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Poland's uninterrupted growth performance: new growth accounting evidence

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ABSTRACT
Since 1992 Poland has experienced an exceptionally long spell of output growth that was not interrupted even by the global economic crisis. Using a growth accounting exercise based on new estimates of flows of capital and labour services in the Polish economy during the period 1996–2013, we study the structure of this growth, highlighting the key role of certain supply-side factors. Most notably, unlike other European countries, the Polish economy recorded both a marked increase in capital deepening, a big improvement in workforce composition (driven mostly by educational attainment), and an uninterrupted process of productivity convergence. We also comment on the supply-side factors which contributed to Poland's relative resilience to the global economic crisis of 2007–2010.

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Growth accounting; Poland; real convergence; productivity convergence; human capital

1. Introduction

After the economic crash that marked the transition from a centrally planned to a market economy, the Polish economy started to recover in 1992. More than two decades on, Poland remains the only European post-communist economy whose growth was not interrupted even by the Russian crisis in 1998, the global financial crisis in 2007–2009, nor the Eurozone crisis that followed soon after. This exceptional performance can be best illustrated by comparing GDP growth in Poland to that experienced by other countries in Central and Eastern Europe. As can be seen from Figure 1, in 1995–2015 Poland experienced the most sustained and stable period of cumulative economic growth among all post-communist countries in Central and Eastern Europe. Its growth rate was higher and more stable when compared to both countries with higher (Czech Republic, Hungary, Slovak Republic, Slovenia) and lower (Bulgaria, Romania) levels of GDP per capita in 1995.

The objective of this article is to provide a supply-side explanation for Poland's exceptional, rapid and uninterrupted growth performance during the period 1996–2013. The pace and structure of economic growth in Poland are studied with the help of a standard growth accounting framework but using a new, arguably more precise calculation of flows of capital and labour services. Based on these new estimates, we also construct an empirical measure

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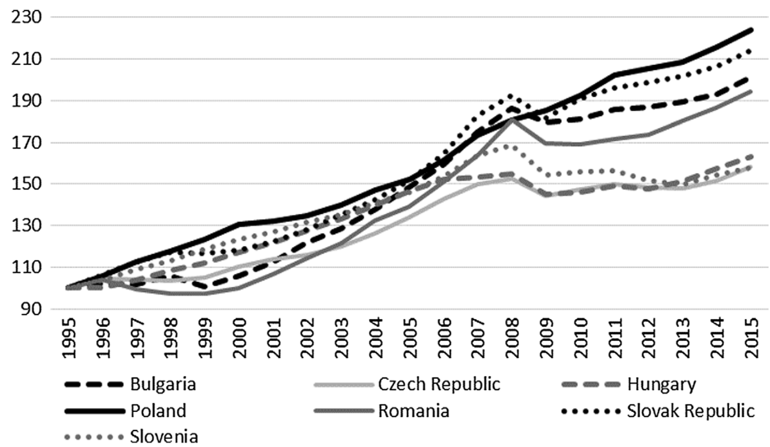

Figure 1. Cumulative growth of GDP per capita in CEE countries (constant 2010 US$, 1995 = 100 for each country). Source: The World Bank.

of output adjusted for capacity utilisation (henceforth, CU-adjusted output). We then use these results to draw some useful conclusions related to Poland's relative resilience to the world economic crisis of 2007–2009.

Hence, apart from being useful at the country level, our results enrich the general debate on lasting impacts of financial crises on the real economy by providing new evidence from a converging open economy which itself did not contribute to the breakout of the world economic crisis but was affected by its spread. Owing to its clear supply-side focus, the contribution of the article is complementary to a range of articles investigating the economic impacts of the crisis from the perspective of demand factors and policy responses (e.g. Baldwin & Giavazzi, 2015; Berkmen, Gelos, Rennhack, & Walsh, 2012; Marelli & Signorelli, 2016; Nabli, 2011) or pre-crisis variables (e.g. Dominguez, Hashimoto, & Ito, 2012; Frankel & Saravelos, 2012; Lane & Milesi-Ferretti, 2011).

Our study is also closely related to a range of studies which view the impact of the crisis on the real economy through the lens of the *potential output* concept (our methodology allows us to define a different but related concept of the level of output adjusted for capacity utilisation). As pointed out by Koopman and Székely (2009), there are three possibilities: (i) full recovery, where there is no loss in the level of potential output in the long term; (ii) permanent loss in the level but no change in the growth rate over the long term; and (iii) permanent loss in the growth rate of potential output and, as a consequence, an ever-increasing reduction in the level. It is argued that the second scenario is the most likely outcome for Western Europe. A similar conclusion has also been reached by the ECB (2011) and Furceri and Mourougane (2012).

Accordingly, Haltmaier (2012) has found that the negative permanent impact of recessions on the level of potential output is likely a result of lower capital–labour ratios due to lower investment.[1] She has also found that while the depth of a recession is critical for reducing trend output in advanced economies, its length is more important for emerging markets. This observation is coherent with the development of economic growth in Poland, which slowed down considerably only in 2012 and 2013, i.e. 4–5 years after the burst of the crisis.

On the other hand, Fernald (2012a) tells a different story for the US economy. According to his calculations, labour productivity and TFP growth in the US slowed down already in the early 2000s, largely due to a reduction in intangible investments. This early slowdown was not recognised at the time. Later on, during the world economic crisis, however, productivity behaved just in line with the previous recessions. Importantly, and contrary to the other literature mentioned above, Fernald (2012a) finds the labour market (as opposed to investment outlays) to be an important factor behind the sharp decline in TFP and a somewhat less pronounced decrease in labour productivity. An increase in the capital–labour ratio was due to falling hours and was accompanied by rising labour quality driven by disproportionate job losses on the side of low-skilled workers. Borio, Disyatat, and Juselius (2013) and Steindel (2009) also point to this direction, arguing that growth of GDP and potential output were overstated prior to the crisis, but for different reasons – the standard measures of potential output had not embedded the information on financial activity and stability.

The literature on the effects of financial crises on potential output in Central and Eastern European (CEE) countries is extremely scarce. The only article in this area which we are aware of is by Halmai and Vásáry (2013) who find that the crisis has reduced potential output growth in these countries to a lesser extent than the EU27 average.[2] Additionally, the average potential output growth rate in the CEE 'catching-up' countries is identified to be significantly higher than the EU27 average, mainly due to intensified capital deepening and higher TFP growth. In the next few years this difference is expected to narrow down due to the ongoing convergence process.

The context of the abovementioned literature justifies why it is worthwhile to focus on the case of the Polish economy. First, the evidence from the region is scarce. Second, Poland is an interesting case to consider in relation to the question on lasting real-economy impacts of financial crises because it is a converging, open economy which has not contributed to the outbreak of any of them, and because it has managed to maintain positive (and often high) GDP growth rates throughout a time span that has very few precedents in the European post-war history.

Our main contribution is to identify the supply-side factors behind Poland's uninterrupted growth performance since 1996. Using a growth accounting approach, we decompose Poland's GDP growth into the shares of labour, capital and TFP, and discuss the supply-side determinants of CU-adjusted output growth. Importantly, following the pioneering work of Jorgenson and Griliches (1967) and especially Fernald (2012a, 2012b), we carefully distinguish the concepts of stocks of production inputs and the flows of services they provide for production purposes, which has never been applied to the Polish economy before. This allows us to draw conclusions on developments of the (time-varying) composition of both production factors, corrected for their remuneration. We analyse the cyclical pattern of the composition components of factor inputs and assess their role in smoothing the recent recession. Finally, having corrected TFP for capacity utilisation and factor composition, we construct a relatively 'pure' measurement of productivity, which allows us to carry out a precise calculation of its contribution to GDP growth before, during and after the crisis.[3]

We demonstrate that Poland's resilience to the crises was not only due to a demand stimulus that was particularly helpful in 2009 and resulted, *inter alia*, from a reduction in labour income taxes, exchange rate depreciation or loosening of monetary policy (for a narrative analysis, see e.g. Chapter 1 of OECD, 2010), but also had important supply-side drivers. In particular, in 2009, i.e. when the financial crisis was most severe: (i) the contribution of capital deepening was highly positive; (ii) there was a strong and positive labour reallocation effect *despite* a lack of significant adjustment in total hours worked; and (iii) CU-adjusted TFP growth did not slow down markedly. While some of these effects could also be observed in other countries during the crisis, the coincidence of all three can be considered exceptional and adds to our understanding of why Poland has fared so well in the midst of the financial turmoil.

