

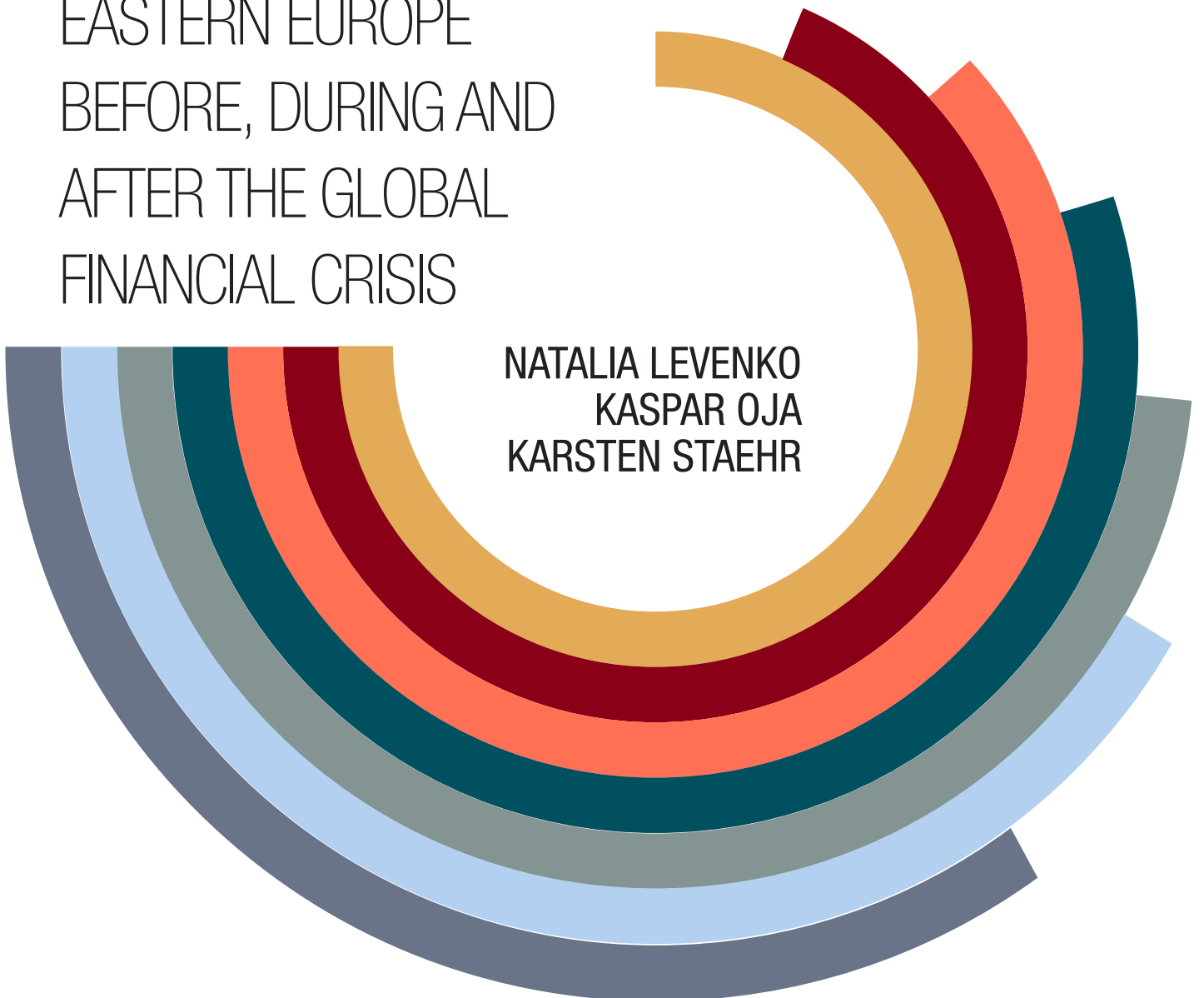


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TOTAL FACTOR PRODUCTIVITY
GROWTH IN CENTRAL AND
EASTERN EUROPE
BEFORE, DURING AND
AFTER THE GLOBAL
FINANCIAL CRISIS

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Total Factor Productivity Growth in Central and Eastern Europe before, during and after the Global Financial Crisis

Natalia Levenko, Kaspar Oja and Karsten Staehr^{*}

Abstract

This paper conducts growth accounting for 11 EU countries from Central and Eastern Europe for the years 1996–2016. Its contributions include the estimation of new capital stock series, adjustment for the utilisation of the capital stock and a time-varying elasticity of output to capital. Before the crisis, growth in total factor productivity (TFP) was the main contributor to output growth in Slovenia, Hungary and Slovakia, while capital deepening was more important in the Czech Republic, Croatia and Poland. During the global financial crisis the contributions of TFP and capital growth differed markedly across the countries, reflecting the very diverse dynamics of the crisis. After the crisis the contribution of TFP growth has been negligible in all of the sample countries coinciding with generally weak output growth. The results are generally robust to changes in estimation methods and parametrisations, but some assumptions are critical for the results.

JEL Codes: F43, O47

Keywords: growth accounting, capital stock, perpetual inventory method, total factor productivity, global financial crisis, Central and Eastern Europe

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Non-technical summary

This paper presents the results of growth accounting for the 11 countries from Central and Eastern Europe (CEE) which joined the European Union in 2004, 2007 or 2011. These are Bulgaria, the Czech Republic, Estonia, Croatia, Latvia, Lithuania, Hungary, Poland, Romania, Slovenia and Slovakia. Growth accounting implies the decomposition of growth in output into contributions from growth in production inputs and a residual which is customarily labelled total factor productivity (TFP).

Growth accounting is particularly pertinent in the CEE countries as they have exhibited unusually volatile growth dynamics since the mid-1990s, implying an uneven convergence process. The countries generally saw robust economic growth from the middle of the 1990s to 2007, then deep setbacks during the global financial crisis in 2008 and 2009 and timid economic recoveries from 2010.

The paper contributes to the literature on growth accounting for the CEE countries in several ways. First, it extends the sample of earlier studies to the years 1996–2016, providing an extended period with one or two full business cycles in most of the countries. Second, the long sample affords a detailed analysis of the contributions of capital and TFP growth before, during and after the global financial crisis. Third, the capital stock is computed using the perpetual inventory method as is customary in the literature, but the data are filtered to remove cyclical components. Fourth, the analysis takes into account the utilisation of the capital stock by using data on capacity utilisation in manufacturing. Finally, the paper contains numerous robustness checks and sensitivity analyses, including simulation studies, providing important insights into the importance of various assumptions.

For the full sample 1996–2016, average GDP growth was generally higher in the CEE countries than in the reference group of the 15 EU countries from Western Europe. On average capital deepening accounted for approximately half, TFP growth for approximately one third, and increased utilisation of capital for the remaining one sixth of GDP growth, while changes in employment did not matter much. These results are however averages; there is indeed substantial variation over time and across the countries.

During the boom in 2002–2007, TFP growth accounted for approximately half of GDP growth and capital deepening for around one third, while higher employment and capital utilisation accounted for the rest. There is substantial heterogeneity across the countries. Slovakia and the Baltic states stand out for very high rates of economic growth and large contributions from TFP growth, while economic growth in Poland, Hungary, the Czech Republic and Slovenia was less brisk and TFP growth was less important in at least some of these countries.

Developments differed markedly across the CEE countries during the global financial crisis in 2008–2009. The Baltic states experienced very large output declines, while Poland and to a lesser extent Bulgaria, Romania and Slovakia weathered the crisis without loss of output. It is notable that the capital stock continued to grow at a brisk rate in all CEE countries during the crisis years, but the rate of utilisation of the capital stock decreased markedly. This shows the importance of taking capital utilisation into account in growth accounting as

the TFP contribution will otherwise be underestimated during downturns like those experienced by many CEE countries after the global financial crisis.

Economic growth has been subdued in the CEE countries since the global financial crisis. The growth accounting reveals that capital deepening and increased capital utilisation have contributed in equal proportions to economic growth, while TPF growth has been virtually absent in most CEE countries in this period. The lack of TFP growth is holding back the catching-up process and casts doubt on the ability of these countries to sustain growth without increased use of resources. The modest TFP growth and its causes in the CEE countries after the global financial crisis are areas warranting further analysis and research.

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1. Introduction

This paper presents the results of growth accounting for the 11 countries from Central and Eastern Europe (CEE) which joined the European Union in 2004, 2007 or 2011. These are Bulgaria, the Czech Republic, Estonia, Croatia, Latvia, Lithuania, Hungary, Poland, Romania, Slovenia and Slovakia. Growth accounting implies the decomposition of growth in output into contributions from growth in production inputs and a residual labelled total factor productivity. Growth accounting is an important first step towards understanding the drivers of economic growth in an economy (ECB, 2005).

Growth accounting is particularly pertinent in the CEE countries as they have exhibited unusually volatile economic growth since the mid-1990s, implying an uneven catching-up process. The countries generally saw robust economic growth from the middle of the 1990s to 2007, then deep setbacks during the global financial crisis in 2008 and 2009 and timid economic recoveries from 2010. Within this overall pattern there is substantial variation across the 11 CEE countries, suggesting that growth may have been driven by different factors in different countries.

Most CEE countries saw rapid economic growth, rapid capital accumulation and large current account deficits in the years before the global financial crisis. Growth accounting may provide important insights into the dynamics and sustainability of such growth spurts. Krugman (1994) and Young (1995) noted that the very rapid economic growth of 6–7 per cent per year experienced by the East Asian tiger economies before 1997 came mainly from accumulation of capital, not total factor productivity growth. Krugman (1994) used this finding to question the longer-term sustainability of the growth performance of the tiger economies, arguing that they were vulnerable to changes in international financing conditions. These worries proved vindicated when the Asian crisis broke out in 1997.

