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Potential Output and the Output Gap in Estonia – A Macro Model Based Evaluation

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Abstract

There have been several data revisions to the output statistics in Estonia during the past six years as methodologies have been harmonised. These changes are significant enough to require corrections to the earlier understanding of Estonia's potential economic growth rate. In this paper the latest data vintage from 2009 is used to estimate Estonia's potential output growth and output gap. The production function approach that has been used shows that the gap varies quite extensively, ranging from -8% in 1999 to $+8\%$ in 2007, while the average potential growth rate in 1997–2009 was around 6%. The macro model simulations expect the potential growth rate to fall in the future. The fall in the marginal productivity of production inputs makes growth slow to about $4-5\%$ in the next five years, if there are no additional shocks to the economy.

JEL Code: E32, F43

Keywords: potential output, potential growth, output gap

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Non-technical summary

Frequent revisions to the output series in recent years have made its level and growth vary significantly across vintages. For example, the GDP figures for 2005 taken in 2006 are approximately 8% lower than the latest available official data for the same period, which were released in 2009. As a consequence of this, the underlying trend has also changed and as a result so has the understanding of what Estonia's potential growth rate actually is.

This paper uses a structural (production function) approach to estimate the path of potential output, focusing on three contributing factors, physical capital, labour and the level of production technology available in the economy. Using the latest data vintage from 2009 the method returns an average of 6% potential growth for 1997–2009, which equals the average actual GDP growth of the same period.

Potential growth has departed from its mean value at certain points, the most recent departures being triggered by the positive shocks of EU accession and credit loosening. These shocks increased investment by raising production capital and the labour supply, causing growth to accelerate to more than 8% in 2003 and 2006. The investment boom in 2006–2007 also generated a large positive output gap, which reached $+8\%$ in 2007. This was a remarkable recovery considering the high average trend growth and the fact that the Asian and Russian crises had pushed the gap down to -8% in 1999.

Macro-model based simulations show that potential growth will settle at lower rates in the near future. The neoclassical Cobb-Douglas production function attributes this to the fall in the marginal productivity of the production inputs of labour, capital and technology. In other words the sources of very high growth, primarily rapid financial deepening and capital accumulation, have been exhausted. Unless there is an unexpected technological breakthrough, potential growth will settle between 4 and 5% in the next five years. However, this growth rate is considerably higher than the EU-27's average, which means that Estonia is still on course to close the gap in average *per capita* income between Estonia and the EU-27.

Contents

1. Introduction

Estonia's actual output data has been revised several times by the national statistical office in the past few years in order to harmonise its methodology with that of Eurostat, the major revisions taking place in 2006, 2007 and 2008. Alongside the other methodological changes, the greatest change came in September 2008 when the statistical office adopted chain linking for the national accounts data.

The last six revisions have changed both the level and growth of the output. The spread between the latest available growth rate and those of the previous data releases reach, in some instances, as much as $4pp$. GDP measurements for 2005 taken in 2006 are about 8% lower than the latest available official data for the same period. Vintages after that of 2006 show smaller deviations, but the spreads still remain quite sizeable (see Appendix 1). These differences are large enough to permit the assumption that the underlying potential growth rate has also changed, and therefore potential output and the output gap have also to be revised.

Apart from the difficulties stemming from the revisions, extracting the cycle from Estonia's actual output data is also problematic because the time period covered by the series is so short. At the present moment the data covers only one full cycle, meaning there are wide error bands when the cyclical position of the economy is determined. The absence of any longer cyclical pattern in the data precludes any very precise estimation of the initial gap value, or of the latest. The problem is more acute when statistical de-trending methods are used, because many of them tend to fit the smoothed series to the actually observed data at both ends of the series (the so called end-point problem). Multivariate methods somewhat dampen the methodological shortcoming but do not eliminate it completely. The method which is least sensitive to a problem of this sort is a structural approach, for example a production function based trend-growth extraction as employed in this paper. The production function method, on the other hand, is open to other types of problems and shortcomings often related to data availability issues, as discussed in this paper.

The paper does not aim to give "the most accurate estimate" of potential output, as this anyway cannot be tested because potential output is unobserved. It rather explains potential output by means of the chosen framework. The approach makes use of three production inputs, capital, labour and technology, the dynamics of which allow potential growth to be decomposed retrospectively and also give pointers for future periods. In some respects the qualitative information on potential growth arising from the analysis is even more important than the numerical calculations, especially as regards the forecast. The kind of knowledge obtained here is intended to answer the questions whether potential growth will bounce back to its historical mean after the current slowdown is over, what the necessary conditions for that to happen are, and why it might not be possible.

The paper is organised as follows: In Section 2 a production function approach is used to give the latest estimates of potential output and of the output gap. These estimates are then compared to an earlier study which applied several statistical de-trending methods. Section 3 provides forecasts of potential growth and of the output gap, based on macro-model simulations. These are discussed in the context of the neoclassical growth concept. The last section, Section 4, draws the most relevant conclusions on the topic.

2. Measuring potential output and the output gap

In the following the potential output, Y^*, is given by the neoclassical Cobb-Douglas production function with Harrod-neutral (labour augmenting) technological progress and constant returns to scale:

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

where K is the outstanding stock of physical production capital, L^* stands for full employment, A is the level of production technology and α denotes the income share of capital. This functional form of potential output originates from the upgraded version of Eesti Pank's macro-econometric model EMMA, where it represents an aggregate supply of monopolistically competing companies seeking to maximise their profits, using the inputs listed above.[1]

Since there are no official data available on physical production capital, this has had to be compiled using some other related statistical data. The relevant time series is calculated by the standard PIM (*Perpetual Inventory Method*) process [2] : $K_t = (1-\delta)K_{t-1} + I_{t-1}$, where I denotes real investment and δ is the depreciation rate. Here only aggregated corporate and government investment is considered, while investment by households is treated as non-productive as it increases the housing stock but adds nothing to potential growth.