We also show that neither the recent nor past recessions seem to have exerted any significant impact on the efficiency with which economic resources are being used for production purposes in Poland. Our output decompositions imply that, on the one hand, the exceptional performance of the Polish economy in 2008–2010 was largely an effect of a range of favourable circumstances. On the other hand, it turns out that the world economic crisis has neither strengthened nor reversed the medium-run downward trend in TFP dynamics in Poland, driven by the productivity convergence process (see e.g. Kolasa, 2008).

The remainder of the article is structured as follows. In Section 2 we describe our methodology and define the flows of services generated by factor inputs as well as TFP. In Sections 3 and 4 we discuss the developments of capital and labour, respectively, carefully distinguishing between the stocks and flows of services. In Section 5 we construct TFP and its CU-adjusted component. Section 6 presents the results of our growth accounting exercise. Section 7 draws conclusions for CU-adjusted output in Poland. Section 8 addresses the cyclical properties of the analysed variables. In Section 9 we comment on the pace and structure of Poland's GDP growth in the years of the world economic crisis. Section 10 concludes.

2. Method

Our empirical method is a slight modification of the growth accounting framework proposed by Fernald (2012a, 2012b). We carry out a series of decompositions of the aggregate production function, which is assumed to exhibit constant returns to scale,[4] as in:

$$Y = A \cdot F\left(Util_K \cdot K\left(K_1, K_2, \ldots, K_n\right), Util_L \cdot L\left(L_1, L_2, \ldots, L_m\right)\right),$$

based on data on output (i.e. real GDP in base prices as of 2005) of the Polish economy Y as well as the flows of services of inputs: capital K and labour L. Each of these two inputs is itself an aggregate of a number of capital or labour types (n and m, respectively), differing in their marginal productivity. Flows of capital and labour services are assumed to be proportional but not equal to their stocks. The (time-varying) coefficients of proportionality are the capital and labour utilisation rates, denoted as $Util_K$ and $Util_L$, respectively. The aggregate production function is augmented with a Hicks-neutral technological change component A, which can be interpreted as CU-adjusted TFP.

Having denoted the growth rates of the respective variables as $\hat{x} = ln\left(\frac{x_{t+1}}{x_t}\right)$, the Törnqvist index of output growth is written down as follows:[5]

$$\hat{Y} = \alpha\hat{K} + (1 - \alpha)\hat{L} + \widehat{Util} + \hat{A},$$

where the growth rate of the capital input (services provided by capital) is given by $\hat{K} = c_1^K \hat{K}_1 + c_2^K \hat{K}_2 + \ldots + c_n^K \hat{K}_n$, the growth rate of labour (labour services) is $\hat{L} = c_1^L \hat{L}_1 + c_2^L \hat{L}_2 + \ldots + c_m^L \hat{L}_m$ and $\widehat{Util} = \alpha \widehat{Util}_K + (1-\alpha)\widehat{Util}_L$ is the weighted average of capital and labour utilisation rates.[6] In accordance with the generality of the above Törnqvist index, allowing us to refrain from making exact functional assumptions on the aggregate production function, the components of input aggregates are weighted proportionally to their (time-varying) shares in total remuneration of the respective inputs: c_i^K is the share of remuneration of K_i in K, c_i^L is the share of remuneration of L_i in L, α is the capital share of GDP at factor prices.[7] Each of these shares is computed as an arithmetic average of the respective values at times t and t+1.

It should be noted that the aforementioned aggregation procedure is not equivalent to a simple summation over all capital and labour types. We shall, in fact, make use of the latter in our analysis as well, in the following way. Denoting the raw sum of capital inputs as $K_{raw} = K_1 + K_2 + \cdots + K_n$ and the raw sum of hours worked as $L_{raw} = L_1 + L_2 + \cdots + L_m$, we shall define the *composition component* of capital and labour, respectively, as $\hat{Q}_K = \hat{K} - \hat{K}_{raw}$ and $\hat{Q}_L = \hat{L} - \hat{L}_{raw}$. Hence, the composition components – differences between the respective weighted and unweighted averages – capture the dynamic effects of shifts in shares of various types of the respective input in its total remuneration. More precisely, any increase in a given composition component should be interpreted as an indication of an observed increase in the share of relatively more productive capital or labour types in the raw input aggregate. For instance, the capital composition component may rise if the share of (relatively more productive) equipment in the total capital stock increases at the expense of structures, and the labour composition component may rise due to an increase of the share of (relatively more productive) people with tertiary education in the workforce.

Having backed out the contribution of increases in capital and labour services to GDP growth, we are left with the *TFP* (or *Solow residual*), which can be further decomposed into two components: the relative change in *capacity utilisation* and a *CU-adjusted measure of TFP growth*:

$$\widehat{TFP} = \hat{Y} - \alpha\hat{K} - (1-\alpha)\hat{L} = \widehat{Util} + \hat{A}.$$

Hence, TFP growth can be viewed as a difference between growth in output and inputs, in line with the voluminous productivity analysis literature (see e.g. Kumbhakar & Lovell, 2000; Ten Raa & Mohnen, 2002), whereas CU-adjusted TFP growth can be defined similarly, except that the input growth component is corrected for time-varying capacity utilisation. Finally, due to being a residual component, TFP growth (and hence also its CU-adjusted variant) is a term where all possible 'other factors' show up: measurement error, time-varying markups, variation in inventories, etc.

From simple algebra we obtain that labour productivity growth, i.e. growth in GDP per hour worked, is equal to the α-weighted average of growth in the use of capital and labour services per hour worked plus TFP:

$$\hat{Y} - \hat{L}_{raw} = \alpha\left(\hat{K} - \hat{L}_{raw}\right) + (1-\alpha)\hat{Q}_L + \widehat{TFP}.$$

It is also straightforward to define *CU-adjusted output* as the output which would have been obtained if factors were fully utilised:

$$\hat{Y}_{adj} = \alpha\hat{K} + (1-\alpha)\hat{L} + \hat{A} = \hat{Y} - \widehat{Util}.$$

Hence, even though our methodology allows us to compute the 'output gap' – the gap between actual and CU-adjusted output – it is not particularly illuminating here because its contribution to GDP growth exactly coincides with the contribution of the rate of capacity utilisation.

Needless to say, all above (supply-side) decompositions rest on the usual set of neoclassical assumptions. Firms in our setup are requested to maximise their profits, with the implication that marginal products are proportional to marginal costs of production. The setup allows for the existence of markups over marginal costs of capital and labour; yet, for the measurement to be consistent, these markups ought to be constant over time.

Finally, note that there are a range of issues which are not accounted for in the above decomposition. First of all, we are silent on the question of what drives TFP growth: the answers could range from technological progress and adoption of more efficient technologies from abroad to changes in technical efficiency of production driven, e.g. by institutional changes or the accumulation of social capital. Second, our aggregative approach requires us to abstract from a range of important issues such as: the sectoral structure of the economy, international competitiveness, the technology content of exports, R&D intensity, mismatch of skills, etc.

3. Capital input

While homogeneity of physical capital is a convenient assumption made in most macroeconomic analyses, it is clear that various types of capital coexist in reality and substitution between them is far from perfect. Since different capital types usually have different marginal products, accounting for changes in the composition of the aggregate capital stock is important if the ultimate goal is to calculate its contribution to changes in output.

As discussed in the previous section, we account for capital heterogeneity by constructing our measure of the capital input not as a simple sum over all capital stock types, but instead we follow Fernald (2012a) and use weights which are meant to capture differences in productivity across individual capital varieties. More specifically, the weight of each capital type i is calculated as $c_i^K = R_i K_i / \sum_i R_i K_i$, where R_i denotes the user cost of variety i. Hence, to calculate changes in the aggregate capital input, we need estimates of individual capital stock levels and their user cost.

As regards the former, we assume that for each type of capital, its stock in a given year is equal to the arithmetic average of the beginning and end of year values, which we calculate using the standard perpetual inventory method:

$$\tilde{K}_{i,t} = \left(1-\delta_i\right)\tilde{K}_{i,t-1} + I_{i,t},$$

where $\tilde{K}_{i,t}$ is capital stock of type i at the end of period t (assumed equal to the stock at the beginning of the next period), $I_{i,t}$ is investment in capital of type i, and δ_i denotes the asset-specific depreciation rate.