The global financial crisis affected the CEE countries very differently; output declined in total by 20 per cent or more in the Baltic states over 2008 and 2009, while Poland maintained positive rates of growth throughout the crisis. How various factors contributed to GDP growth during the crisis may provide insights into the reasons for these diverging developments. Fernald and Matoba (2009) argue that GDP declined in the USA largely because employment fell and the utilisation of the capital stock was reduced, while TFP growth held up relatively well.

Economic growth has generally been subdued in the CEE countries since the global financial crisis. This has led to concerns that the CEE countries may risk getting caught in a middle income trap with low growth and very slow catching-up (Staeher, 2015).¹ A first step towards understanding the slowdown in growth would be to examine how far it is associated with slower growth rates of capital and total factor productivity (Dimelis and Dimopoulou, 2002). Such an analysis may also give an indication of the prospects for economic growth in the years ahead.

Growth accounting provides an immediate gauge of the challenges for growth in an economy (Hulten, 2001). Total factor productivity growth is the residual that is left when the

¹ A related discussion emerged in the USA after Summers (2013) asked whether the USA was caught in secular stagnation after the crisis.

effects of other factors that impact economic growth have been accounted for. This residual has been labelled the Solow residual, and has been called manna from heaven because TFP growth boosts GDP growth without requiring the use of additional resources. A less favourable labelling of the Solow residual is as a “measure of our ignorance” (Abramovitz, 1956, p. 11).

TFP growth has been depicted as a rough proxy of technical change (Solow, 1957); a measure of changes in production technology or technical progress (Hoekman, 2007); a measure of productivity, efficiency and technological change, or unexplained growth (Dimelis and Dimopoulou, 2002); and changes in institutions and a backwash of armed conflicts (Baier et al., 2006). TFP growth may also embody the effects on production of externalities, changes in the sectoral composition of production (Easterly and Levine, 2002), or the quality of institutional factors and management of the economy (Fischer, 1993). We simply take TFP growth as the share of economic growth that is not determined by changes in employment or physical capital utilised; we focus on the developments of TFP growth and do not seek to explain the factors behind these developments.

Numerous studies have reported results from growth accounting since the pioneering work of Abramovitz (1956) and Solow (1956). Rapacki and Prochniak (2009) provide a list of publications using growth accounting and which are published between 1994 and 2005. A key finding is that the level and dynamics of the estimated TFP growth vary considerably across countries and sample years, and this indeed underscores the need for such analyses for each case of interest.

A number of studies provide results for a large number of countries.² Baier et al. (2006) consider 145 countries over 57 years and find that TFP growth makes an unimportant contribution to average output growth. TFP growth is on average only 0.13 per cent per year and amounts to approximately 8 per cent of the growth in total output per worker. TFP growth in Western European countries and in Newly Industrialised Countries contributes 18–25 per cent of overall growth, while countries in Central and Eastern European, Central and Southern Africa, and the Middle East often exhibit negative TFP growth.

Dimelis and Dimopoulou (2002) decompose economic growth in the EU countries before and after the introduction of the Maastricht Treaty in 1992. The period 1981–1996 is divided into three sub-periods and TFP growth is found to have been the main source of growth in all three sub-periods. However, most of the EU countries experienced recessions at some point in 1986–1991 and TFP growth generally decelerated in those years.

Though growth accounting studies are numerous, there are only a few that cover the CEE countries and then they typically only cover the catching-up phase before the global financial crisis. Vanags and Bems (2005) is an early study covering the three Baltic states and the years 1996–2003. The contribution of TFP growth is found to vary between 45 and 60 per cent of total GDP growth. The authors conclude that the growth dynamics of the Baltic states in the early transition phase resembled those of major European countries during the Bretton Woods era but not those of the Asian tiger economies.

² Summers and Heston (1991) and Maddison (2007) report data on TPF growth for a very large number of countries but do not explicitly state the method and assumptions used.

Arratibel et al. (2007) find that TFP growth contributed more to GDP growth than capital accumulation did during the catching-up process in the eight CEE countries that joined the EU in 2004. They argue however that the importance of accumulation might be underestimated given that investment may promote innovation and knowledge transfer. Iradian (2007) examines the contribution of capital, labour and TFP growth in the transition countries for the years 1996–2006. TFP growth accounted for 25–49 per cent of overall growth in the CEE countries, which is a higher contribution from TFP growth than is often found in fast growing economies.

Rapacki and Prochniak (2009) consider 27 transition economies in Europe for the years 1990–2003. They calculate the capital stock series using the perpetual inventory method, but the initial capital stock is determined simply by setting the capital-output ratio at either 3 or 5. The Baltic states had the fastest rates of TFP growth among the CEE countries in the sample while the Czech Republic and Hungary had the lowest rates.

The only study to include the crisis period and its immediate aftermath is Dombi (2013a). The study provides growth accounting results for 10 CEE countries in 1996–2012.³ The main source of economic growth is found to be capital accumulation, which is probably due to the low capital intensity and comparatively low TFP growth in the beginning of the sample. The results are different however for the catching-up years 1996–2007 and the crisis years 2008–2012. Dombi (2013a) also finds notable differences between a group consisting of the Visegrad countries and Slovenia and a group of lesser-developed countries consisting of Bulgaria, Romania and the Baltic states.

This paper contributes to the literature on growth accounting for the CEE countries in several ways. First, it extends the sample of earlier studies to the years 1996–2016, providing an extended period with one or two full business cycles in most of the countries. Second, the long sample affords a detailed analysis of the contributions of capital and TFP growth before, during and after the global financial crisis. Third, the capital stock is computed using the perpetual inventory method as is customary in the literature, but the data are filtered to remove cyclical components. Fourth, the analysis takes into account the utilisation of the capital stock by using data on capacity utilisation in manufacturing. Finally, the paper contains numerous robustness checks and sensitivity analyses, including simulation studies, providing important insights into the importance of various assumptions.

The rest of the paper is organised as follows. Section 2 describes the methodology of growth accounting, including the challenges that the perpetual inventory method raises. Section 3 discusses the data sources and model parameters used. Section 4 presents the baseline results using the full time sample and various subsamples. Section 5 provides the results of various robustness checks, including simulation exercises. Finally, Section 6 contains the concluding comments.

³ Dombi (2013b) covers the period 1996–2007 but provides more detailed documentation of the method and data used.

2. Methodology

The starting point for all growth accounting studies is a hypothesised aggregate production function (Abramovitz, 1956; Solow, 1957). We prefer the rather general specification $Y_t = A_t F_t(h_t K_t, L_t)$. The variable Y_t is output or value added in period t . The variable K_t is the economy-wide capital stock available at the beginning of period t , while $h_t \in (0, 1)$ is the rate of capital utilisation in period t so $h_t K_t$ is the capital actually utilised for the production of Y_t . The variable L_t is employment, $F_t(\cdot)$ is an aggregator function, and A_t is a factor scaling the aggregator typically interpreted as total factor productivity (TFP). If the production function is time differenced and perfect competition and constant returns to scale are assumed, the growth rate of output can be written as:

$$\frac{\Delta Y_t}{Y_{t-1}} \approx (1 - \alpha_t^K) \frac{\Delta L_t}{L_{t-1}} + \alpha_t^K \frac{\Delta K_t}{K_{t-1}} + \alpha_t^K \frac{\Delta h_t}{h_{t-1}} + \frac{\Delta A_t}{A_{t-1}} \quad (1)$$

The operator Δ denotes the first difference. The term α_t^K is the elasticity of output to capital utilised in period t ; it is assumed to be time-varying, reflecting that the aggregator function $F_t(\cdot)$ can vary over time. Notice that we do not impose the assumption of the aggregator function $F_t(h_t K_t, L_t)$ being a Cobb-Douglas function. This is indeed the reason for the elasticity α_t^K being allowed to vary over time.

Eq. (1) decomposes output growth into components stemming from growth in employment, growth in available capital, growth in capital utilisation and, finally, the Solow residual or TFP growth, $\Delta A_t / A_{t-1}$. Data on output and employment are readily available, but data on the available capital stock, capital utilisation and elasticity of output to capital must be computed.

2.1. The capital stock

Existing data on the capital stock for the CEE countries are generally subject to some concern as there are many missing observations while the dynamics do not appear reasonable for many of the countries (see Subsection 4.1). This applies to data from Eurostat and Ameco, the Macroeconomic database of the European Commission. The key endeavour is thus to produce reliable estimates of the available capital stock. Most studies in the literature use the perpetual inventory method, which computes the capital stock as the sum of past investments net of depreciation. The starting point is the capital accumulation equation according to which the capital stock K_t in the beginning of period t can be written as:

$$K_t = K_{t-1} - \delta K_{t-1} + I_{t-1} \quad (2)$$

The variable I_{t-1} is the investment in period $t-1$. It is assumed that a fixed fraction $\delta \in (0, 1)$ of the capital stock is worn out or depreciated every period, so δK_{t-1} is the capital depreciation in period $t-1$. Iterating eq. (2) gives the capital stock as a weighted infinite sum of all historical investment rates:

$$K_t = \sum_{i=1}^{\infty} (1-\delta)^i I_{t-1-i} \quad (3)$$

Investments are evidently not known for an infinite number of periods. If, however, the capital stock can be calculated for one particular period, then the capital stock series for the entire sample period can be computed by forward or backward iteration of eq. (1). The known capital stock serves essentially as an “anchor” for the whole capital series and we therefore label it the anchor capital stock and the corresponding period the anchor period.