The size of the capital stock and its growth rate are determined by the initial value chosen for the capital stock, K_0, and δ. Changes in either value

[1] See Kattai (2005) for a general overview of the model. Though not up to date it provides information on most of the features still present in the updated model, including the structure of the supply side of the model economy and the theoretical underpinnings of potential growth.

[2] See OECD (2001) for a detailed overview of the method.

have a major effect on the calculated series in the beginning of the sample but become less significant in a longer time horizon. The starting value for K in 1996q1 is chosen so that it roughly matches the real value of the assets of companies, as published by the national statistical office (Statistics Estonia, 2009).[3] According to the statistical office, companies held about 67 billion kroons of assets at the beginning of 1996, which gives a real value of about 75 billion kroons. This is the value at which the PIM calculation is initiated, with the capital to output ratio equalling a little more than 100%.

Initial capital estimates for individual countries are often derived from corporate accounting but this has some significant drawbacks. Pula (2003) stresses that (a) accounting data may differ from real economic conditions because they are affected by tax regulations; (b) they are evaluated at historical prices, meaning there is no uniform price base; and (c) in transition economies the turbulent flow of assets may not have been reflected in book values. For these reasons this paper treats the aggregate asset value as a rough indication or approximation, and not as a perfect point estimate.

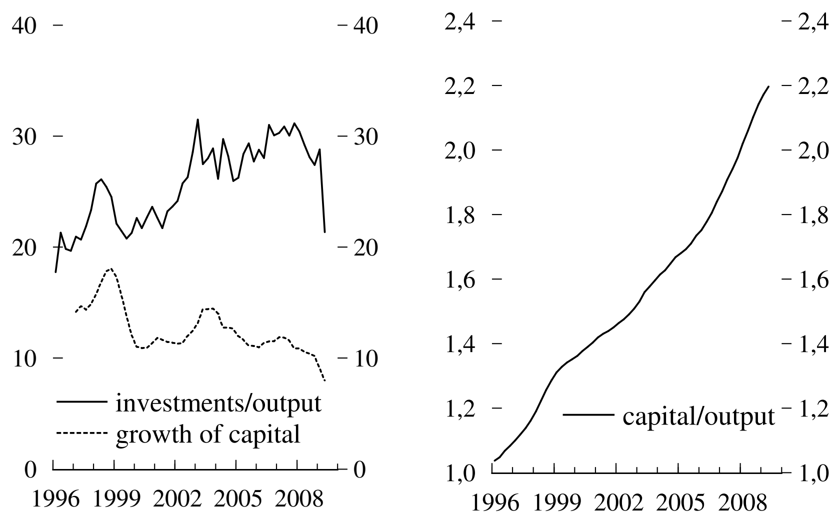
The depreciation rate, δ, is set at 0.05 per year. This rate is well within the plausible range used in the literature on the subject. Bergheim (2008) reviews a number of studies and summarises that most of them use a depreciation rate of between 0.05 and 0.07. He also proves in an experiment that switching from, for example, $\delta = 0.06$ to $\delta = 0.05$ causes no major change in the paths of capital stock.

Calculations show that the non-residential capital stock has been growing remarkably fast, at an annual growth rate that has stayed above 10% in most periods (see Figure 1). This high growth rate is due to the high investment to output ratio, which stayed close to 30% between 2003 and 2008. Growth was faster in the beginning of the sample because of the low initial level of the capital stock. These two facts taken together have resulted in a rapid deepening of capital, a process which has increased the capital to output ratio by around 100% during the past 14 years, from 105% to 220% of GDP.

The absence of any official data makes it impossible to say whether the calculated capital stock is close to the "true" data. One way to test the reliability of the synthetic series is to compare it with data from other countries. A country with a similar historical background and economic development would make the best comparison. An article by Pula (2003) offers a good benchmark in this respect, even more so because, like the present paper, he measures non-residential capital rather than the overall stock in the economy.

[3]The statistical office only publishes nominal asset values. Real asset values are obtained by deflating assets with the investment deflator, which is considered to be the most appropriate price index in this case.

He finds that the non-residential capital to output ratio in Hungary was 150% in 1999, which is just a little higher than that which has been measured for Estonia (see panel b in Figure 1). Given that capital deepening is positively correlated with the level of economic advancement, a small gap between the Estonian and Hungarian capital to output ratios in 1999 can be explained by Hungary's slightly higher income level. However, this indicates that the data derived on capital stock lie in a reasonable range in order to produce plausible results from measuring potential output.



(a) Investment to output ratio and annual growth rate of the capital stock

(b) Capital to HP-filtered output ratio

Figure 1: Investment activity and capital accumulation

There were three peaks in investment during the past 14 years that affected the potential growth rate, and they occurred in 1998, 2003 and 2007. The first peak was caused by increased export revenues, which were used to enlarge production capacity, and also by high FDI inflows. The occurrence of the Asian and Russian crises shortly after this peak changed the investment climate and the investment to output ratio fell back to its earlier level, but that short period of intense investment was enough to raise the capital to output ratio by about one third, from 105% to 135% of GDP. In 2003, the positive shock to investment was triggered by accession to the EU, but worked through expectations channel as the shock took place a year before Estonia actually joined the EU. The 2007 peak in the investment was generated by the loosening of the credit supply, which made it easier for companies to gain access to external financing.