To estimate the user cost of capital, we use the standard first-order condition for the optimal capital input choice which can be written as (see e.g. Jorgenson & Griliches, 1967):

$$R_{i,t} = \left(r_t + \delta_i - E_t \pi_{i,t+1}\right) P_{i,t},$$

where $P_{i,t}$ is the purchase (investment) price for capital i, $E_t \pi_{i,t+1}$ is the expected rate of price appreciation for capital type i between the current and next period, whereas r_t stands for the nominal interest rate, normalised such that the total capital income share coincides with the one reported in the national accounts.[8] This formula implies that those capital types which depreciate and lose their value fast, and hence must be highly productive to compensate for their user cost, receive a relatively high weight in the calculation of aggregate capital services. In particular, if capital growth is concentrated primarily in the highly compensated types, the service measure will grow at a faster rate than the raw aggregate which is obtained as a simple sum.

In our baseline capital input calculations we distinguish between the following four physical capital types: non-residential buildings and structures, transport equipment, other machinery and equipment, and intangible fixed assets. All data sources are presented in the Appendix 1, which additionally reports several robustness checks, including the role of information and communication technologies (ICT).

Figure 2 plots our estimates of capital input growth, compared to raw estimates that do not take changes in capital composition into account. According to both measures, the capital input responds to the business cycle with a lag. In particular, its contribution clearly decelerated following the slowdowns in economic activity, like those observed in Poland in the early 2000s and during the world economic crisis. Looking at the averages, the volume of capital services over the period of 1996–2013 was growing at 5.1% per annum, i.e. somewhat faster than what one might find by looking just at raw numbers (4.7%). However, adjusting for capital composition makes a significant difference only during the first five years of our sample, being hardly distinguishable from raw estimates from 2002 onwards.

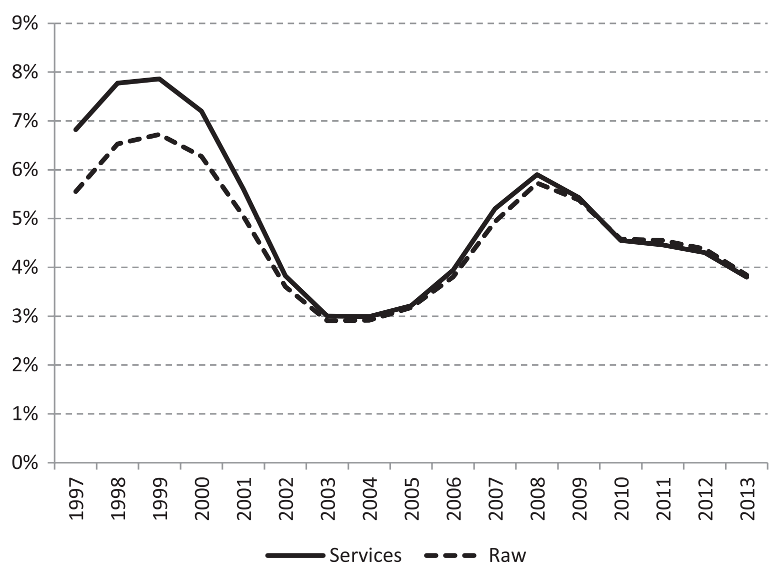

Figure 2. Capital input growth. Source: Own calculations.

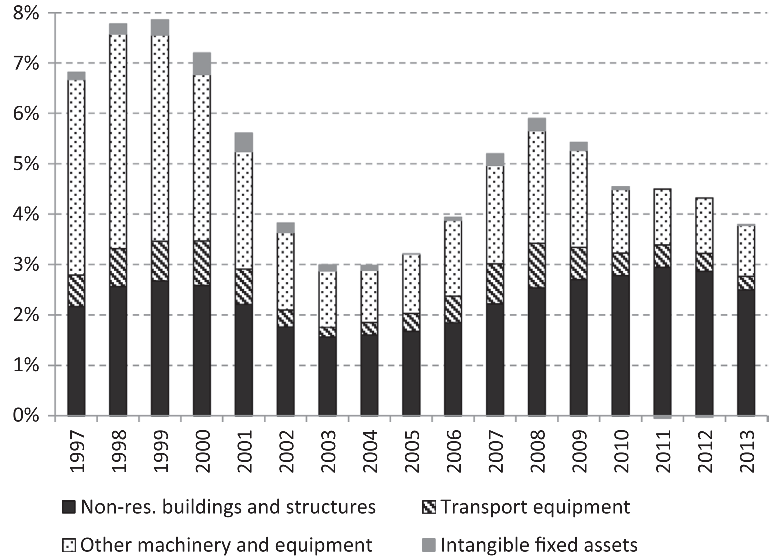

Figure 3. Decomposition of capital services growth. Source: Own calculations.

The contributions of individual capital types to aggregate capital services growth are presented in Figure 3. Over the analysed period, buildings and structures were the most stable component, contributing 1.6–3.0 pp. per annum to aggregate capital dynamics. Another important capital type, machinery and equipment, was far more volatile, with its annual contribution ranging between 1.0 and 4.3 pp. The dynamics of this relatively productive type of investment (i.e. depreciating and losing value faster than buildings and structures) was particularly high during the second half of the 1990s, so in the period of structural transformation of the Polish economy. This is also the main reason for the significant difference between the raw and composition-adjusted measures of aggregate capital during the first years of our sample. The remaining two capital types played generally a much smaller role.

Summing up, during the last 12 years our preferred estimates of the rate of capital accumulation do not significantly differ from those obtained while ignoring physical capital heterogeneity. However, the contribution of this production factor to economic growth in the late 1990s was substantially higher than one might have assessed by looking at the raw measure of capital.

As we show in the Appendix 1, using an alternative breakdown of capital that accounts for the role of ICT increases the average growth rate of capital services by 0.3 pp. This difference is mainly driven by the estimates obtained for the beginning and middle of our sample, virtually disappearing as from 2006.

4. Labour input

Although growth accounting exercises based on macro data frequently assume hours worked to be a homogenous input to the production process, both wages and marginal productivities of different types of workers can in fact be very different in reality. This reflects both employees' innate characteristics, such as their human capital (educational attainment, work experience, tenure) and differences in labour productivity of the same persons across, sectors, which tend to be stubbornly persistent due to slow and inefficient labour relocation.

As a consequence, ongoing changes in the composition of the labour input can have a significant influence on growth accounting results, even when viewed in the long-term cumulative sense. The problem is expected to be particularly acute if the sectoral structure of employment is unstable or if there are significant and asymmetric improvements in educational attainment of the population. Such changes were indeed observed in Poland in the last two decades.

In order to account for the heterogeneity of workers and hours worked, we stratify workers by their educational attainment, age, gender, and sector in which they work (see the Appendix 2 for data sources and details). This allows us to draw a clear distinction between raw measures of the labour input (employment, hours worked) and our main variable of interest: the actual flow of labour services, corrected for the differences in labour productivity across employees and workplaces.

More precisely, our approach to capturing changes in labour composition follows Bell, Burriel-Llombart, and Jones (2005). It is based on the estimation of means for each of the considered groups of workers.[9] We assume that the growth rate of the quality-adjusted labour input is given by the following Törnqvist index:

$$\hat{L}_t = \Delta \ln L_t = \ln\left(\frac{L_t}{L_{t-1}}\right) = \sum_i \left[\frac{s_{i,t} + s_{i,t-1}}{2}\right] ln\left(\frac{h_{i,t}}{h_{i,t-1}}\right),$$

where $h_{i,t}$ represents hours worked by workers from group i at time t and $s_{i,t}$ is the share of labour compensation of group i at time t. The weights in the index are given by average shares in the periods t and t–1. Similarly to the capital input, growth rates of the composition-adjusted labour input are then obtained as a weighted average of growth rates of total hours worked by groups of workers, with weights given by their respective shares in total labour compensation. Hence, the quality-adjusted index grows faster than the unadjusted one if and only if the groups with relatively higher wages experience relatively faster growth in hours worked.