Most growth accounting studies use the first year of the sample as the anchor year. This choice reduces the importance of the estimate of the anchor capital stock for the estimates of the capital stock for the later parts of the sample. Given the extreme volatility in the CEE countries in the beginning of the sample, we believe that it is not suitable to use 1995 or 1996 as the anchor year but prefer instead to use a later year when the transition process was largely complete and all of the CEE countries had relative stable environments with positive rates of economic growth.

This discussion raises the issue of how to find an estimate of the anchor capital stock given that no reliable capital stock data are available.⁴ Using eq. (2) it is straightforward to show that the growth rate of the capital stock is $\Delta K_t / K_{t-1} = I_{t-1} / K_{t-1} - \delta$. If the economy is in a steady state in the anchor period T , then the capital stock grows at a constant rate, \tilde{g}_K . The investment in the anchor period T is labelled \tilde{I}_T , where the tilde indicates that it is the steady state investment for the anchor period, not necessarily the actual investment in the period. The capital stock in the anchor period, \tilde{K}_T , is then:

$$\tilde{K}_T = \frac{\tilde{I}_T}{\tilde{g}_K + \delta} \quad (4)$$

It follows from eq. (4) that to compute the anchor capital stock we need measures of the steady-state investment \tilde{I}_T in the anchor period, the steady-state growth rate of capital \tilde{g}_K and the depreciation rate δ .

The investment \tilde{I}_T in steady state is time dependent and this underscores the importance of choosing the anchor year carefully so that the economy can reasonably be considered to be in a steady state in the year chosen. The actual investment in the chosen anchor year will in any case be affected by various shocks and these need to be eliminated.

The steady-state growth rate of capital, \tilde{g}_K , can be computed in various ways. One option is to use the growth rate of investment (De la Fuente and Doménech, 2006; Berlemann and Wesselhöft, 2014; OECD, 2009), while another option is to use the growth rate of output since the growth rates of the capital stock and output are identical in steady state (Harberger, 1988). It may be necessary to remove the effects of various shocks to the growth rate of

⁴ Besides the perpetual inventory method two alternative methods have been used for calculating the initial or anchor capital stock. One is to compute the capital-output ratio in the first year from, for instance, the capital-output ratio in the last observable years or from the labour-output ratio in the first years (Nehru and Dhareshwar, 1993; Berlemann and Wesselhöft, 2014). Another way is to construct a very long artificial investment series assuming a constant growth rate for investment (Jacob et al., 1997; Kamps, 2006). These methods have substantial limitations for catching-up economies.

investment or output. The steady-state growth rate of capital can for instance be found by HP-filtering or averaging the growth rate of investment or output. Alternatively it can be found by regressing the log investment on time (Berlemann and Wesselhöft, 2014).⁵

The depreciation rate δ is of key importance both for the capital stock in the anchor period and for computing the capital stock from period to period, cf. eq. (2). It is customary in the literature to assume that the depreciation rate is constant over time and typically also across countries. We follow the same approach, partly to ensure that any differences in the results across countries do not arise from different depreciation rates being used. An arguably superior way of estimating the depreciation rate would be to use a weighted average using the shares of different types of capital stock as weights. In practice this is not feasible due to data availability issues.

2.2. Capital utilisation

Solow (1957) stressed that it is capital in use that enters the production function, not capital in place. The estimates of TFP growth will incorporate changes in capacity utilisation if the capital stock is not adjusted to match changes in the utilisation of it (Mourre, 2009). Leaving out the utilisation of the capital stock would typically lead to TFP growth being underestimated during downturns when capital is left idle, and overestimated during booms when capital utilisation is high.

It is particularly important to account for the utilisation of capital in the CEE countries for two reasons. First, during the transition process in the 1990s the CEE countries experienced structural reforms and large declines in output. This created dead capital, or structurally unused capital, that was left over from the era of central planning and which was unusable under the new market economic conditions (Campos and Coricelli, 2002; Izyumov and Vahaly, 2008; Bah and Brada, 2009). Estimates of dead or unused capital in the transition economies differ a lot across various studies.⁶ Second, the CEE countries have had unusually large business cycles throughout the sample years resulting in downturns with notable under-utilisation of the installed capital stock. This was for instance prevalent after the global financial crisis when many of the countries experienced deep recessions.

A key question is how the rate of utilisation of the capital stock can be measured and incorporated into growth accounting. Solow (1957) uses the unemployment rate to estimate the utilisation of capital, arguing that labour and capital may more or less be utilised to the same degree. He admits that this is not the best proxy for capital in use, but it does to some extent take account of cyclical movements in the economy.

Izyumov and Vahaly (2008) argue that it is possible to account for the weak capacity utilisation in the early transition period by applying a higher rate of depreciation during this

⁵ The methods give identical results if the smoothing parameter is sufficiently large.

⁶ It is uncertain how much of the capital stock was made obsolete during the transition period. Bah and Brada (2009) consider different studies and conclude that the decline in the capital stock in the early transition period was about 50 per cent. Izyumov and Vahaly (2006) report figures between 15 and 50 per cent of the capital stock. Campos and Coricelli (2002, p. 806) simply state: “We do not know much about what happened to communist capital. Did it depreciate very fast? How much of it was reallocated to the emerging private and informal sector?”

period. This method is however only applicable in the early transition period in the 1990s and not in later periods. Moreover, some CEE countries saw very large output declines after the transition while others saw smaller declines so there is no reason to expect that the same higher depreciation rate would apply for all CEE countries (Brada, 1989).

We believe the most appropriate approximation is obtained by using the capacity utilisation in manufacturing as a proxy for the utilisation of capital in the entire economy, effectively assuming that capital is utilised in other sectors of the economy at the same rate as in manufacturing. The same approach is used in Kuboniwa (2011).⁷ An advantage of using capacity utilisation as a proxy for the economy-wide utilisation of capital is that it can account both for idle or dead capital that is due to the transition process, and for idle capital that is due to standard business cycles.

The utilisation of capital may be incorporated in growth accounting either by adjustment of the capital stock series using data on capacity utilisation, or by inclusion of changes in capacity utilisation as a separate factor. This paper uses the second approach and thus obtains a separate estimate for the importance of changes in the utilisation of the available capital stock.

2.3. The elasticity of output to capital

The elasticity of output to capital is another key variable in the decomposition. The variable is not directly observable but the assumptions of constant returns to scale and competitive markets mean that the elasticity of output to capital, α_t^K , is equal to the share of capital income in total income or, alternatively, to one minus the estimate of the share of labour income in total income.

Estimating the elasticity from the income shares can lead to biased estimates if the assumptions are not satisfied. This may for instance be the case if spillovers of capital or other sources of increasing returns to scale are quantitatively important (Barro, 1998). Caselli and Feyrer (2007) note that capital income includes not only the returns to reproducible capital, but also the returns to non-reproducible capital such as land and natural resources. The perpetual inventory method implies that the capital stock is computed using investment flows that represent only the reproducible capital stock, and so standard measures of the elasticity of output to capital may lead to the marginal productivity of reproducible capital being overestimated.

Some growth accounting studies compute the elasticity of output to capital using annual data on income shares, with the result that the elasticity is time-varying. This is the approach followed in this paper. Other studies use averages over longer periods, implying that the elasticity is constant over time. A typical estimate of the elasticities is 0.33 for capital and 0.67 for labour (Romer, 2001, ch. 1).⁸

⁷ The issue of capital utilisation is discussed in Vanags and Bems (2005) and Rapacki and Prochniak (2009) but the capital stock series in the papers are not adjusted.

⁸ Solow (1957) computes a time-varying share of capital income in total income using US data and finds an average of 0.35. Nehru and Dhareshwar (1993) and Fisher (1993) use a constant share of 0.40, Vanags and Bems (2005) and Baier et al. (2006) use a constant share of 0.33, Gollin (2001) estimates the capital share to be between 0.25 and 0.35, while Rapacki and Prochniak (2009) use shares of 0.30 and 0.40.

3. Data and modelling choices

The sample consists of 11 CEE countries: Bulgaria, the Czech Republic, Estonia, Croatia, Latvia, Lithuania, Hungary, Poland, Romania, Slovakia and Slovenia. For comparison we also include aggregate data for the EU15, the Western European EU members with relatively high levels of per capita income. The data cover the years 1995–2016, so growth rates can be computed for the years 1996–2016.

If not mentioned otherwise, the data source is Eurostat (2017). The gross domestic product, gross value-added, gross fixed capital formation (investments) and compensation to employees are from the ESA2010 national accounts (code: *nama_10_gdp*). Since ESA2010 data are not available for some countries for the whole sample, we impute some observations using the growth rates for the ESA95 definitions of the variables (codes: *nama_gdp_c*, *nama_gdp_k*).⁹ The data for the total number of employees and people employed follow the domestic employment concept in the ESA2010 national accounts (code: *nama_10_pe*). However, some observations are missing and these have been imputed using the growth rates for employment according to the ESA2010 national concept or the ESA95 domestic concept (code: *nama_aux_pem*).¹⁰

3.1. Anchor capital stock

The anchor capital stock is calculated from eq. (4) using 2003 as the anchor year. The year 2003 is chosen because it occurs in the short interval after the transition process was largely completed in the CEE countries and before the countries were to experience the exceptional booms that preceded the global financial crisis and the subsequent downturns. The year 2003 was indeed a year in which the output gap was small or non-existent in all of the sample countries.