It may be noticed that the turning point in capital growth appears about three quarters after the turning point in the investment to output ratio. This is caused purely by the additive process of capital accumulation. It could be argued whether the capital stock should contain any cyclical pattern at all, because it is automatically carried over to the calculation of potential growth, which is often supposed to be acyclical. In this paper it is assumed that new investment increases production capacity and therefore affect potential growth regardless of the level of volatility in capital growth. There are modelling techniques that would dampen the fluctuations in capital growth, assuming no real rigidities in investment, such as *Time to Build* concept (Kydland and Prescott, 1982) which distributes current investments over time on the grounds that it takes some time to put new equipment into operation. This is a realistic assumption but the growth in investment has been four times more volatile than the growth in aggregate output in Estonia, making swings in capital growth too large to be smoothed out anyway.

Labour input is expressed in equation 1 by its natural level. Full employment, L^*, equals $(1 - u_t^*)N_t$, where u^* is the natural rate of unemployment (NAIRU or *Non Accelerating Inflation Rate of Unemployment*) and N is the amount of labour available in the economy. The natural rate of unemployment is given for the *full time equivalent employment*. This paper considers work-time adjusted employment to be a more precise and consistent measure of the labour input than actual employment expressed as the number of people employed. As Figure 2 shows, actual employment has been growing faster than its full time equivalent, a process that can be attributed to the increased role of part-time workers. Both measures were practically equal in 1996 but have been diverging ever since. Accordingly, the number of people employed in 2009 fell only to the levels of 2005, but full time equivalent employment reached its historical lowest point. Similarly, headline unemployment has been more volatile, falling to only 4% in 2007 even though the full working-time adjusted unemployment rate was around 9% at the time.

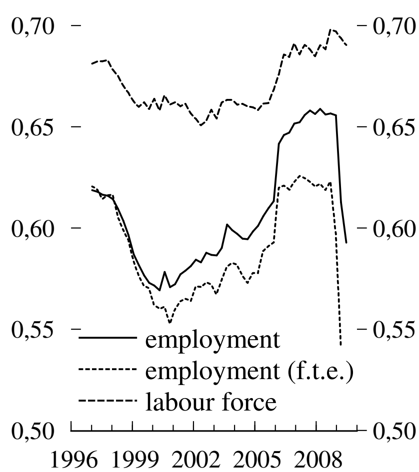
NAIRU is estimated by a state-space modelling technique. The approach is inspired by the "triangle" model of inflation[4] , developed by Gordon (1997). With some modifications to the initial model the unobserved NAIRU is filtered through the following system of equations:

$$\pi_t = \beta_1 \mathbb{E}\{\pi_t\} + \beta_2(1 - u_t^*/u_t) + \beta_3 \Delta u_{t-1}/u_t + \beta_4 \pi_t^P + \beta_5(\pi_{t-1} + \pi_{t-5}) + \nu_t, \quad (2)$$

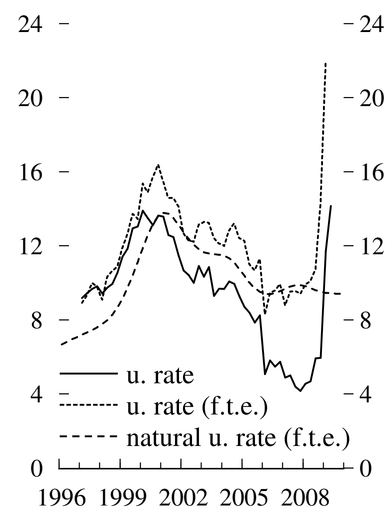
$$u_t^* = \beta_6 u_{t-1}^* + \varepsilon_t. \quad (3)$$

[4]"Triangle" in the name of the model refers to the dependence of the inflation rate on three basic determinants: inertia, demand and supply (Gordon, 1997).

The inflation rate observed, π, is a function of inflation expectations, $\mathbb{E}\{\pi_t\}$, which are proxied by the moving average of inflation of the previous four quarters. β_1 is constrained to be unity, which is necessary to have stable inflation, imposed by the definition of NAIRU. The second term stands for the unemployment gap between the measured unemployment, u (full time equivalent), and NAIRU. The unemployment gap is classified as a demand factor for inflation, creating accelerating or decelerating impulses to it. $\Delta u_{t-1}/u_t$ is inserted into the equation in order to control for any rapid changes in the unemployment rate. Supply shocks are captured by oil price movements, π_t^P, and the last regressor represents inertia in inflation. Error terms ν and ε have zero means and variations σ_ν and σ_ε. To get time-varying NAIRU the assumption $\sigma_\varepsilon \neq 0$ must hold if $\beta_6 = 1$.



(a) Labour force, actual and full time equivalent (f.t.e.) employment (mln.)



(b) Actual, full time equivalent (f.t.e.) and natural unemployment rates (share)

Figure 2: Labour market indicators

Figure 2 shows that NAIRU has followed the dynamics of the unemployment rate but stayed below it for most of the time. As well as illuminating the prevailing inflationary pressures in the economy, it also implies that the "potential" labour input of employment at the NAIRU level has, on average, been lower than the actual employment.

In the calculation of potential output it has been assumed that Estonia shares the same production technology as more developed countries, or, for ease of interpretation, with the EU-27, and that there are no restrictions on access to production technologies used worldwide. Developed countries are assumed to have reached their steady states and therefore, as neoclassical growth theory predicts, the output growth of these countries equals the speed of their technological progress. This suggests that the level of technology advances by about 2% annually in the EU-27 on average, as this is the group's average economic growth (eurostat, 2009).