The growth rate of the unadjusted labour input, on the other hand, captures the dynamics of the total number of hours worked, $\hat{L}_{raw} = \Delta \ln H_t$, treating all hours worked as homogenous. It can also be further decomposed into the growth rate of employment $\Delta \ln E_t$ (the extensive margin) and the growth rate of average hours worked per worker $\Delta \ln \overline{H}_t$ (the intensive margin). Finally, the difference between the growth rates of the quality-adjusted and unadjusted labor input captures the contribution of the labour composition component ('quality' of hours worked):

$$\hat{Q}_L = \Delta \ln Q_t = \Delta \ln L_t - \Delta \ln H_t = \Delta \ln L_t - \Delta \ln \bar{H}_t - \Delta \ln E_t.$$

Using the properties of the Törnqvist index, we can calculate the separate contributions of each of the features taken into account (educational attainment, age, gender, sector) to the growth of the quality-adjusted labour input. For example, the partial 'education-specific' labour composition component, capturing the differences between groups according to their educational attainment but ignoring all other dimensions of worker heterogeneity, is computed as:

$$\Delta \ln Q_t^E = \Delta \ln L_t^E - \Delta \ln H_t.$$

This is called a *first-order partial index* of characteristic *i*. Since the current study singles out four distinct labour force characteristics, we compute four partial indexes of this kind. Furthermore, one could also consider individual contributions of combinations of (two or more) worker features, leading to analogous calculations of second- and higher-order labour force productivity decompositions. For example, the second-order index capturing the joint contribution of education and age could be calculated as follows:

$$\Delta \ln Q_t^{E,G} = \Delta \ln L_t^{E,G} - \Delta \ln H_t - \Delta \ln Q_t^E - \Delta \ln Q_t^G.$$

We find that a large majority (72%) of variance of the labour composition component is already accounted for by the first-order decomposition. Second-order contributions, calculated to adjust the results of the first-order decomposition, add a further 24%, leaving only less than 4% to higher-order contributions which have therefore been disregarded. The changes unexplained by first- or second-order contributions were never higher than 0.1 percentage points of the annual change.

Our results imply that unadjusted measures of the labour input, which assume homogeneity of employees and disregard any changes in the composition of the labour force, lead to a significant underestimation of aggregate labour input growth (Figure 4). Crucially, we find that the divergence is particularly pronounced after 2002, and that the cumulative effect of labour composition is substantially larger compared to that of capital composition discussed in the previous section.

The number of employed persons in Poland decreased in the years 1995–2002 by 6.5% (the unemployment rate exceeded 20% in 2002) but then increased steadily until 2013. In 2013 it was actually 8.0% higher than in 1995. However, due to the gradual decline in the average number of hours worked per worker in the economy, the dynamics of the unadjusted

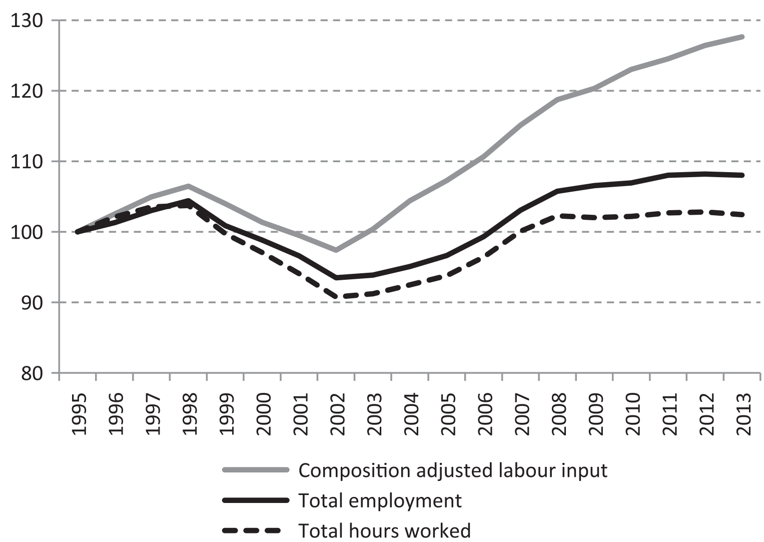

Figure 4. Cumulative labour input growth (year 1995 = 100). Source: Own calculations.

labour input is a bit less impressive. In 2013, the total number of hours worked in the economy was higher than in 1995 by only 2.4%. On the other hand, taking into account the changes in the composition of labour, i.e. increases in the employment share of better paid and more productive workers, entirely overturns these negative conclusions. In fact, we find that our measure of labour service flows (quality-adjusted labour input growth) decreased between 1995 and 2002 only by about 2.6%, after which it began to increase rapidly, reaching a 27.6% higher level in 2013 as compared to 1995. Such a huge influence of the labour composition component confirms that without the correction, our estimates of the total labour input would have been heavily biased downwards.

The decomposition of labour input growth into the contributions of the number of workers, average hours worked per worker and the labour composition component (Figures 5 and 6) allows us to describe its evolution in more detail. We find that changes in employment were the most important factor behind the cyclical variation of the total labour input: employment fluctuated procyclically with a deep decline in the period 1999–2002, huge positive growth in the period 2005–2008 and relatively lower amplitude since 2009. Average hours worked decreased throughout almost the whole period, but the waves of a deeper decline appeared in the periods of economic slowdowns like 1999–2002, 2009–2011 and 2013. In contrast to those changes, the contribution of labour composition (labour 'quality') was consistently positive in every year of the discussed period, albeit perhaps somewhat countercyclical due to the selection of more productive workers during economic slowdowns in 2003–2004 and in 2009–2010.

These results are in line with the only earlier publication in this area that we are aware of, i.e. Bukowski, Magda, Marć, and Zawistowski (2006). This report argues that in the period 1992–2005, improvements in human capital, measured by the changes in the percentage of persons with tertiary education, had a greater impact on Poland's output growth than changes in total employment and flows between sectors.

These results are also not surprising in the context of the huge jump in the share of persons with tertiary educational attainment in Poland in the beginning of the twenty-first

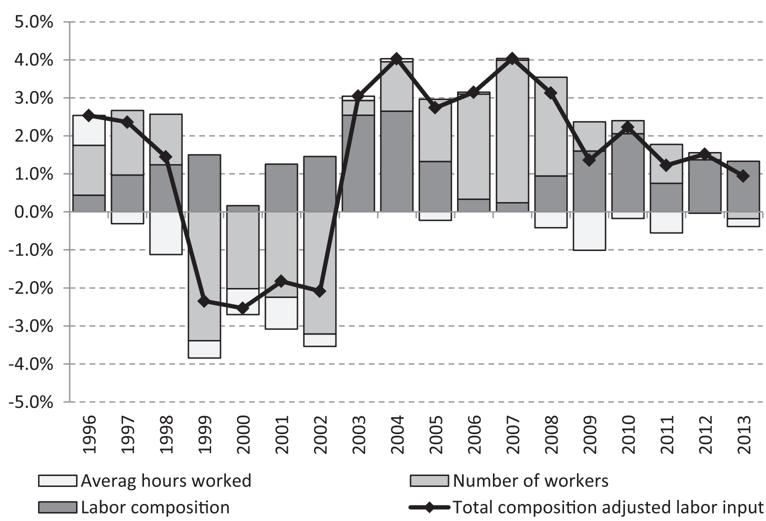

Figure 5. Decomposition of annual labour input growth. Source: Own calculations.

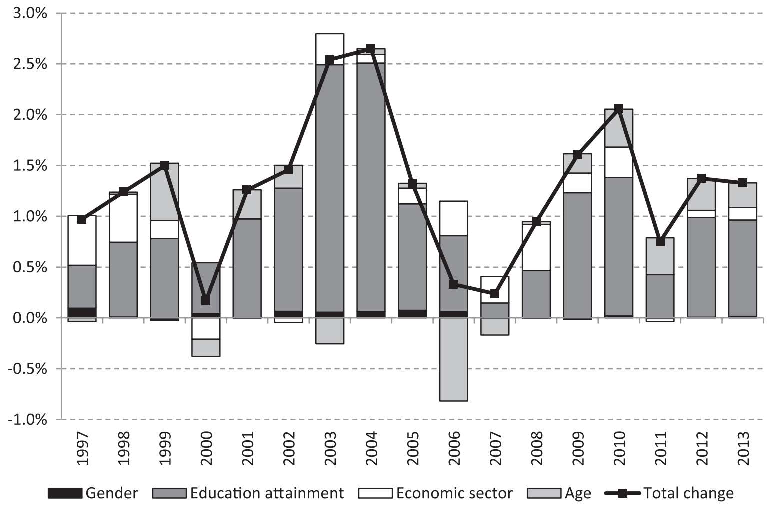

Figure 6. Breakdown of the labour composition component. Source: Own calculations.