The actual investment variable may be affected by the business cycle or other shocks, so to compute the investment in the anchor year, \tilde{I}_T , we smooth the actual investment and GDP series, both in logs, using a Hodrick-Prescott filter with $\lambda = 100$. Next we compute the investment-to-GDP ratio using the smoothed series and then take the average over the years 2001–2005. Finally, to get the steady state level of investment in 2003, we multiply the average smoothed investment-to-GDP ratio by the smoothed GDP in 2003. As discussed in Subsection 3.1 we proxy the steady state growth rate of the capital stock with the growth rate of GDP, since that exhibits less volatility than the growth rate of investment and may be less susceptible to catching-up effects.

⁹ The imputed national accounts data are the volume of the gross domestic product, value added and gross fixed capital formation for Bulgaria in 1995, and compensation to employees from 1995 to 1999 for Poland.

¹⁰ For Croatia the data for employees and the self-employed for 1996–1999 are imputed using growth rates from the ESA95 data, the data for 1995 are imputed using data for 1996, and both the total employment and the number of employees for 2016 were imputed using the data of the national concept. For Poland the total employment for 1995–1999 is imputed using the national concept and the number of employees is imputed using the ESA95 data of domestic concept.

The steady state growth rate of the capital stock, \tilde{g}_K , is proxied by the smoothed growth rate using an HP filter with $\lambda = 100$. However, we do not use the filtered growth rate directly, but calculate a five year average growth rate that includes the filtered growth rate from two years before and two years after the anchor year. The averaging is meant to eliminate possible cyclical effects which the filtered growth rate may contain and which could distort the results.

The depreciation rate is taken to be constant over time and equal to 0.05 for the 11 CEE countries and the EU15. The same depreciation rate is used by De la Fuente and Doménech (2006) and it is within the range between 0.04 and 0.10 used in most papers in the literature.¹¹

3.2. Capital utilisation

In the baseline computations the rate of capital utilisation is proxied by the rate of capacity utilisation in manufacturing (codes: *BS_ICU_PC*, *ei_bsin_q_r2*). The quarterly data are annualised by taking averages. Data for capacity utilisation for the EU15 are computed as the capacity utilisation in each of the countries weighted for the relative size of the economy. No data are available for Ireland so the country does not enter the calculations; this should be inconsequential given the size of the Irish economy. The data on the capacity utilisation of Austria and Sweden for 1995 are also missing, so these countries are not included in the average capacity utilisation for the EU15 for that year.

For the CEE countries there are no data on capacity utilisation for Croatia in 1995–2008, for Hungary in 1995 and for Romania in 1995–2000. To avoid losing these observations, we predict the rate of capital utilisation using information on the dynamics of output growth in these countries. This is done by regressing the change in the rate of capacity utilisation on relative output growth using panel data estimations for the 11 CEE countries in the sample.

The estimated relationship is then used to predict the missing observations for the rate of capacity utilisation.¹²

3.3. Elasticity of output to capital

The time-varying elasticity of output to capital, α_t^K , is computed as one minus the share of labour income in total income. We calculate the labour elasticity by dividing the total labour income by gross value added, which is the difference between GDP and net product taxes.

¹¹ See for instance Vanags and Bems (2005), Griliches (1980), Nehru and Dhareshwar (1993), Romer (1988), Baier et al. (2006), Kamps (2006), Rapacki and Prochniak (2009), Berlemann and Wesselhöft (2014), Harberger (1988), and Nadiri and Prucha (1996).

¹² The change in the capacity utilisation is regressed on GDP growth and a constant in a panel estimation for the 11 CEE countries (but not the EU15) using all the available data. If this is estimated using a fixed effect estimation, the fixed effects are small and statistically insignificant so we prefer to use panel OLS. The result is shown below with standard error in brackets:

$$\Delta CU = -1.018 + 0.519 \cdot GY$$

(0.519) (0.055)

The variable ΔCU is the change in the capacity utilisation in percentage points and GY is the growth rate of output in per cent per year. The relationship is used to predict the missing observations for the rate of capacity utilisation using output growth rates.

Total labour income is equal to compensation to employees and the income of the self-employed. We assume that the income of the self-employed is equal to the pay of employees so that total labour income is compensation per employee times total employment. Due to a lack of data for some countries we use the closest observation available to calculate α_t^K .¹³

The capital elasticities computed vary over time and countries. The average is 0.41 for the 11 CEE countries and 0.37 for the EU15. The lowest share of capital is 0.16 in Romania, while the highest figure is 0.54 in Slovakia. These results are within the range of findings in Mankiw et al. (1990).

4. Baseline results

We use the methodology set out in Section 2 and the assumptions in Section 3 to compute baseline series for the stock of available capital. For comparison across countries it is useful to consider the capital-output ratio, here computed as the real capital stock relative to real output. Figure A.1 in Appendix A shows the capital-output ratio of the capital stock series for each of the 11 CEE countries and the EU15 along with the available capital-output ratios from Eurostat and Ameco.

We find capital-output ratios that are typically higher than those in Ameco and lower than those in Eurostat, when data from Eurostat are available. The differences between our results and the Ameco data are very small for the EU15 suggesting that the computation method is inconsequential for this country group. Our estimate of the capital-output ratio for Poland is also close to the estimates from Eurostat and Ameco. There are however very large differences for Latvia but this is unsurprising given that the ratios from Eurostat and Ameco both appear unreasonable. The differences are also noticeable for the Czech Republic, Hungary, Slovenia and Slovakia, the most developed CEE countries in the mid-1990s. In conclusion, the capital series computed in this paper result in capital-output ratios that appear reasonable when compared across countries and over time.

4.1. Full sample

Table 1 presents the baseline results for the full sample 1996–2016. The table exhibits the average annual GDP growth over the period and the average annual contributions from changes in employment, capital utilisation, capital and TFP. Evidently, the average contributions sum to the average output growth apart from deviations due to rounding.

¹³ The compensation to employees as a share of value added for Poland in 2016 is replaced by the same indicator from 2015, as newer data are not available. The share of employees in total employment for Croatia in 1995 is replaced by the same variable for 1996.

Table 1: Decomposition of output growth, 1996–2016

	Output growth	Contributions			
		Employment	Capital	Utilisation	TFP
EU15	1.60	0.51	0.59	0.00	0.50
Bulgaria	2.37	−0.04	1.26	0.49	0.67
Czech Rep.	2.46	0.09	1.49	0.25	0.63
Estonia	4.08	−0.06	1.67	0.70	1.77
Croatia	2.05	0.33	0.67	0.40	0.65
Latvia	4.13	−0.12	1.86	1.09	1.30
Lithuania	4.31	−0.22	2.00	1.30	1.24
Hungary	2.24	0.25	0.99	0.12	0.89
Poland	3.99	0.20	1.80	0.19	1.80
Romania	2.87	−0.96	1.43	−0.05	2.45
Slovenia	2.55	0.12	0.74	0.47	1.22
Slovakia	3.96	0.22	2.36	0.42	0.96
CEE average	3.18	−0.02	1.48	0.45	1.27

Notes: All values are annual averages for 1996–2016. Output growth is average annual growth in per cent. The annual contributions of employment, utilisation, capital and TFP are denominated in percentage points. The sum of the contributions may not add up to output growth due to rounding. The CEE average is the unweighted average for the 11 CEE countries.

Source: Authors' calculations; see text.

The average output growth varies from 2.1 per cent to 4.3 per cent in the CEE countries, while it is 1.6 per cent for the EU15. The fastest growing countries, which are the Baltic states, Poland and Slovakia, exhibit contributions from the growth of capital of 1.7–2.4 percentage points and from the growth of TFP of 1.0–1.8 percentage points. The contribution from the growth in capital utilisation is noticeably higher in the Baltic states than in Poland and Slovakia. This is consistent with the transitional recessions being much deeper in the Baltic states than in the more developed CEE countries such as Poland or Slovakia.

The contributions of labour, capital and TFP are effectively equal in the EU15, with the contribution from capital utilisation being zero, but the contribution of labour in the CEE countries is negligibly small with the sole exception of Romania where the relative contribution of labour is negative due to a diminishing labour force.

In contrast to Dombi (2013a), we do not find capital accumulation to have been the main source of economic growth in the period as a whole. Our findings indicate it to have been so only for the Czech Republic and Slovakia, where the contribution from capital growth is more than one half of average output growth. If the contribution of capital utilisation is added to that of capital, then the number of countries with substantial physical capital growth of greater than 50 per cent of output growth is six out of eleven countries. This suggests that the growth of physical capital played an important role during the period being examined, but it was not the main source of growth. Indeed, in line with Arratibel et al. (2007) our results show that the contribution of TFP growth was quite significant in all the sample countries, varying between 0.63 and 2.45 percentage points, which corresponds to between 26 and 85 per cent of the contribution, with a mean of 1.25 percentage points or 39 per cent.

4.2. Sub-periods

The CEE countries experienced pronounced boom-bust cycles and large changes in annual GDP growth over the sample years. These features make it pertinent to repeat the growth decomposition for various subsamples. We consider four sub-periods; the years 1996–2001 are the late transition period, the years 2002–2007 are the pre-crisis period when most CEE countries experienced economic booms, 2008–2009 are the years in which the global financial crisis affected the CEE countries, and the years 2010–2016 are the post-crisis recovery period.

Table 2 reports the growth accounting results for the late transition period. During this stage, almost all the sample countries show relatively high output growth, with Bulgaria and Romania lagging behind. There are generally large contributions from TFP growth, with the Czech Republic and Slovakia as exceptions. High TFP growth during these years of the catching-up period may be related to the transition process as new production technologies were introduced and better managerial practices were applied (Arratibel et al., 2007, p. 11).