The constant 2% rate of technological progress for Estonia can easily be a target for criticism because it may be undervalued, at least for the beginning of the sample. It can be argued that the production technology inherited from the planned-economy era was outdated and therefore the initial level of technology was low. Technological catch-up probably caused the speed of progress to exceed that in advanced countries, but this hypothesis remains unexplored in this paper. The possibly higher speed of progress is indirectly characterised by faster capital accumulation in the same period, as it is realistic to assume that new investments are at least partially made to replace older and less productive (technologically less advanced) physical production capital. If this is so, then higher capital growth also translates into faster technological advancement.

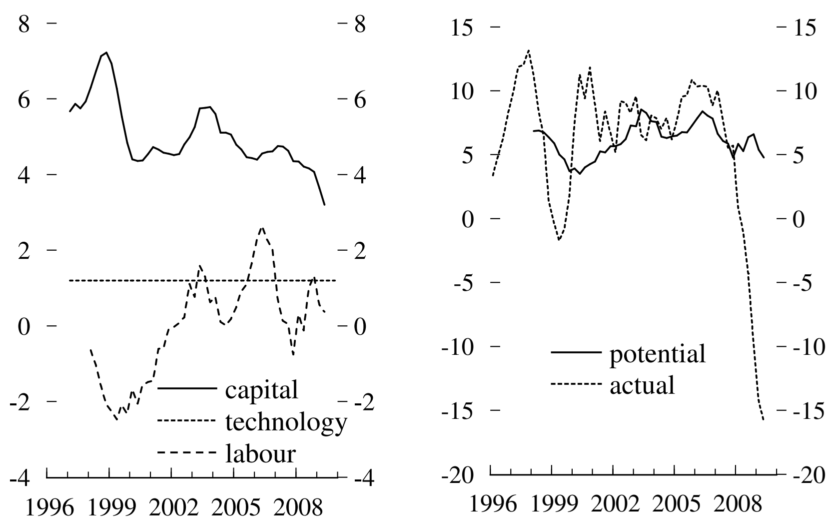
The level of technology is determined by the following accumulation process: $A_t = (1+g)A_{t-1}$ or equivalently: $A_t = A_0 e^{gt}$ for subsequent calculational convenience, where $g = 0.02$ annually. The initial level of technology, A_0, is determined by the principle that average potential output and average actual output must be equal in the long run (and in the sample): $m\{K_t^{\alpha}(L_t^* A_0 e^{gt})^{1-\alpha}\} = m\{Y_t\}$, from which:

$$A_0 = m\left\{\left[\frac{(Y_t)}{(K_t^{\alpha}(L_t^* e^{gt})^{1-\alpha})}\right]^{\frac{1}{1-\alpha}}\right\}, \tag{4}$$

where $m\{.\}$ denotes mean value. Equation 4 may however return a biased value for A_0, because the period under observation is short and contains quite large shock impulses (the Asian and Russian crises, EU accession, and the credit boom and contraction, as described above) which may have caused the mean value of actual output to differ from the mean value of potential output. As there is no reliable way to test this, it is best to treat the means as equal.

Potential output is calculated using equation 1, in which the income share of capital, α, equals 0.4. Panel a in Figure 3 plots the factor contributions to the potential growth. The greatest source of growth has been capital accumulation, which has averaged 5%. Figure 3 also reveals that despite the high investment to output ratio (see panel a in Figure 1) capital accumulation is trending downwards. The neoclassical growth model used here explains this by the continuously falling marginal productivity of the capital input, which is an expected scenario as a country develops towards a steady state.

The contribution of technological progress is constant and equals 1.2%. Labour input has contributed negatively on average, which is caused by the ageing of the population coupled with a negative natural increase rate and net emigration. Although the labour contribution has been slightly negative but close to zero on average, it has been a significant source of variation in potential growth. This is especially noticeable around 2006 when the available labour supply jumped by more than 4% (see also panel a in Figure 2). Mean potential growth has been around 6% with at least two higher growth periods culminating in 2003 and in 2006/2007, the second of these periods being mostly generated by a peak in the labour supply (see panel b in Figure 3). The earlier acceleration was mainly due to the higher level of investment, but was also supported by the favourable labour market conditions.



(a) Factor contributions to potential growth

(b) Annual growth rates of actual and potential output

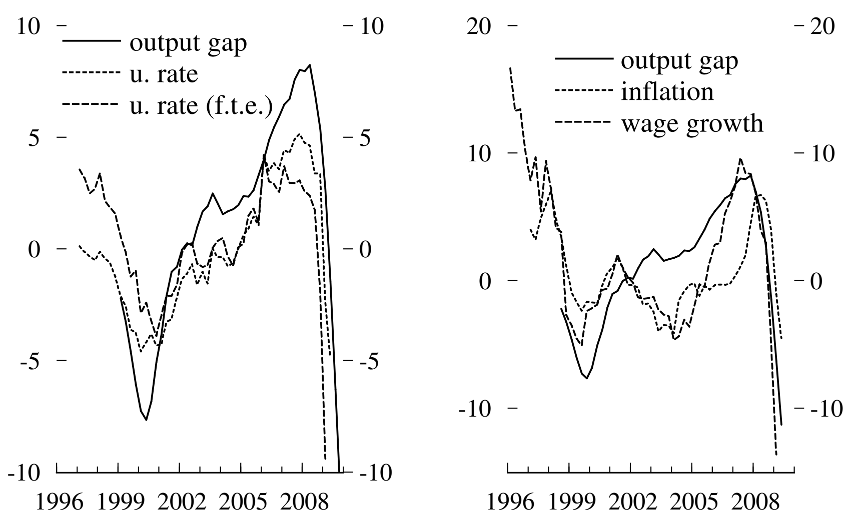
Figure 3: Potential growth rate and contributions