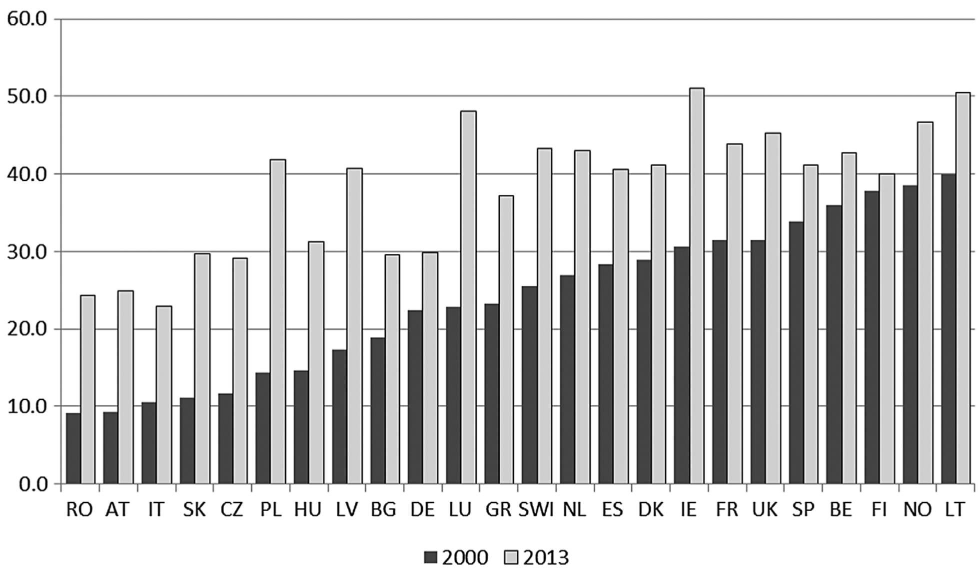

Figure 7. Changing shares of persons with tertiary education in the age group 25–29 in European countries in 2000* and 2013. Source: Eurostat, *comparison of countries is limited to the period 2000–2013 because for many countries earlier data are not available.

century (Figure 7), whose magnitude was impressive even when viewed against the fact that increased popularity of tertiary education in the considered period was an international phenomenon. In 2000, the share of young persons (aged 25–34) with tertiary education in Poland was one of the lowest in the EU. In about 15 years it reached 42%, significantly more than the EU average (36%) or the Euro area average (32%). This jump in formal education was the biggest among the EU countries and – with time – it also significantly improved the formal educational attainment of the whole working age population (and will continue to improve it in the years to come). As a result, employers in Poland could have relatively easily improved the human capital of their employees, as shown in the decomposition.

Additionally, we have performed a set of robustness checks, presented in the Appendix 2. These tests include: a comparison of our results with their counterparts based on data from the Polish Structure of Earnings Survey, an assessment of the influence of the migration flows not fully included in LFS data before the census in 2011, and an analysis of the extent to which our results depend on changes in relative wages of different groups.

Summing up, our estimates of (composition-adjusted) labour input growth are very different from the ones obtained when ignoring worker heterogeneity. As we shall see shortly, this implies that the contribution of the labour input to economic growth in Poland over the period 1995–2013 was substantially higher than one might assess by looking at its unadjusted measure only. The main reason for such a discrepancy is the increase in the average productivity of workers caused by an increasing share of employees with tertiary education. It was possible due to the huge increase in the popularity of tertiary educational attainment among young persons from the generation born in the early 1980s. Furthermore, the labour composition component also plays an important role in mitigating the procyclical fluctuations of the aggregate labour input.

5. TFP growth

Having constructed the measures of capital and labour services, we are in the position to calculate the *Solow residual (TFP growth)* and *CU-adjusted TFP growth* as defined in Section 2. Figure 8 plots the unadjusted TFP growth rate obtained under three different assumptions regarding the measurement of capital and labour input growth. The bold line represents our baseline version, in which composition effects caused by changes in the makeup of both capital and labour are taken into account. The grey line shows what happens when we disregard the abovementioned effects and assume that there is no heterogeneity among different types of capital or labour inputs. The dashed grey line ('services with ICT') provides

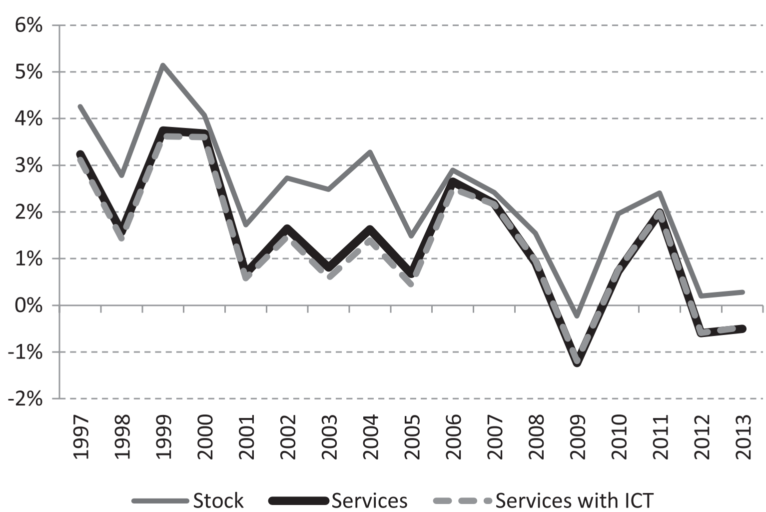

Figure 8. Unadjusted TFP growth (Solow residual) with and without accounting for changes in the composition of inputs. Source: Own calculations.

an additional robustness check (see the Appendix 1), allowing us to compare these two scenarios with one that capitalises on the available data on ICT expenditures in Poland.

Our calculations allow us to draw several conclusions regarding the role of input composition effects in growth accounting. First, using raw stocks instead of composition-adjusted measures of capital and labour services leads to a substantial overestimation of TFP growth, by 0.9 pp. per annum on average. In particular, looking at the recent recession, we see that in 2006–2007 the gap was relatively small (0.3 pp.), then in 2008–2010 it widened up to 1.3 pp., and in 2011 both estimates converged again. Second, accounting for ICT has very little impact on our estimates of TFP growth – in contrast to the findings for the US economy (Fernald, 2012a).

TFP growth discussed above should not be taken as a literal measure of increases in factor productivity, though (e.g. Basu, Fernald, & Kimball, 2006). The basic reason is that short- to medium-run variation in observed TFP growth can be driven largely by changes in the utilisation rate of production factors.

As discussed in Section 2, we have addressed this concern by adjusting TFP growth with a survey-based measure of capacity utilisation, provided by the NBP in its Quick Monitoring Survey. Consistently with the characteristics of this dataset, we depart from Fernald (2012a, 2012b) and apply the utilisation rate to capital only. Labour utilisation rates are, as opposed to Fernald's data, already included in our direct, LFS-based measure of hours worked. A discussion of the properties of the capacity utilisation measure and some robustness checks are presented in the Appendix 3.