Table 2: Decomposition of output growth, 1996–2001

	Output growth	Contributions			
		Employment	Capital	Utilisation	TFP
EU15	2.76	0.93	0.61	−0.04	1.25
Bulgaria	−0.66	−0.81	−0.49	−0.36	1.00
Czech Rep.	2.01	−0.43	1.65	0.77	0.01
Estonia	6.21	−0.70	0.74	1.85	4.33
Croatia	3.44	−0.47	0.28	0.46	3.17
Latvia	5.39	0.11	0.57	1.84	2.87
Lithuania	5.02	−0.88	1.26	2.47	2.18
Hungary	3.12	0.54	0.80	0.29	1.49
Poland	4.60	−0.42	1.50	−0.68	4.20
Romania	0.76	−1.05	0.46	−0.35	1.69
Slovenia	4.05	−0.05	0.72	1.39	1.99
Slovakia	3.53	−0.28	3.21	1.18	−0.58
CEE average	3.41	−0.40	0.97	0.75	2.09

Notes: All values are annual averages for 1996–2001. Output growth is average annual growth in per cent. The annual contributions of employment, utilisation, capital and TFP are denominated in percentage points. The sum of the contributions may not add up to output growth due to rounding. The CEE average is the unweighted average for the 11 CEE countries.

Source: Authors' calculations; see text.

Very high contributions from TFP are recorded in the Baltics, primarily in Estonia, but they are also seen in Croatia and Poland and to a lesser extent in Hungary, Romania and Slovenia.¹⁴ Romania takes a special position as the economy was growing slowly while TFP

¹⁴ The five countries with the highest contributions from TFP growth in 1996–2002 coincide with those identified in Rapacki and Prochniak (2009). The large contribution of TFP growth in the Baltic states is also in line with the findings in Bah & Brada (2009). The results for the Baltic states are broadly in line with those in

growth was relatively high. Growth in employment is negative in the majority of the CEE countries during the first sub-period. The average contribution of capital growth is roughly one third, while the average contribution of capital utilisation is one fifth. Nevertheless, the total of the contributions of growth in the capital stock and in the rate of utilisation is on average less than the contribution of TFP growth during this sub-period.

Table 3 presents the results of the growth accounting for the pre-crisis years 2002–2007. Average growth in the CEE countries is almost double what it was in the previous sub-period as is the contribution of growth in physical capital. The contribution of employment growth was positive in almost all the sample countries. The TFP contribution was also notable and in this sub-period it again exceeds both the capital contribution and the overall capital contribution which takes account of capacity utilisation. The quite strong growth in physical capital not only in the CEE countries but also in the EU15 is also worthy of note.

Table 3: Decomposition of output growth, 2002–2007

	Output growth	Contributions			
		Employment	Capital	Utilisation	TFP
EU15	2.10	0.66	0.74	0.15	0.55
Bulgaria	6.48	1.35	2.08	2.10	0.95
Czech Rep.	4.84	0.43	1.55	0.40	2.46
Estonia	7.86	0.82	2.78	0.48	3.79
Croatia	4.83	2.37	1.07	0.71	0.69
Latvia	9.40	1.13	3.20	1.27	3.80
Lithuania	8.35	0.65	2.58	1.49	3.62
Hungary	3.67	−0.08	1.35	0.23	2.17
Poland	4.57	0.58	1.43	1.22	1.34
Romania	6.36	−1.39	1.33	0.50	5.91
Slovenia	4.61	0.68	1.09	0.30	2.53
Slovakia	6.87	0.53	2.31	0.25	3.78
CEE average	6.17	0.64	1.89	0.75	2.88

Notes: All values are annual averages for 2002–2007. Output growth is average annual growth in per cent. The annual contributions of employment, utilisation, capital and TFP are denominated in percentage points. The sum of the contributions may not add up to output growth due to rounding. The CEE average is the unweighted average for the 11 CEE countries.

Source: Authors' calculations; see text.

Table 4 shows the growth accounting results for the crisis years 2008–2009. The output performance during the crisis varied markedly across the 11 CEE countries. The contribution from capital accumulation is still high during these two years, but the contribution of capacity utilisation is negative in all the CEE countries. The contribution of TFP to output growth varies from −4.83 percentage points in Estonia to 2.88 percentage points in Slovakia, indicating different dynamics during the crisis. The Baltic states saw very large declines in GDP stemming from large declines in employment, utilisation and TFP growth, while capital

Vanags and Bems (2005), who reported TFP growth of 2.8, 2.6 and 2.9 percentage points for Estonia, Latvia and Lithuania respectively.

continued to contribute positively to GDP growth. Poland exhibited relatively rapid economic growth during the crisis years 2008–2009 and, notably, this was accompanied by substantial positive TFP growth.

Table 4: Decomposition of output growth, 2008–2009

	Output growth	Contributions			
		Employment	Capital	Utilisation	TFP
EU15	-2.14	-0.30	0.83	-2.72	0.04
Bulgaria	1.22	0.16	3.91	-3.00	0.15
Czech Rep.	-1.07	0.10	2.06	-3.45	0.23
Estonia	-10.07	-3.30	2.92	-4.86	-4.83
Croatia	-2.67	1.08	1.40	-0.92	-4.23
Latvia	-8.97	-4.47	3.96	-5.48	-2.98
Lithuania	-6.09	-2.52	3.98	-3.76	-3.81
Hungary	-2.84	-1.30	1.36	-3.19	0.30
Poland	3.53	1.19	2.62	-2.04	1.77
Romania	0.70	-0.61	4.18	-2.75	-0.13
Slovenia	-2.25	0.23	1.44	-2.51	-1.40
Slovakia	0.10	0.26	2.78	-5.81	2.88
CEE average	-2.58	-0.83	2.78	-3.45	-1.08

Notes: All values are annual averages for 2008–2009. Output growth is average annual growth in per cent. The annual contributions of employment, utilisation, capital and TFP are denominated in percentage points. The sum of the contributions may not add up to output growth due to rounding. The CEE average is the unweighted average for the 11 CEE countries.

Source: Authors' calculations; see text.

Dimelis and Dimopoulou (2002) find that the slowdown experienced by the majority of the EU15 countries during the recession in Western Europe in the early 1990s was due mostly to declining contributions from capital and labour. Our results for the crisis period in the CEE countries are consistent with this finding if capital is adjusted for capacity utilisation. However, we also find very large negative TFP contributions in some of the countries most affected by the crisis.

Table 5 shows that output growth was slower in the post-crisis period than it was before the crisis. The distinctive result from the growth decomposition in this sub-period is that growth in all the countries in the sample is largely due to the accumulation of capital stock and a growing rate of capital utilisation. Bulgaria, Poland, Romania and Slovenia are the only countries with positive, though quite small, contributions from TFP growth.

Table 5: Decomposition of output growth 2010–2016

	Output growth	Contributions			
		Employment	Capital	Utilisation	TFP
EU15	1.25	0.25	0.37	0.68	−0.04
Bulgaria	1.79	−0.62	1.30	0.83	0.28
Czech Rep.	1.81	0.24	1.15	0.72	−0.29
Estonia	3.06	0.68	1.15	1.50	−0.27
Croatia	−0.16	−0.96	0.47	0.47	−0.14
Latvia	2.29	−0.14	1.22	2.16	−0.96
Lithuania	3.23	0.26	1.55	1.57	−0.16
Hungary	1.73	0.74	0.73	0.82	−0.56
Poland	3.10	0.13	2.12	0.68	0.16
Romania	2.32	−0.60	1.57	0.49	0.87
Slovenia	0.86	−0.24	0.25	0.67	0.18
Slovakia	2.96	0.38	1.55	1.71	−0.68
CEE average	2.09	−0.01	1.19	1.06	−0.14

Notes: All values are annual averages for 2010–2016. Output growth is average annual growth in per cent. The annual contributions of employment, utilisation, capital and TFP are denominated in percentage points. The sum of the contributions may not add up to output growth due to rounding. The CEE average is the unweighted average for the 11 CEE countries.

Source: Authors' calculations; see text.

4.3. Annual data

The business cycle affects the results substantially and it may therefore be instructive to consider the growth accounting results for each year separately. Figure 1 shows the contribution from TFP growth for the 11 CEE countries and the EU15 for each year from 1996 to 2016. It is notable that changes in capital utilisation are included separately suggesting that the TFP estimates do not include changes in capital utilisation stemming from the business cycle.

The rate of TFP growth is generally higher in the CEE countries than in the EU15, but it is also much more volatile. The larger volatility is particularly pronounced around the global financial crisis but it also appears in individual years elsewhere. Negative rates of TFP growth often coincide with economic and financial crises like the inflation crisis in Bulgaria in 1996, the exchange rate crisis in the Czech Republic in 1997 and the deep downturn in Slovakia in the late 1990s. Positive TFP growth rates are prevalent in the years before the global financial crisis. A part of these annual changes in TFP growth may be explained by the swift and substantial sectoral changes as shown in Kuusk et al. (2017).