The output gap varied quite dramatically in 1997–2009, from lows of -8% in 1999 and -10% in 2009 [5] up to a peak of $+8\%$ in 2007. The downturn which began in 1998 with the Russian crisis was followed by a quick recovery, and the large negative gap had eroded away by 2002/2003 (see panel a in Figure 4). 2002–2003 was the most balanced growth period of the last decade, with actual output equalling the potential, in terms of both levels and growth

[5] This is the latest period of estimates. Given the previous dynamics of the output gap and the current state of the economy, the present downturn will result in a deeper negative output gap than did that of 1999. This issue is discussed in more detail later in the paper.

rates. There were no major shocks to economic growth in these years as the impacts of the Asian and Russian crises had been overcome and the boost from EU accession was still yet about to come. Furthermore, in these years the unemployment rate was fairly close to its natural level (see panel b in Figure 2). In 2004 the accession to the EU and the subsequent loosening of the credit market created a sizeable 8% positive output gap through the real estate and investment booms.

Figure 4 shows that the extracted gap series is highly correlated with other cyclical indicators. Correlation with unemployment is 0.94 or 0.64 depending on whether the actual or full time equivalent rate is considered. The actual unemployment rate follows the gap somewhat better at the end of the sample, which reflects the tensions in the labour market, generated by the boom. The sharp increase in wages, especially in the construction sector, attracted people to accept part-time jobs, not only in construction, and this widened the spread between the actual and full time equivalent unemployment numbers.



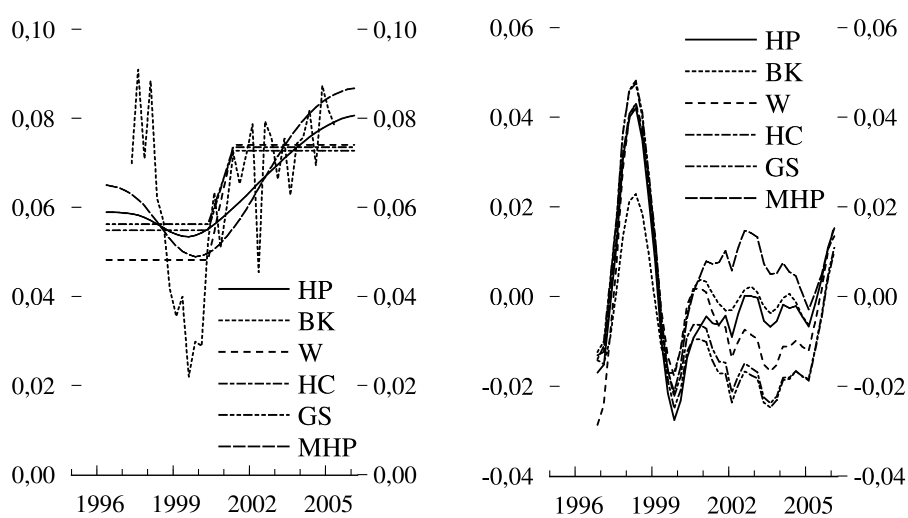
(a) Output gap (yearly average, NB!: lagged by 4q) and demeaned negative actual and full time equivalent (f.t.e.) unemployment

(b) Output gap (yearly average, NB!: lagged by 2q), demeaned inflation and nominal wage growth

Figure 4: Comparison of the output gap with unemployment and inflation

The co-movement with prices accords with the Phillips curve ideology. The correlation of the gap with wage inflation is 0.72 and with CPI inflation is 0.31. The lower correlation with CPI inflation can be explained by two major reasons: wages react first to the cycle and then via increased production costs they finally pass through to consumer prices (demand-side effects are relatively weaker); and inflation is also influenced by foreign price impulses and administrative factors, loosening somewhat the tight relation with the cycle.

An earlier study by Vahter (2006), which exploits a number of statistical filtering methods, plots a somewhat different view of potential output. The study was conducted in early 2006, which means that the output data used were of the older vintage and the study does not provide estimates of the potential output for the turbulent years 2006 and 2007, which were characterised by booms in credit, investment and real estate (the latest observation available was the first quarter of 2006). However, all the gap estimates jump upwards at the end of the sample, indicating that a phase of growth had begun by the beginning of 2006 (see Figure 5). This matches the outcome of the production function approach shown above, though the results are quite different in the other aspects.



(a) Potential growth rates (b) Output gap (yearly averages)

Figure 5: Potential growth rates and output gap estimates based on different uni- and multivariate filtering techniques (study by Vahter (2006)): Hodrick-Prescott (HP), Baxter-King (BK), Watson (W), Harvey-Clark (HK), Gerlach-Smets (GS), multivariate Hodrick-Prescott (MHP)

All the filtered gap series consistently show that there was a large positive output gap in 1997 and the response to the Asian and Russian crises in the succeeding years was only modest, so that the estimated gap was only -2% in 1999. This is completely different from the results that the production function plots, according to which the crises hit the economy while it was close to balanced growth and consequently pushed it below its potential. Filtered data from Vahter (2006) would suggest that the crises pushed the overheating economy back to its long-term output level rather than hurting the prospects for growth. There is a lot of variability in the filtered gap estimates for the years 2001–2005. Three of them — the uni- and multivariate Hodrick-Prescott and the Baxter-King filters — are close to zero and more comparable to the result obtained from the production function. The remaining three gap estimates are negative, as the methods of Harvey-Clark, Gerlach-Smets and Watson basically show no recovery from the downturn at the end of the nineties.