Since correcting for capacity utilisation has no impact on the magnitude of capital and labour composition effects, we proceed directly to the comparison between TFP growth before and after the adjustment. Both variables are presented in Figure 9. We find that adjusting for capacity utilisation indeed helps to wipe out some variation in TFP growth at business cycle frequencies; even then our estimates of CU-adjusted TFP growth remain far from

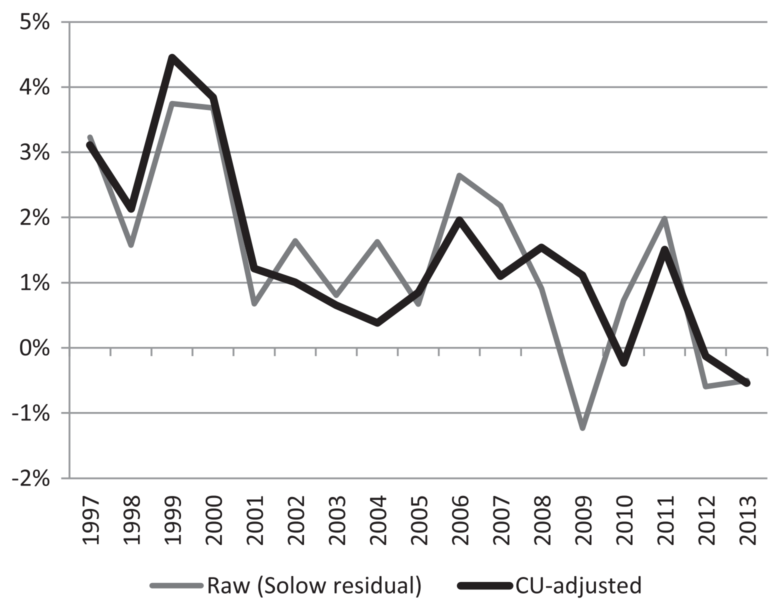

Figure 9. Unadjusted TFP growth (Solow residual) and CU-adjusted TFP growth. Source: Own calculations.

smooth, though. In particular, they imply a sudden drop in 2010 and an immediate V-shaped rebound in 2011, followed by another drop in 2012. Although this is an indication of a double-dip recession with respect to Poland's productivity growth, nevertheless it seems that the current behaviour of CU-adjusted TFP growth remains different than after the crisis of 2000–2002 when its path was decidedly L-shaped. The main distinction between both crises lies in their sources. While the first one was rather structural and largely internal for Poland, the recent one had, for the case of Poland, purely external origins.

Summarising all the abovementioned findings, we conclude that our 'service-based' approach should capture TFP growth more accurately than the other approaches taken in the literature. The main advantage of our setup is that it allows for an *explicit* inclusion of composition effects driven by the changing structure of inputs. The heterogeneity of capital and labour would otherwise be *implicitly* disguised in TFP growth estimates. Since the composition effects are either gradually decreasing over time (capital) or countercyclical (labour), one should take them into account while analysing the behaviour of productivity both in the long and short run.

6. Growth accounting results

Having constructed all our input and output measures as carefully as possible, we are in the position to carry out the growth accounting exercise specified in Section 2. The results, based on our preferred (baseline) specifications, are presented in Figure 10. As inputs, we use the flows of services of capital and labour (*K* and *L*). We also decompose TFP growth into the components attributable to capacity utilisation (*Util*) and productivity (*A*).

We observe that GDP growth in Poland in the period 1996–2013 has in fact been driven to a decisive extent by the accumulation of physical capital. Its contributions have been remarkably stable across the business cycle and consistently positive throughout the considered period, amounting typically to 1.5–2 pp. per annum. The contributions of CU-adjusted TFP growth have also been consistently positive and often substantial (hiking up to 4 pp.

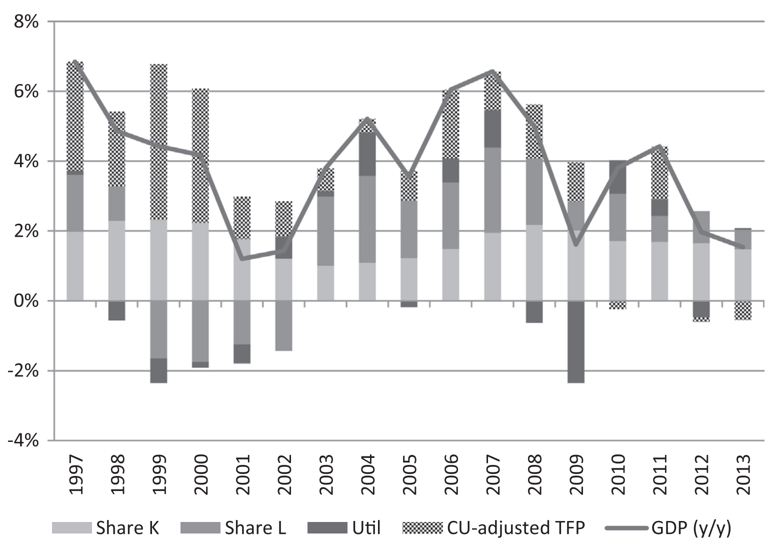

Figure 10. Contributions to GDP growth in Poland, 1996–2013. Source: Own calculations.

per annum in 1998–2000), whereas the contributions of labour have been also generally positive, but subject to much stronger cyclical volatility.

The predominant role of capital accumulation uncovered by the above decomposition agrees with the view of Poland as an economy undergoing the process of neoclassical real convergence towards its wealthier neighbours and trading partners, such as Germany and other highly developed Western European countries. Given the vast difference in capital endowments between Poland and the EU average in 1996, the neoclassical theory predicts physical capital accumulation to be the key contributor to Poland's GDP growth over the following years. However, this theory also predicts endogenous adjustment of capital in response to technological progress and hence our standard growth accounting clearly underestimates the role of the latter (for exposition, see Klenow & Rodríguez-Clare, 1997; Madsen, 2010, 2011). To disentangle these two effects we alternatively decompose output growth according to the following equation:

$$\hat{Y} = \frac{\alpha}{1-\alpha}(\hat{K} - \hat{Y}) + \hat{L} + \frac{1}{1-\alpha}\widehat{Util} + \frac{1}{1-\alpha}\hat{A},$$

which is just a rearrangement of our baseline formula, such that capital deepening induced by technological change is attributed to CU-adjusted TFP.[10]

Figure 11 presents the results of this alternative decomposition. As expected, the contribution of capital deepening is now substantially smaller but still substantial, adding on average 0.5 pp. to annual GDP growth. Interestingly, it was particularly strong in 2009, exceeding 2 pp. and hence greatly cushioning the scale of slowdown in output growth during the world economic crisis. We discuss this result in more detail in the following sections.

Table 1 complements these general findings with a quantitative assessment of the impact of the choice of factor measurement method on the growth decomposition for the whole considered period. We see that, as far as the capital contribution is concerned, it contributes

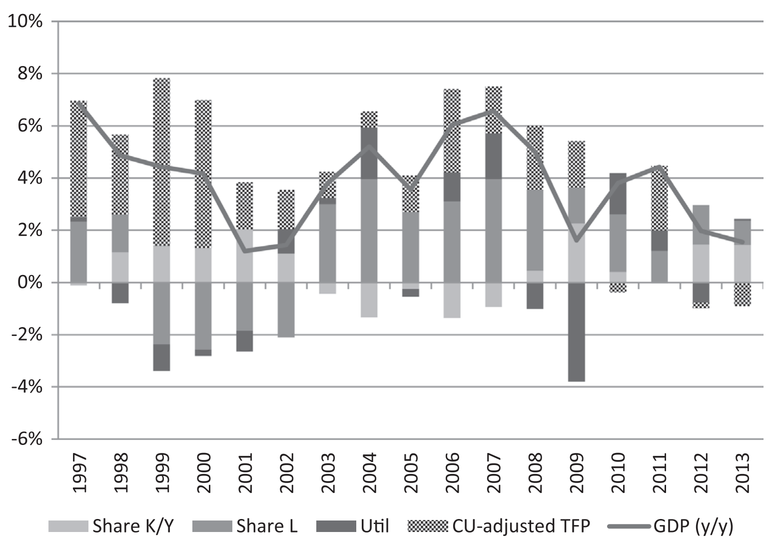

Figure 11. Contributions to GDP growth in Poland, 1996–2013, alternative decomposition. Source: Own calculations.

Table 1. Contributions to GDP growth (1996–2013 averages).

	Measure	Share
Capital	Services	44.1%
	Services+ICT	46.3%
	Raw	41.5%
	Raw+ICT	48.2%
Labour	Services	20.1%
	Raw	−0.8%
Util	Util	−0.3%

Source: Own calculations.

Table 2. Contribution of CU-adjusted TFP growth (1996–2013 averages).

		Labour	
		Services	Raw
Capital	Services	36.1%	56.9%
	Services+ICT	33.9%	54.8%
	Raw	38.7%	59.6%
	Raw+ICT	32.0%	52.8%

Source: Own calculations.