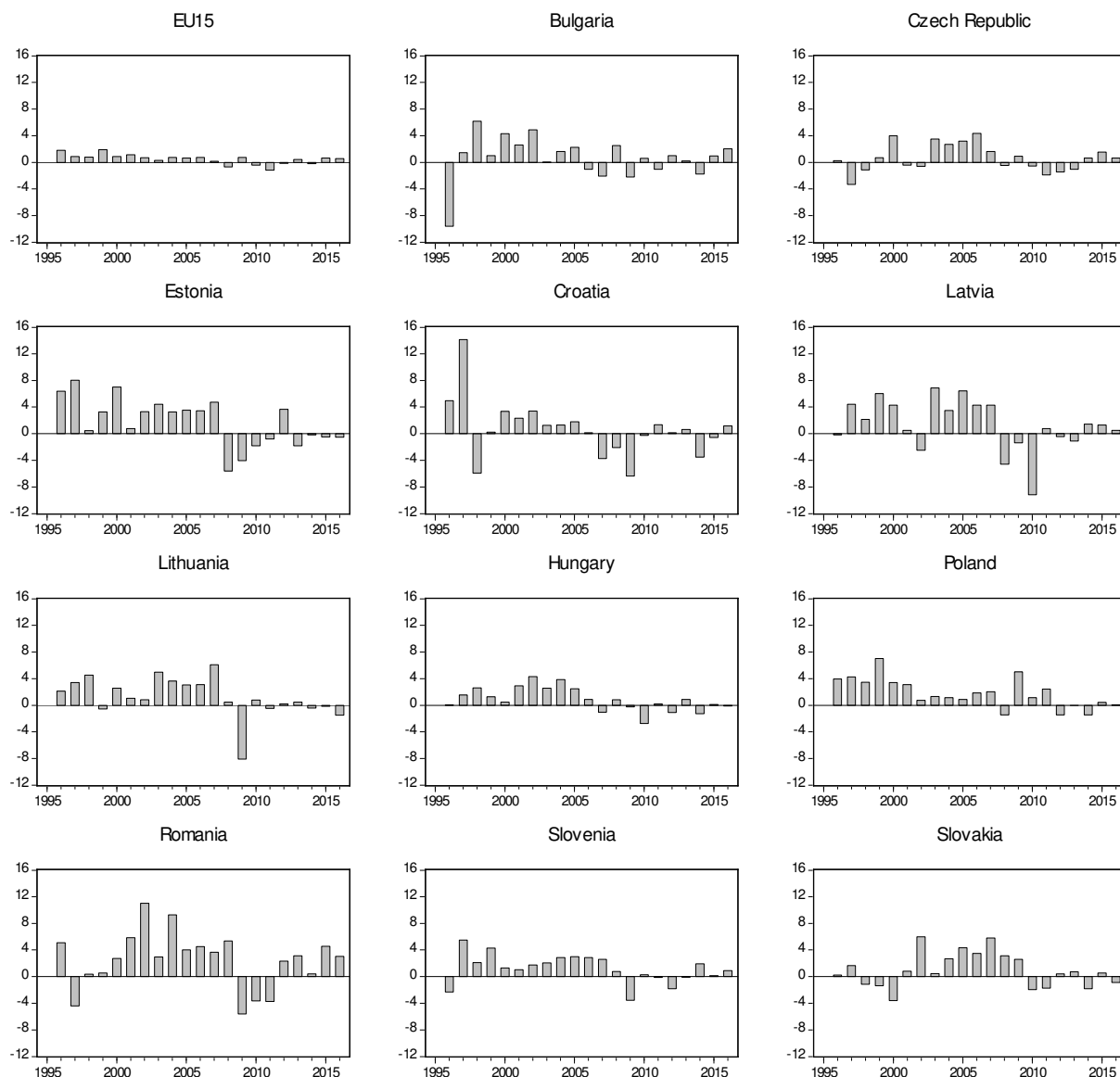


Figure 1: Contribution of TFP growth to output growth in 11 CEE countries and the EU15

Source: Authors' calculations: see text.

5. Robustness analyses

The calculation method and parametrisation of the baseline computations in Section 4 largely follow those used in the literature while taking into account the particularly volatile economic environment in the CEE countries. This section shows the sensitivity of the results by, first, changing the calculation methods and assumptions individually and, then, by simulating the distribution of the contribution of TFP growth to economic growth using various distributional assumptions.

5.1. Changing assumptions

The robustness check involves changing the key assumptions and parameters of the model to assess the sensitivity of the results to these changes. The TFP growth contributions of the baseline and under various assumptions are presented in Table 6 for the entire sample period 1996–2016 and in Table 7 for the post-crisis period 2010–2016.

Table 6: Contribution from TFP growth, baseline and robustness checks, 1996–2016

	(6.1)	(6.2)	(6.3)	(6.4)	(6.5)	(6.6)	(6.7)	(6.8)
	Baseline	Anchor year 1998	Anchor year 2014	Growth rate of invest.	Unempl. for cap. util.	Empl. in hours	Elasticity $\alpha^K = 0.33$	Deprec. rate $\delta = 0.08$
EU15	0.50	0.32	0.76	0.48	0.48	0.67	0.54	0.56
Bulgaria	0.67	-0.31	1.50	-2.80	..	0.76	1.07	0.92
Czech Rep.	0.63	0.84	1.45	0.60	0.88	0.75	1.17	0.68
Estonia	1.77	0.69	2.98	0.36	..	..	2.31	2.02
Croatia	1.02	0.52	2.01	0.20	..	..	0.98	1.18
Latvia	1.30	-0.02	2.72	-0.73	..	1.36	2.17	1.61
Lithuania	1.24	0.57	2.59	0.21	..	1.00	2.20	1.47
Hungary	0.92	0.57	1.45	0.64	..	1.25	1.10	1.03
Poland	1.80	1.74	2.69	1.57	..	..	2.16	1.78
Romania	2.45	2.30	3.26	0.99	..	2.46	2.65	2.57
Slovenia	1.22	0.97	1.40	1.08	..	1.35	0.99	1.32
Slovakia	0.96	1.54	1.01	1.87	..	1.11	1.86	0.91
CEE av.	1.27	0.86	2.10	0.36	..	1.26	1.70	1.41

Notes: All values are annual averages for 1996–2016. The contribution of TFP growth is in percentage points. The symbol .. indicates that data for computation of the TFP growth are not available. The CEE average is the unweighted average for the 11 CEE countries.

Source: Authors' calculations; see text.

Table 7: Contribution from TFP growth, baseline and robustness checks, 2010–2016

	(7.1)	(7.2)	(7.3)	(7.4)	(7.5)	(7.6)	(7.7)	(7.8)
	Baseline	Anchor year 1998	Anchor year 2014	Growth rate of invest.	Unempl. for cap. util.	Empl. in hours	Elasticity $\alpha^K = 0.33$	Deprec. rate $\delta = 0.08$
EU15	-0.04	-0.13	0.09	-0.05	0.64	0.29	0.05	0.08
Bulgaria	0.28	-0.12	0.77	-0.64	1.22	0.30	0.75	0.49
Czech Rep.	-0.29	-0.19	0.13	-0.30	0.23	-0.25	0.21	-0.15
Estonia	-0.27	-0.60	0.33	-0.68	0.74	-0.38	0.15	0.03
Croatia	-0.14	-0.35	0.50	-0.45	0.47	..	-0.30	0.06
Latvia	-0.96	-1.34	-0.26	-1.47	0.56	-0.78	0.04	-0.55
Lithuania	-0.16	-0.40	0.57	-0.50	0.92	-0.26	0.81	0.17
Hungary	-0.56	-0.73	-0.26	-0.70	-0.09	0.27	-0.33	-0.37
Poland	0.16	0.13	0.76	0.04	0.70	0.18	0.91	0.14
Romania	0.87	0.78	1.46	0.25	1.31	1.12	1.55	1.11
Slovenia	0.18	0.09	0.25	0.13	0.93	0.15	-0.02	0.41
Slovakia	-0.68	-0.46	-0.66	-0.31	0.83	-0.51	0.34	-0.48
CEE av.	-0.14	-0.29	0.33	-0.42	0.71	-0.02	0.37	0.08

Notes: All values are annual averages for 2010–2016. The contribution of TFP growth is in percentage points. The symbol .. indicates that data for computation of the TFP growth are not available. The CEE average is the unweighted average for the 11 CEE countries.

Source: Authors' calculations; see text.

The anchor year is the year for which the capital stock is computed using assumptions about the steady state; see eq. (4) in Subsection 2.1. Most studies use the first year as the anchor year but this study uses 2003 because economic conditions were relatively stable in the CEE countries at this time. We assess the sensitivity of the results using different anchor years. The results when the anchor year is 1998 and 2014 are reported in Tables 6 and 7; we cannot use earlier or later anchor years because the computation of the anchor capital stock uses a Hodrick-Prescott filter and subsequent averaging over five years. The contributions from TFP growth are generally somewhat smaller than in the baseline case when 1998 is chosen as the anchor year, while the contributions are larger when 2014 is the anchor year. The largest differences can be found for the Baltics and Bulgaria and to some extent for Croatia and Poland.

If the growth rate of output is replaced by the growth rate of investment in the formula for anchor capital as discussed in Subsection 2.1, the contribution from TFP growth for the full sample 1996–2016 is considerably smaller across all the countries except Slovakia, and it even becomes negative for two countries, Bulgaria and Latvia. These results are in large part due to the volatility of investment and the very high investment rates for some of the CEE countries. The differences are however much less pronounced in the last sub-period 2010–2016, as shown in Table 7.

The next robustness exercise follows Solow (1957) and uses the unemployment rate to compute capacity utilisation. The new measure is calculated as one minus average annual unemployment as a percentage of the labour force (code: *une_rt_a*). The unemployment rate

for the EU15 is found using weights computed from the average population each year (code: *demo_gind*). However, as data for 1995–1999 are missing for all or some years for all the countries except the Czech Republic, we do not present the TFP numbers for the full sample but only for the post-crisis years 2010–2016. Using the unemployment rate to compute capacity utilisation gives considerably higher contributions from TFP growth than those found in the baseline estimations. Unemployment was more stable than the capacity utilisation in manufacturing used in the baseline computation so using the unemployment rate reduces the contribution of capital utilisation.