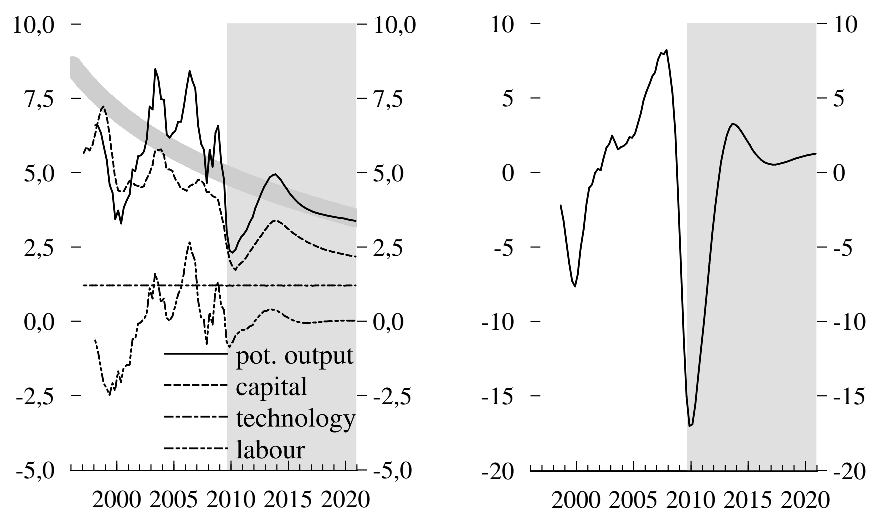
Panel b in Figure 5 also reflects the possible end-point problem as all the filtered potential output series tend to match the actual output at both ends of the sample, with the gap close to zero. Interestingly the uni- and multivariate filters both show the same pattern, although the multivariate filters should be less sensitive to the problem. The possible end-point problem indicates that the high positive gap in 1998 is most likely overestimated and the negative gap in 1999 underestimated.

These previous considerations, taken all together, would imply that the potential growth rates presented in Figure 5 are likely to be underestimated in the first part of the sample and overestimated at the end of the sample. All filtering techniques generate an upward trending potential growth rate, which may be a consequence of the statistical approach, allowing the potential output to follow the actual data too closely. The difference between the filtered and the production function based outcomes may also be due to the data revisions in between the two studies, although methodological issues can not be ignored.

3. Projection of potential growth and the output gap

The macro-econometric model of the Estonian economy, EMMA (Kattai, 2005), is used to produce a forecast of potential output and the output gap. The equations for potential output are those described earlier in this paper. The forecast starts from the third quarter of 2009 and runs up to the end of 2020. Simulations are run without any add-factors or adjustments from outside the sample. The state sector is set to follow the most conservative rule, that its expenditures must equal its earned revenues. Therefore the state sector is not able to smooth the cycle in the simulations. The results are in no way a part of the official forecast of Eesti Pank, they only represent the outcome of an independent simulation exercise related to the macro model's long-term properties.

Panel a in Figure 6 shows that after the recovery from the down-phase, potential growth stays between 4 and 5% during the next five years, until 2015. Before elaborating this outcome in detail, the long-term properties of the whole model should be discussed. In the model long-term growth is determined by the aggregate supply of companies. All companies share the same production function defined in equation 1, and they set the level of production by choosing inputs that would maximise their profits. Companies are operating in an economy that is catching-up, and they face falling marginal productivity of capital. This explains the relatively higher growth of capital stock (and potential output) when the capital to output ratio is low. In the long term, the capital to output ratio is expected to reach its optimal level, after which the mature economy will grow at the rate of technological progress. Until that point is reached, a steady decrease in potential growth can be witnessed. If the economy is hit by neither shocks nor structural shifts, the underlying theoretical framework would project a very smooth downward trending potential growth rate over the course of capital deepening. The grey shaded line in Figure 6 illustrates the likely outcome in that case (the line is purely theoretical not computational).



(a) Potential growth and factor contributions

(b) Output gap (yearly moving average)

Figure 6: Forecasts of the potential growth rate, factor contributions and output gap

Any departure from the purely theoretical grey line may, and indeed should, be related to a specific shock or to a structural or institutional change in the economy. It has already been shown that around 2002–2003 the gap was close to zero and that actual growth equalled its potential (see Figure 4), therefore the shaded line crosses the calculated potential growth at this period. In the preceding period the shaded line is above the calculated potential growth, meaning that if access to credit had been as easy as it was after 2005, then companies would have invested more because of the higher marginal productivity of capital, and capital stock would have grown faster, boosting the potential growth. The structural shift occurred in 2005 when the liberalisation of the credit market eased external financing. Combined with the contemporaneous increase in the labour supply, this resulted in a peak in potential growth in 2006–2007. This probably would not have occurred, or at least not so sharply, if the financing conditions had been the same over the whole period.

Extracting the shock impulses from the calculated potential growth series for 1997–2009 would generate a trend-line similar to the grey line that is predicted by the theory. Therefore a fall in potential growth in the next few years cannot be treated as a step downwards but as a transition to an underlying shock-free trend growth. The fall in potential growth around 2010 is caused by a cut in investments as bank loans become less accessible than they used to be. The additive process of capital accumulation shifts the cycle in the growth of the capital stock forwards by about three qaurters compared to the cycle in investments. Consequently the low point in investing activity shows up in the capital stock three quarters of a year later, while a recovery in investments takes the same time to affect the capital stock and thereby potential growth. The latest crisis episode has been more severe than was the slowdown in 1999, as potential growth sinks to -2.5% in 2010.

The figure of $4 - 5\%$ growth is obtained under a believably optimistic assumption of zero growth in the labour supply. If the upward shift in the labour supply in 2006 (see panel a in Figure 2) was not structural but cycle-generated, then it should be followed by a decline and the contribution of the labour input should become negative.

Another assumption that has an impact is the constant rate of technological progress. In this case a conservative point of view is taken, which foresees no technological breakthrough. If such a breakthrough were to happen, it would add extra growth to the potential output, but exploring this lies beyond the scope of the present paper.

