we use Production Account data by economic activity and subtract the value added by financial intermediation, public administration and the imputed rent of owner occupied dwellings. When these data are not available, we use data on government consumption and the imputed rent from the Use of Income account. One can't help noticing the discrepancy of the sector composition of employment and output aggregates, but since we are interested in constructing real growth rates, this should not impair the results significantly. Due to the very limited number of cases, we do not attempt an econometric estimation of a production function, but rather present an illustrative decomposition of observed output growth into contributions by labour, capital and TFP, the latter derived as a residual:

$$a_t = \frac{(1+y_t)}{\left[1+\left(\frac{\alpha_t+\alpha_{t-1}}{2}\right)l_t+\left(1-\frac{\alpha_t+\alpha_{t-1}}{2}\right)k_t\right]}-1 \text{ ,}$$

where lower case letters denote growth rates.

We equate α to the labour share of value added. This we construct by multiplying the ratio of the compensation of employees to total value added for the overall economy with the total number of persons employed and dividing it by the number of employees under labour contract. Thus, we obtain a labour share of about 60 per cent, which stays quite stable during the period under investigation. Although the theoretical assumptions that would make this evaluation legitimate are not actually fulfilled, this value is quite similar to the typical results of analogous calculations for other economies[10] (Faal, 2005; Denis et al., 2006). The following table summarizes the data and the results of the calculations.

[9]If one were to estimate a production function econometrically it would be more appropriate to use the overall number of the population in working age. By using the number of persons actually employed, we directly account for the utilization rate of labour resources.

[10]Minassian (2001) suggests using the share of personal consumption in domestic demand as a measure of labour intensity of output. This renders the capital share rather low, however, and makes the approach relevant for lesser developed, and heavily decapitalized economies.

Table 6

		1998	1999	2000	2001	2002	2003	2004
Capital (tangible and intangible fixed assets)	million BGN e.o.p.	17,136	18,927	21,615	25,594	29,650	38,635	43,278
Consumption of fixed capital	million BGN	1729	1784	1916	2466	3024	3652	4382
% of capital		11.5	9.9	9.5	10.4	10.9	10.7	10.7
Gross fixed capital formation	million BGN	1971	2414	2758	3958	4591	5368	6455
% of capital		13.1	13.4	13.6	16.8	16.6	15.7	15.8
Investment, net (real growth of capital),%		1.6	3.5	4.2	6.3	5.7	5.0	5.1
Employment growth,%		0.7	-2.6	-3.0	-0.2	0.5	6.9	3.0
Value added	million BGN	10,098	10,619	13,672	15,652	17,410	18,592	19,993
Real growth contributions,%		3.2	1.3	4.5	5.3	5.9	3.8	6.2
K	percentage points	0.5	1.2	1.5	2.4	2.2	2.0	2.0
L	percentage points	0.4	-1.7	-1.9	-0.1	0.3	4.1	1.8
A	percentage points	2.3	1.8	4.8	3.0	3.3	-2.3	2.3
1-α (capital share),%		33.8	35.7	38.8	38.5	40.2	39.5	41.4
Capital-output ratio		1.5	1.5	1.7	1.5	1.5	1.6	1.8

The calculations make evident two important trends: increasing total factor productivity as well as a rising capital output ratio. They have been quite pronounced and sustained[11] during the years of the Currency Board Arrangement and give reason to believe that output potential has been expanding.

Future work

This paper presented the results from the application of two of the most widely used approaches to estimating potential output: the unobserved components method and growth accounting. The unobserved components method enabled us to estimate a relationship between (cost) inflation and the

[11]The decline in TFP in 2003 reflects certain developments on the labour market. On one hand, with the registration of labour contracts with the National Social Security Institute, which started in 2003, some of the hidden employment was formalized. On the other hand, the Ministry of Labour and Social Policy launched several employment creation programmes. There is probably also an underlying tendency of declining average hours worked due to the rapid employment growth in the services sector where part-time jobs are not uncommon.

output gap (a modified Phillips curve). We established a statistically significant positive relationship between unit labour costs and the output gap, which implies that ULC developments are informative of the cyclical position of the economy. A specification of the Phillips curve with the CPI or the GDP deflator establishes an inverse relationship with the estimated output gap.

Even univariate unobserved components models (without a Phillips curve) have significant advantages in comparison with the Hodrick-Prescott filter which is a limited special case. A second order random walk specification for the long term component is better suited to track time varying trends while an AR(2) specification for the short term component can take account of the cyclical pattern of deviations from trend output. The unobserved components method is also a convenient short-term forecasting tool.

The specifications of the Phillips curve that we used feature only a limited number of endogenous variables. Identifying and including additional, exogenous, determinants of inflation, for instance import prices, is a natural and necessary direction of future research.

Kuttner's model is based on two strong assumptions: adaptive inflation expectations (see Gerlach and Smets, 1997) and a stable relationship between output and prices, of which the Phillips curve is only a reduced form representation. The second assumption can be easily challenged for an economy like Bulgaria's, undergoing structural changes (Faal 2005). Constructing and estimating models overcoming these drawbacks demands more sophisticated tools.

The growth accounting methodology is extremely helpful in formulating scenarios about the future development of the economy. They can be made quite elaborate and take account of demographic and labour market developments and investment decisions by firms. This approach is indispensable to the quantitative analysis of the process of real convergence with the developed economies.

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