As an additional robustness check we use employment in hours instead of persons in employment (code: *demo_gind*). This measure of employment could be expected to be more precise.¹⁵ The data are missing for Estonia and Poland for 1995–1999 and for Croatia for 1995–2007, and the TFP figures are therefore not reported for these countries for the full sample period. The results are very close to those of the baseline. The only noticeable differences are observed for the EU15 and for Hungary in the post-crisis period when the negative contributions from employment become positive.

As a further robustness check the country-specific and time-varying values of the share of capital in total income, α_t^K , are changed to a constant value of 0.33, which is a value commonly used in the growth accounting literature. This change increases the TFP contributions for all the countries except Slovenia, whose original average share of capital was 0.29.

Changing the depreciation rate δ from 5 per cent to 8 per cent does not change the results much. It increases the contributions from TFP growth a little as the computed level of the available physical capital is typically reduced.

To sum up, the sensitivity analyses in this subsection show that the results are reasonably robust to the specific modelling choices and parameterisations used. The key exception relates to assumptions about the computation of the anchor capital, in particular the anchor year chosen and the measure of the growth of capital in steady state. We believe that the choices of 2003 as the anchor year and the smoothed output growth rate as a proxy for the steady state growth rate of the capital stock are appropriate given the very volatile environment of the CEE countries during the two decades considered.

5.2. Simulations

In practice several of the assumptions about modelling choices are highly uncertain and it might therefore be pertinent to consider the outcome of simulations in which it is assumed that various parameters follow distributions, not singular points. We run simulations to ascertain the distribution of the TFP contributions given selected assumptions for the depreciation rate and the anchor year, as these variables seem to matter a great deal for the results. We draw the depreciation rate from a normal distribution $N(0.05, 0.01)$. The anchor year is drawn from a set of years between and including 1998 and 2014, each having an equal probability of appearing as the anchor year. This is the largest sample that can be used in the robustness test,

¹⁵ We do not use employment measured in hours for the baseline results because data are missing at the beginning of the period for several of the sample countries.

as the years before 1998 and after 2014 are lost due to smoothing of the equilibrium indicators. The anchor year and the depreciation rate are drawn independently.

The simulated distributions shown in Figures 2 and 3 visualise the uncertainty of the estimates of the contribution of TFP growth, taking into account the uncertainty around both the value of the depreciation rate and the anchor year. However, these distributions cannot be interpreted as exact measures of estimation errors and confidence bands should not be derived from these distributions.

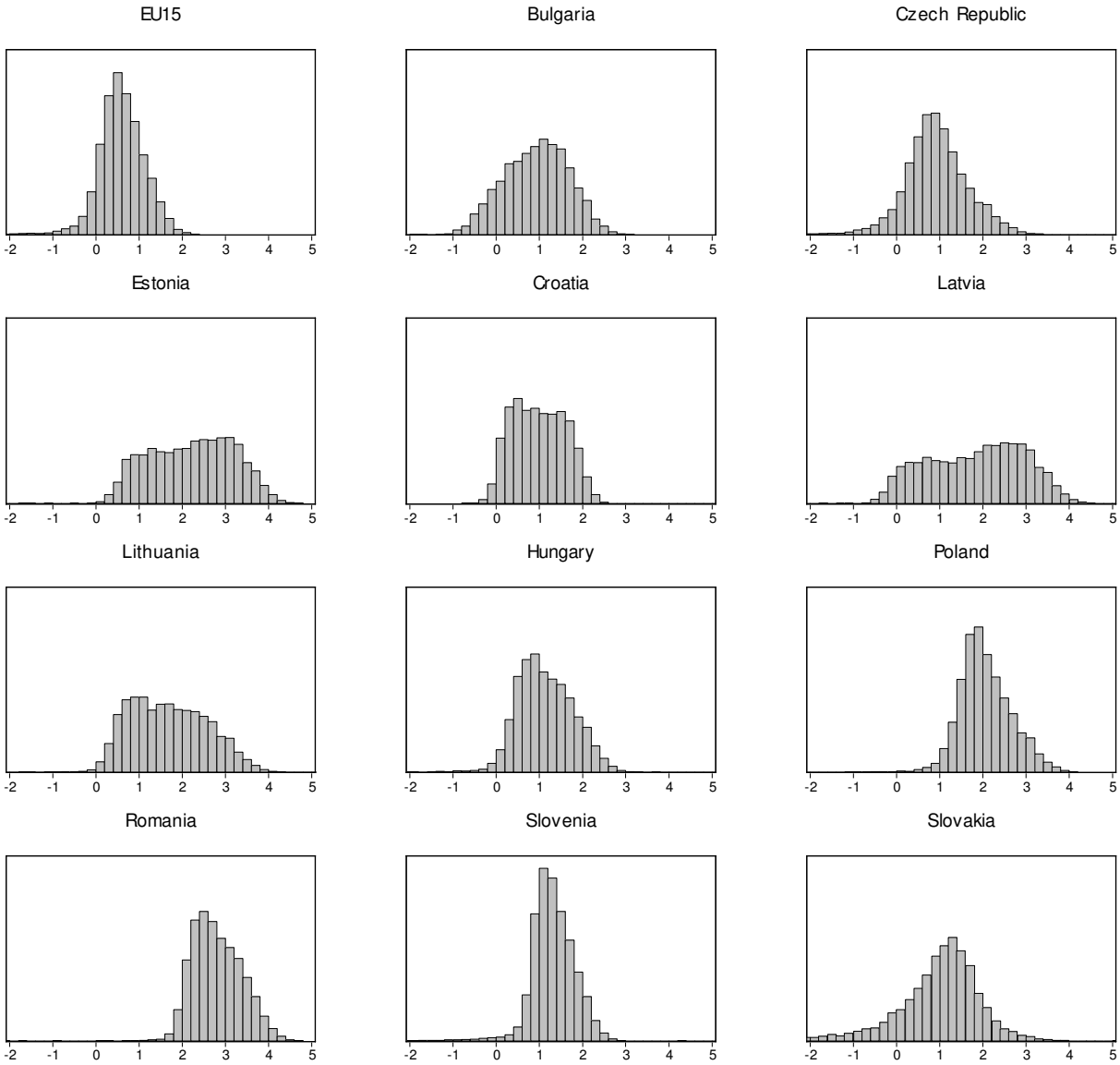


Figure 2: Simulated distribution of the contribution of TFP growth, 1996–2016

Source: Authors’ calculations: see text.

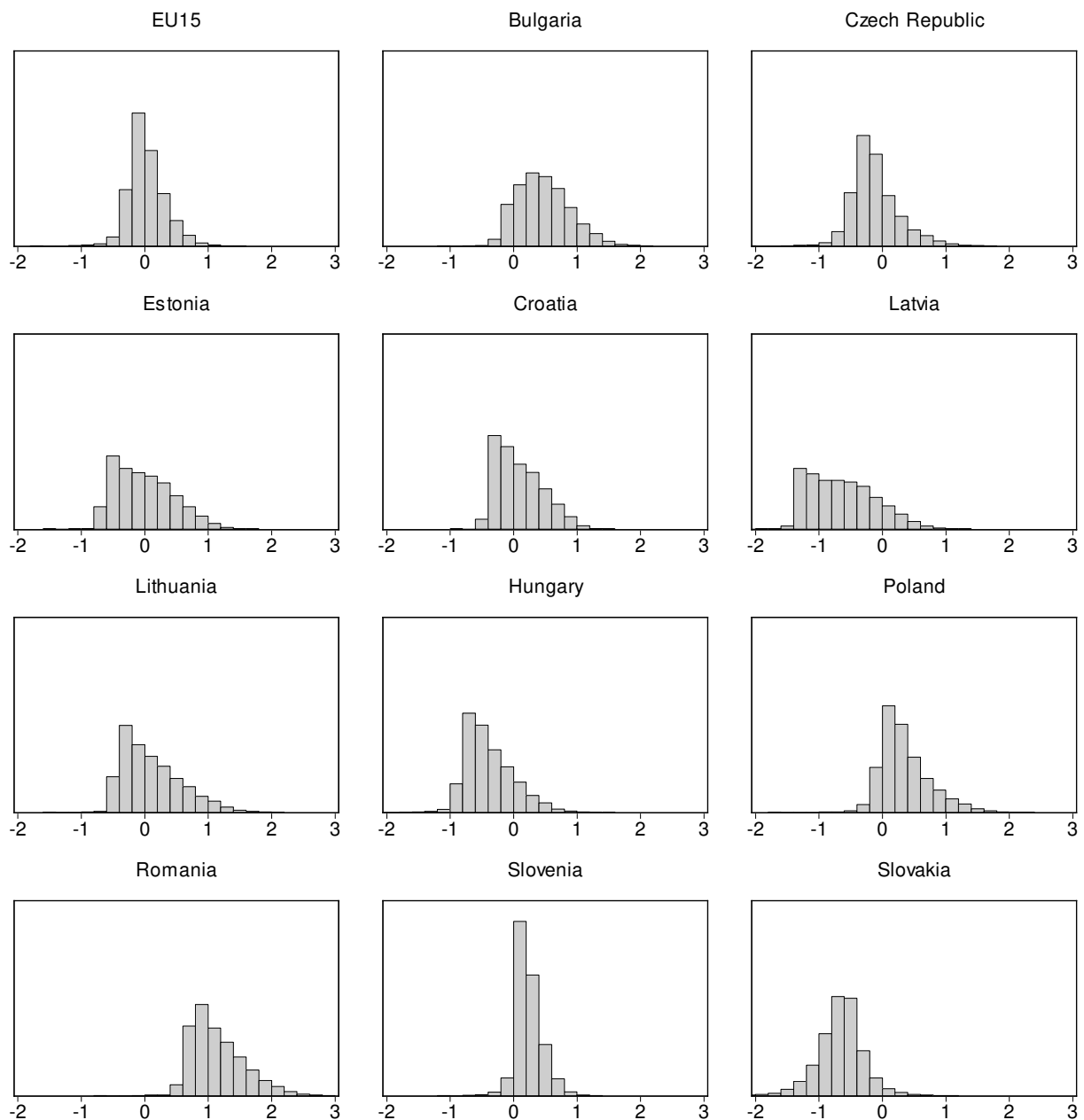


Figure 3: Simulated contributions of TFP growth, 2010–2016

Source: Authors' calculations, see text.