The period starting from 2015 describes how the economy will probably evolve in a longer perspective. In this case the outcome is no longer driven by the inertia from the earlier shocks, as the impact of the shocks has vanished and new shocks have not been added, but by the macro-model's theoretical underpinnings. Now the concept of convergence prevails, the closing of the gap between the *per capita* income levels of Estonia and the EU. In 2008 the relative income in Estonia was 67.4% of that in the EU-27 in purchasing power parity terms (PPP) [6] , which is a great improvement from the lowly 45% of 2000 (eurostat, 2009). Although average growth in the forecast period is lower than the historical average, it still remains higher than in the EU-27, and the gap is closed over time. According to the theory, the growth rate declines smoothly until real convergence is achieved, after which Estonia will share the same steady growth rate with the EU, there is no kink in growth when income levels have converged.

The forecast for the output gap shows a rapid response to the high values seen earlier, and it drops to about -17% by 2010 (see panel b in Figure 6). The downswing is greater than the preceding upswing, indicating the vulnerability of the economy. On the other hand, the predicted recovery from the lowest point is quite fast. 2010 marks the bottom of the cycle, after which growth starts to pick up. Investments will start to grow again and build up the capital stock, supporting potential growth. The exit from the trough will generate a slight positive gap because of inertia in several variables.

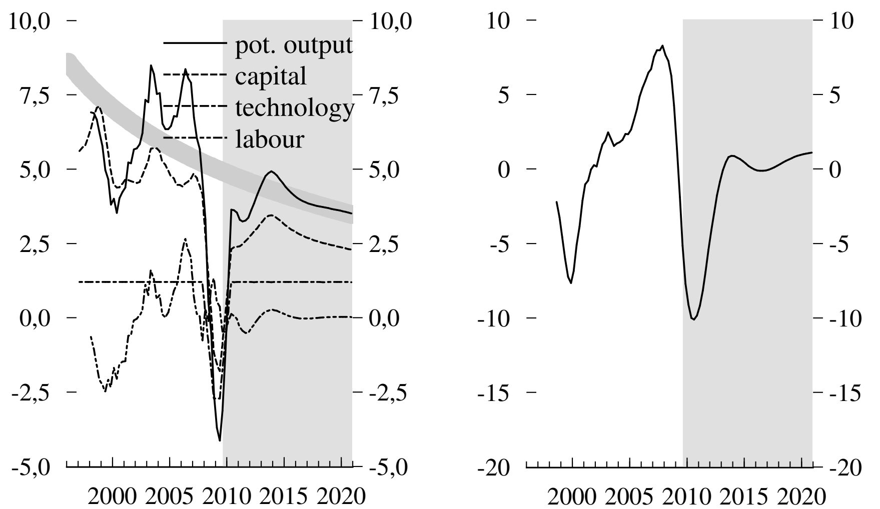
Crisis episodes are often related to a fall in the level of potential GDP, which may be permanent or temporary depending on the sources of growth of the country (see for example Reinhart and Rogoff (2009), Haugh et al. (2009)). European Commission (2009) assumes that the cumulative fall in the EU-8 as a result of the global crisis will average 5.9%. The macro model is used to run another simulation which mimics this fall to assess the consequences on later potential growth in comparison to the previous exercise. In order to test the scenario, the levels of technology and capital stock are negatively shocked during 2008q1–2009q2. The decline in both can be justified because investments made in the boom phase were tilted towards specific sectors, such as construction and real estate, and the capital stock generated and the technology brought in do not necessarily match the new demand structure. The beginning of the adjustment period coincides with the turning point for economic growth, and the adjusted period overlaps most of the substantial drop in output. The drop in production capital and technology is hypothetical and is specific to the current scenario analysis, as the event itself remains unquantifiable at the present time and can only be witnessed *ex post*.

Figure 7 depicts the outcome of the simulation. Panel a demonstrates the negative growth of the capital and technology inputs and consequently of potential output. In level terms it translates into a fall during the predetermined $1^1/_2$ years of 5.9%. From 2010, after the forced adjustment, the model predicts comparable potential growth to the scenario without the sudden drop in production capital and technology, as growth stays between 4 and 5% in the

[6]The estimated relative income level for 2009 is 59.3%.

following five years and between 3 and 4% after that. Since there is no post-shock acceleration in growth, GDP stays permanently lower than it was in the first simulation.

Due to the fall in potential GDP, the gap does not reach the same negative levels that it did in the previous case. The lowest point is approximately -10% in 2010, although this is still greater than in 1999. The speed of recovery, the time it takes the gap to return to zero, is independent of whether the underlying trend GDP shifts or not. The economy adjusts in the same time frame but to different levels.



(a) Potential growth and factor contributions

(b) Output gap (yearly moving average)

Figure 7: Forecasts (shaded area) of potential growth, factor contributions and the output gap with a permanent shift in the level of potential output

Detecting a downward shift in potential GDP is possible only *ex post*, so for now it can only be considered as a hypothetical scenario. Whether this scenario materialises or not, the model simulations prove that in terms of growth the economy is expected to return to its pattern of long-term growth. Unless there is an acceleration in technological advancement, potential growth settles to a more modest rate of around $4 - 5\%$ initially, that is in the next five years, then decreases steadily afterwards as the economy matures. Rather than being sudden or unexpected, as it may seem in comparison to the earlier credit-accelerated growth, a fall in the growth rate from its high historical values actually follows the rules of growth theory, suggesting that as income levels increase, economic growth steadily slows down.