41.5–48.2% of total GDP growth irrespective of whether we take input composition effects into consideration or not (and whether, as a robustness check, we distinguish between ICT and non-ICT capital). The situation is vastly different with the labour input, though. The raw number of hours worked has fallen slightly in Poland between 1996 and 2013, and thus the contribution of hours worked was negative on average (–0.8% of total GDP growth). The labour composition effect was much stronger and has more than compensated for that, however, so that in the baseline scenario the contribution of labour services to output growth is positive and amounts to +20.1%. As mentioned above, this is primarily due to a secular increase in education attainment in Poland in the considered period. The contribution of capacity utilisation rates is small because this variable has exhibited cyclical variability around a constant mean value.

The residual contribution to GDP growth – by construction – comes from changes in capacity utilisation adjusted TFP. Encompassing everything that cannot be traced back to improvements in the quantity or quality of production inputs, they may include, e.g. the benefits of disembodied technological progress, process innovation, adoption of superior management practices, increases in technical and allocative efficiency, improvements in the institutional environment of the economy, etc. According to our baseline specification, CU-adjusted TFP growth has contributed 36.1% of total GDP growth throughout the period 1996–2013 (Table 2). Its role in explaining growth increases considerably, however, to more than 50% if labour is measured as the raw number of hours worked.[11] The reason is that in such a case, all changes in labour composition, in particular the effects of the upward trend in educational attainment, are shifted in the accounting procedure from the labour component to TFP growth. Given that human capital is naturally embodied in workers, we therefore view it as vital to augment the measure of labour services with the composition component as we do in our baseline scenario.

To put these discrepancies in a dynamic perspective, in Figure 12 we present the time paths of capital and labour composition effects, both as growth rates and level indices. This

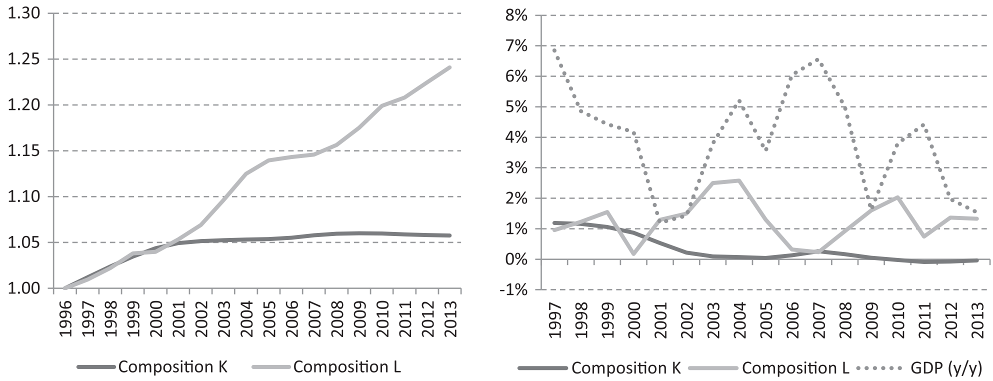

Figure 12. Labour and capital composition components, index 1996 = 100 (left panel) and growth rates (right panel). Source: Own calculations.

figure serves as another illustration why capital composition effects play a relatively minor role when compared to labour composition effects. As argued above, the increases in the capital composition component have been active only in the first years of the sample, mirroring the rapid accumulation of machinery and equipment. After 2001, the composition component has remained essentially constant. The labour composition component, on the other hand, has been growing strongly (up to 2.6% per annum) throughout the whole period and displayed substantial countercyclical variability. The cumulative increase in the level of the capital composition component amounted to just 5.8% between 1996 and 2013, whereas the labour composition component grew (cumulatively) by as much as 24.1%.

7. CU-adjusted output

The consecutive step of our analysis consists in computing the level of *CU-adjusted output*, i.e. the level of output which would have been obtained absent the variation in capacity utilisation. The results for the period 1996–2013 are presented in Figure 13. We see that the discrepancies between the actual and CU-adjusted output have not been large across the years. Both variables have recorded cumulative growth of approximately 94%. The level of the 'output gap', computed as the log difference between the actual and CU-adjusted output[12] has been strongly procyclical (positive in expansions, negative in downturns), but its magnitude reached at most 2% of GDP (in 2007). Interestingly, even though during the outbreak of the world economic crisis in 2008–2009, the economy indeed recorded a sharp decline in capacity utilisation, this fall was partly due to capacity over-utilisation during the preceding boom period, and it was then followed by a quick rebound. Hence, if anything, our results indicate that the impact of the recent crisis on the Polish economy was milder than the impact of the previous recession of 2000–2002. As argued above, this could be due to the fact that from the Polish perspective, the recent recession was of an entirely external origin whereas the former one revealed serious structural problems.

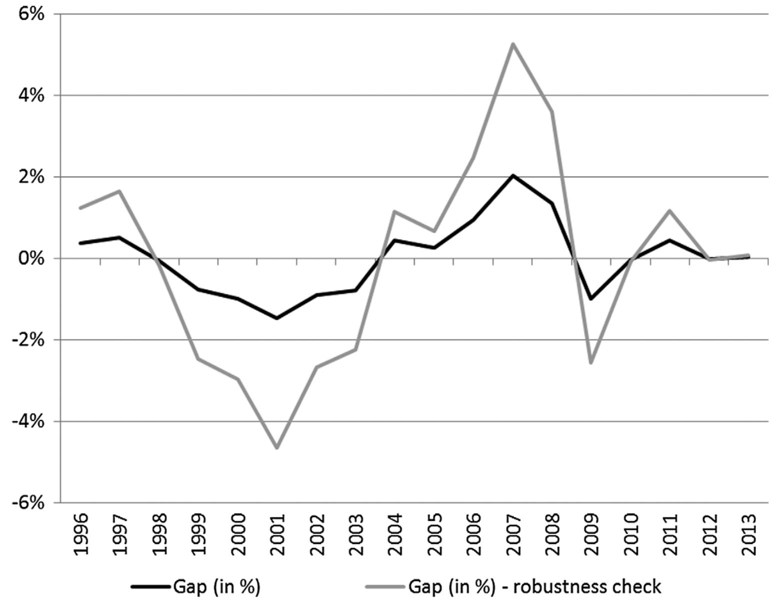

Figure 13. Dynamics of the gap between actual and CU-adjusted output in Poland. Source: Own calculations.

Table 3. Cyclical properties of the constructed variables.

		Correlation with output	Relative variance	Autocorr. (1st order)
Capital	Services	0.25	0.71	0.86***
	Services+ICT	0.29	0.69	0.88***
	Raw	0.19	0.41	0.82***
	Raw+ICT	0.25	0.31	0.76***
Labour	Services	0.52**	1.46	0.67***
	Raw	0.62***	1.48	0.68***
Utilisation		0.41*	1.67	−0.01
TFP		0.67***	0.63	0.30
CU-adjusted TFP		0.44**	0.57	0.56***

Source: Own calculations.
*$p < 0.1$; **$p < 0.05$; ***$p < 0.01$.

8. Cyclical properties of inputs

In Section 6 we have assessed the relative contribution of each of the production inputs as well as capacity utilisation and CU-adjusted TFP growth to total GDP growth, aggregated across the whole period 1996–2013. We have also provided an indication that all these components in fact exhibit distinct patterns of cyclical variability. This issue will now be studied more systematically.

Table 3 presents a summary of key cyclical properties of all the constructed variables: their contemporaneous correlation with output, relative variance (measured as a percentage of the variance of GDP), and degree of persistence (the first-order autocorrelation coefficient). Although these numbers should be interpreted with caution because they are based on just 18 observations, some properties clearly stand out.

First, the capital input is very weakly (statistically insignificantly) procyclical, exhibits a relatively small amplitude of fluctuations, and is very persistent over time. These properties hold true regardless of the definition of the capital variable, i.e. whether it is the (raw) stock or the (adjusted) flow measure of capital services. The capital composition component plays a negligible role here.

Second, the labour input is clearly procyclical (and statistically significantly so). It is also almost 50% more variable across the business cycle than GDP, and quite persistent. The labour services measure is somewhat less procyclical than raw hours worked, in line with the finding that the labour composition component varies countercyclically.

Third, the capital utilisation rate is procyclical, highly variable, and exhibits essentially no autocorrelation. The Solow residual (unadjusted TFP growth) inherits some properties of capacity utilisation, albeit it is significantly *less* variable than GDP. CU-adjusted TFP growth exhibits a comparable amount of procyclicality but, on the other hand, relatively little variance, and relatively more persistence. These properties of this residual variable are reassuring that our decomposition exercise has succeeded in capturing the broad pattern of impact of variability of inputs on the variability of output along the aggregate production function (Growiec, 2013).