Figure 2 reveals that the simulated distributions of TFP contributions are flatter for most of the CEE countries than for the EU15. This is largely driven by the choice of the anchor year. The anchor year should matter less for countries and economic areas which are on their steady-state growth path. This is indeed the case for the EU15 and also Slovenia, which had a higher income level in the 1990s than the other CEE countries. The Baltic states, on the other hand, have quite flat simulated TFP contribution distributions, suggesting the estimates of the contribution of TFP growth to GDP growth in these countries are rather uncertain.

Figure 3 shows the distributions of the TFP contributions for the post-recession period. They vary less than those for the full sample because the relevance of the anchor year declines in time as the anchor capital stock depreciates. As for the full sample, the simulated TFP contributions of the EU15 and Slovenia have narrower distributions than those in most CEE countries. For several of the countries the TFP contributions are not indisputably different from zero, but the masses of the distributions are still concentrated on either the positive or the negative side of the vertical axis. For most of the countries the mode of the distribution is on the negative side for the post-recession sub-sample, while for Bulgaria, Romania and Slovenia the mode of the TFP contribution is on the positive side. For Poland and the EU15 the mode of the simulated distribution is close to zero, as are the baseline results.

The simulation results presented in Figures 2 and 3 illustrate that estimations from growth accounting are necessarily associated with substantial uncertainty. This is a reminder that the results in Section 4 should be interpreted with some caution. The simulations however also revealed that there are clear patterns or tendencies in the results and this is particularly the case for the post-crisis period.

6. Final comments

This paper decomposes GDP growth in the 11 CEE countries over the years 1996–2016. The exercise is complicated by the countries exhibiting highly unusual growth dynamics over the two decades and the paper therefore includes innovations such as a revised way of computing the capital stock and the treatment of capital utilisation as a separate contribution. The results are generally robust to changes in modelling assumptions and parametrisations, especially for the later part of the sample.

For the full sample 1996–2016, average GDP growth was generally higher in the CEE countries than in the reference group of the 15 EU countries from Western Europe. On average capital deepening accounted for approximately half, TFP growth for approximately one third, and increased utilisation of capital for the remaining one sixth of GDP growth, while changes in employment did not matter much. These results are however averages; there is indeed substantial variation over time and across the countries.

During the boom in 2002–2007, TFP growth accounted for approximately half of GDP growth and capital deepening for around one third, while higher employment and capital utilisation accounted for the rest. There is substantial heterogeneity across the countries. Slovakia and the Baltic states stand out for very high rates of economic growth and large contributions from TFP growth, while economic growth in Poland, Hungary, the Czech Republic and Slovenia was less brisk and TFP growth was less important in at least some of these countries. This somewhat heterogeneous pattern across the CEE countries is also noticed in Dombi (2013a, 2013b).

The substantial contribution of TFP growth during the boom may be seen to set the CEE countries apart from the experiences of the newly industrialised countries (NIC) in Southeast Asia during the boom preceding the 1997–1998 Asian crisis. Young (1995) found that the NICs had exceptionally high ratios of investment to GDP, implying that capital deepening was thus the predominant source of economic growth while TFP growth was of little impor-

tance. Krugman (1994) indeed argued that the financing of the capital accumulation could threaten financial stability, a conjecture that proved accurate. TFP growth was an important contributor to GDP growth in the CEE countries, suggesting that the causes of the crisis in CEE countries differed from those of the NIC countries.

Developments differed markedly across the CEE countries during the global financial crisis in 2008–2009. The Baltic states experienced very large output declines, while Poland and to a lesser extent Bulgaria, Romania and Slovakia weathered the crisis without loss of output. It is notable that the capital stock continued to grow at a brisk rate in all CEE countries during the crisis years, but the rate of utilisation of the capital stock decreased markedly. This shows the importance of taking capital utilisation into account in growth accounting as the TFP contribution will otherwise be underestimated during downturns like those experienced by many CEE countries after the global financial crisis (Fernald and Matoba, 2009; Fernald, 2014).

Economic growth has been subdued in the CEE countries since the global financial crisis. The growth accounting reveals that capital deepening and increased capital utilisation have contributed in equal proportions to economic growth, while TFP growth has been virtually absent in most CEE countries in this period. The lack of TFP growth is holding back the catching-up process and casts doubt on the ability of these countries to sustain growth without increased use of resources (Vuegelers, 2011). The subdued TFP growth and its causes in the CEE countries after the global financial crisis are areas warranting further analysis and research.

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Appendix A. Capital-output ratios

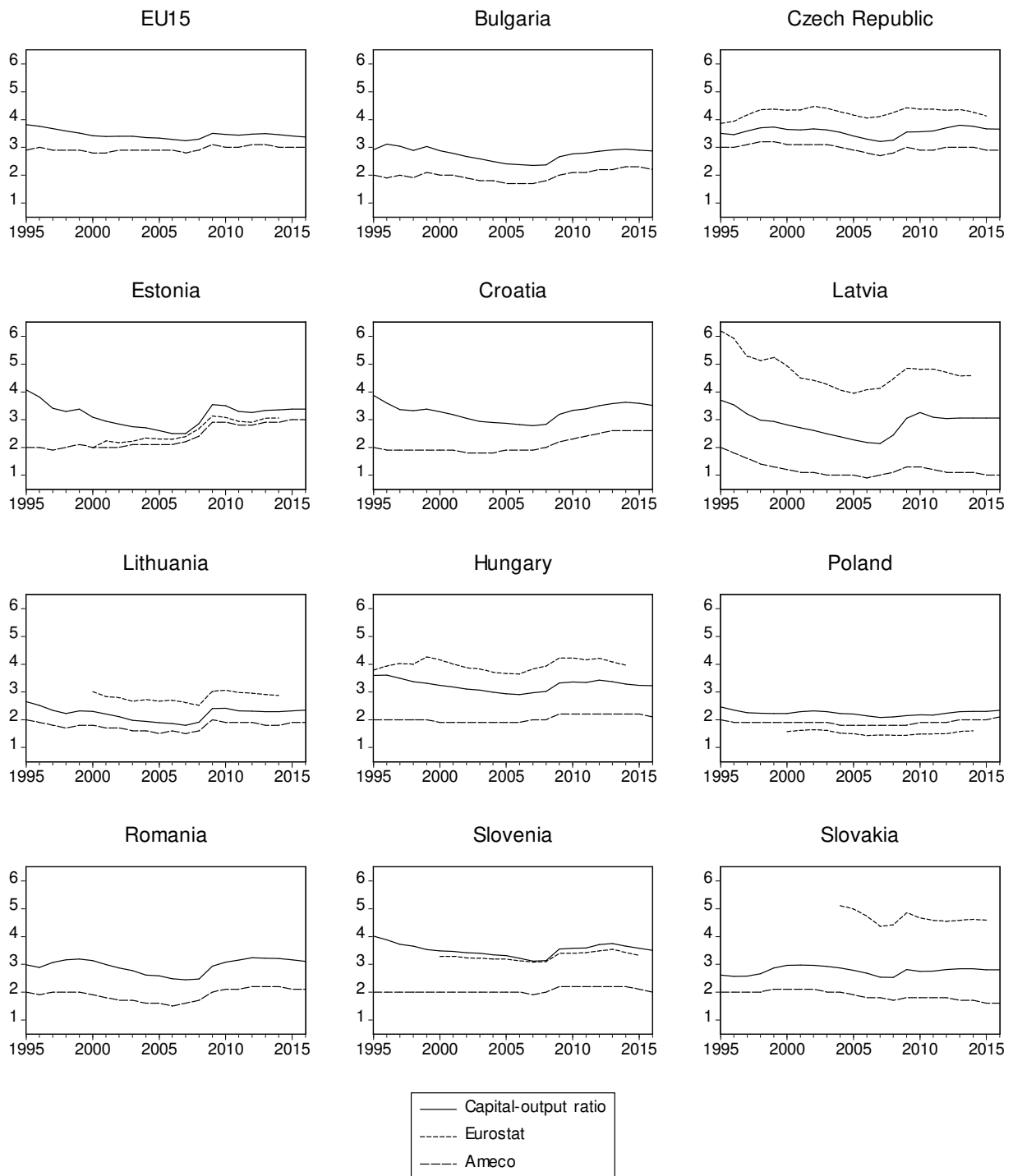


Figure A.1. Capital-output ratio for 11 CEE countries and the EU15

Source: Eurostat (codes: *nama_10_gdp*, *nama_10_nfa_st*, *nama_10_an6*), Ameco (code: *8.1 AKNDV*) and authors' calculations, see text.

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