4. Conclusions

Understanding of what Estonia's potential growth rate is has changed during recent years because of the frequent revisions of output statistics. Estimating unobserved potential GDP is made more difficult because the time series is so short, covering only the last 12–13 years, depending on the selected variables. Although relatively short, however, this time span is rich in shock episodes. In the beginning of it domestic output was heavily affected by the Asian and Russian crises, then EU accession soon after opened new growth channels and boosted growth, which was later reinforced by the credit boom, which ended after the unfavourable shocks from the global crisis. These events form one full cycle, within which potential GDP has to be detected.

Using the latest data vintage available, the production function approach returns 6% average potential growth for the period 1997–2009, although there are quite sizeable peaks, which are generated by the shocks listed earlier and by structural changes such as shifts in the labour supply for example. These factors have also made the gap fluctuate quite widely from -8% in 1999 to $+8\%$ in 2007.

The model-based forecast shows that sources of high growth have vanished and unless an unforeseen technological breakthrough happens, potential growth will settle on a more stable but considerably lower path. This finding is, of course, conditional on the method chosen, in this case the production function approach, which predicts falling marginal returns on production inputs and therefore steadily slowing potential growth. This happens until the economy matures and reaches its steady state.

The predicted potential growth rate lies between 4 and 5% in the next five years and between 3 and 4% in the years after that. These rates are realistic if there are no major shocks, negative or positive, which could bend potential growth downwards or upwards. In any case, the present paper does not aim to provide the most precise prediction of potential output growth but uses numerical model simulations to consider that the sources of rapid growth have already been used up to a large extent over the course of economic development, and average growth in the future will remain lower than the historical average. The productivity of one additional unit of a production input, like an investment in fixed capital or technology, is lower than before, and therefore trend growth also slows down. The actual measured growth rate may depart from trend growth depending on the cyclical movements.

Recent data shows that the ongoing downturn is more severe than that of 1999. Model simulations, however, predict quite a quick recovery from the lowest point, at which the output gap reaches -17 or -10% depending on whether the capital generated in the boom times matches the new demand structure or not. In the first case the negative output gap is more pronounced but the economy adjusts back to its previous GDP level, but this does not happen in the second case when the accumulated production capacities cannot be fully used to meet the new demand structure. In this second case the negative gap is smaller but at the cost of a fall in the level of potential, and actual GDP. It can only be verified *ex post* whether the former or latter holds, once there is enough data on the adjustment of the economy.

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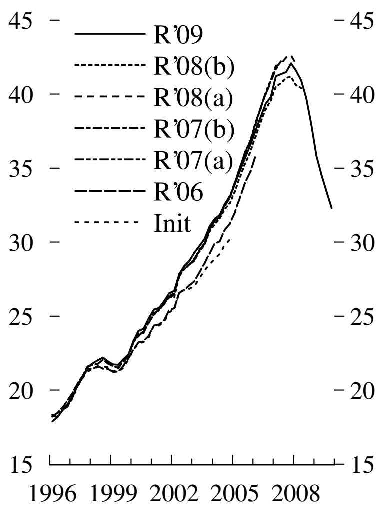
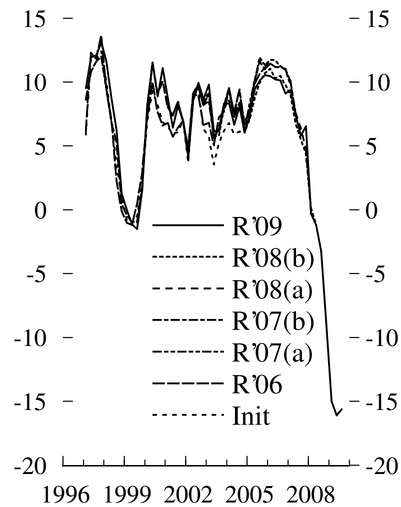
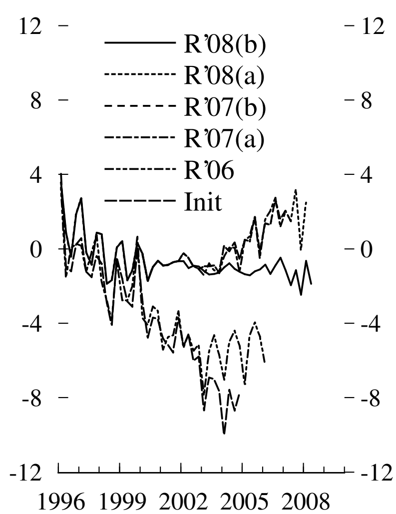
Appendix 1. Output revisions



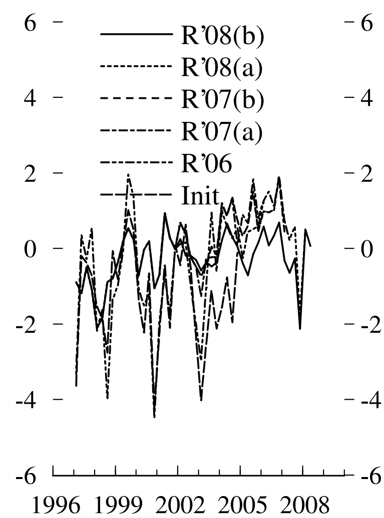
(a) Revised output series, seasonally adjusted (billion kroons)



(b) Revised output growth series (%)



(c) Deviations of earlier vintages of GDP level data from the latest release (%)



(d) Deviations of earlier vintages of GDP growth data from the latest release (*pp.*)

Figure 8: Output statistics and their revisions by successive vintages: data available in 2006 (Init), revised in 2006 (R'06), first revision in 2007 (R'07(a)), second revision in 2007 (R'07(b)), first revision in 2008 (R'08(a)), second revision in 2008 (R'08(b)), last available vintage (R'09)

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