The aforementioned results confirm the indication that, while the capital composition effect was active only in the first few years of the sample and essentially acyclical, the labour composition effect might in fact be driving some of our decomposition results – and thus it requires more detailed scrutiny. To this end, in Table 4 we present the cyclical properties of both composition effects.

It is clear from Table 4 that the labour composition effect is countercyclical. This result is consistent with our finding that labour composition improves during downturns. The employees who are relatively less productive because of being less well-educated, being in less productive age cohorts, or being employed in less productive sectors of the economy, are more likely to be fired from the job. Such 'selection' effects do not seem to operate during booms, though, at least in our data.

9. Supply-side factors behind Poland's relative resilience to the world economic crisis

Having analysed the detailed results of our decomposition exercises, let us now draw some quantitative inference regarding the last sub-period of our sample, covering the times of the world economic crisis (2008–2009) and four years immediately following the crisis. These results may shed some light on the question if the world economic crisis has exerted lasting influence on the Polish growth potential and which supply-side channels might have been affected.

Table 4. Cyclical properties of the composition effects.

	Correlation with output	Relative variance	Autocorr. (1st order)
Composition K	0.36	0.06	0.96***
Composition L	−0.33	0.15	0.34

Source: Own calculations.
*$p < 0.1$; **$p < 0.05$; ***$p < 0.01$.

Table 5. Why has Poland been the 'green island' in 2009?

	Output	Capital (raw)	Composition K	Labour (raw)	Composition L	Utilisation rate	TFP	CU-adj. TFP
Growth (in %)	1.62	5.24	0.05	−0.25	1.59	−6.16	−1.23	1.11
Contrib. (in pp.)	1.62	2.00	0.02	−0.15	0.99	−2.35	−1.23	1.11

Source: Own calculations.

Table 6. Comparison of contributions of the labour input to value added growth.

	Contribution of hours worked to value added growth (percentage points)		Contribution of labour composition change to value added growth (percentage points)	
	Average 1997–2008	2009	Average 1997–2008	2009
Poland	−0.04	−0.15	0.79	0.98
Netherlands	0.30	−0.79	0.72	0.14
Belgium	0.21	−0.94	0.63	0.10
Great Britain	0.45	−1.40	0.38	0.65
Germany	0.12	−2.11	−0.02	0.50
Italy	0.22	−2.20	0.54	0.36
Sweden	0.44	−2.39	0.63	0.09
Finland	0.13	−2.69	0.91	0.54
Japan	0.31	−2.77	−0.39	0.29
USA	0.48	−3.20	0.28	0.46
Spain	1.88	−3.77	0.30	0.67

Source: Own calculations (Poland), KLEMS database (other countries, the sample of which was limited by the availability of data until 2009 in the KLEMS database).

First, let us recall the anecdotal fact that Poland has been dubbed the 'green island' (in the 'red sea') in the midst of the world economic crisis: it was the only EU country which recorded positive GDP growth in 2009. Moreover, Poland's annual growth rate was actually quite large at the time, amounting to 1.6%. Our decomposition exercise, summarised in Table 5, elucidates that this number was driven largely by rapid capital accumulation, improvements in labour composition and CU-adjusted TFP growth, accompanied by just a tiny adjustment of employment, and was only counteracted by an abrupt decline in the capacity utilisation rate.

In fact, when viewed from the supply-side perspective, the key reason for Poland being the 'green island' in 2009 is that thanks to earlier investments (Poland's investment rate reached its local maximum in 2008, just before the crisis) the dynamics of capital accumulation have remained strong at the time. Moreover, the decline in the use of the raw labour input (total hours worked) has been more than compensated by labour composition effects – in line with the countercyclical mechanism of positive selection of more productive workers during downturns. Below we look at these two factors in more detail.

Starting with labour input, Table 6 compares our data for Poland with the calculations for other countries available in the KLEMS database (O'Mahony & Timmer, 2009). The results suggest that in the period before the crisis (1997–2008) the average contribution of total working hours to output growth was lower in Poland than in any other country in the sample due to the exceptionally deep reaction of the labour market to the 1999–2002 recession and an ongoing trend of reduction in hours worked per employee. In 2009, in contrast, the reduction of the raw labour input was relatively mild and caused only by the decrease in

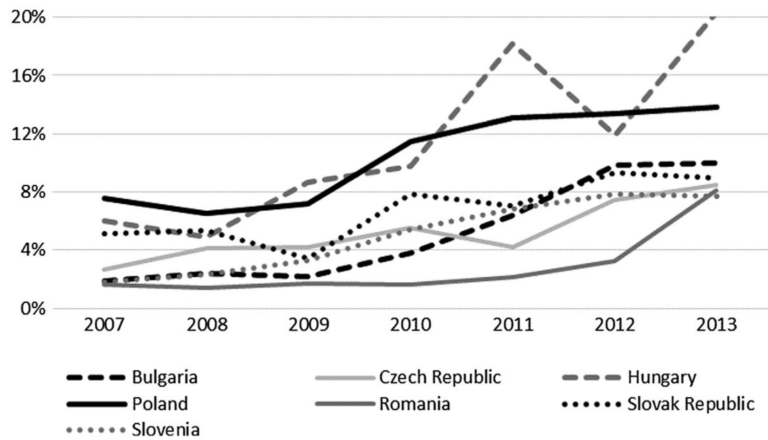

Figure 14. Direct contribution* of structural and cohesion EU funds to nominal GFCF growth. Source: Own calculations based on Eurostat and European Commission data.

Table 7. Impact of the world economic crisis on Poland's CU-adjusted output and TFP.

	Output	CU-adjusted output	CU-adjusted output (RC)	TFP	CU-adjusted TFP
1996–2008	4.42%	4.34%	4.23%	1.95%	1.85%
2008–2013	4.45%	4.89%	5.63%	0.08%	0.34%
1996–2004	3.99%	3.98%	4.00%	2.12%	2.10%
2004–2008	5.29%	5.06%	4.67%	1.60%	1.36%
2008–2013	4.45%	4.89%	5.63%	0.08%	0.34%

Source: Own calculations.

average hours per worker (see also Figure 5). As discussed above, in the period before the crisis Poland experienced a huge positive labour composition effect (due to mass higher education) that contributed on average 0.8 pp. to annual output growth. Only in Finland was this contribution higher in that period. In 2009 this effect in Poland was even stronger and amounted to almost 1 pp.[13]

Turning to capital accumulation, Figure 14 shows that the inflow of structural and cohesion funds from the EU was an important source of investment funding in Poland. In fact, the direct contribution of these funds to nominal investment growth reached 7 pp. in 2007–2008 and was the highest among the comparable post-communist countries of the region. Since participation of EU funds in financing investment projects is always only partial, one may expect that the total contribution (including e.g. multiplier and spillover effects) of EU funds to investment growth was markedly higher. As the EU programmes focus mainly on longer-term projects, they contributed positively to the continuation of capital deepening at the outset of the crisis. Their contribution has even increased since 2009, but it has not compensated for the decrease in private gross fixed capital formation. Overall, the EU funds helped sustain high investment demand in Poland during the times of financial market turmoil and drying commercial credit supply, contributing positively to both capital accumulation and aggregate demand.

But has the world economic crisis impacted Poland's potential for sustained growth in the *following* years? As argued intuitively above and as shown quantitatively in Table 7, our (partial, supply-side) answer to this question is negative. The average rates of output growth and CU-adjusted output growth have hardly changed when comparing the periods 1996–2008 and 2008 onwards, driven to a larger extent by a *transient increase* in both growth rates during the boom 2004–2008 than the subsequent decline: CU-adjusted output growth in 2008–2013 was actually 0.9 pp. above the 1996–2004 average. Moreover, given the scarcity of data points in our analysis, one should not interpret any differences below, say, 1 pp. as economically or statistically meaningful.

The next argument why we do not view the observed differences in CU-adjusted output growth rates before and after the crisis as driven by a slowdown in CU-adjusted output growth follows from the results of our additional robustness check, which makes a different assumption regarding capacity utilisation (see the Appendix 3). The result is even more striking here: there was an *increase* in CU-adjusted output growth after 2008.

On the other hand, we observe a continued downward trend in the pace of Poland's TFP growth. The average CU-adjusted TFP growth rate fell after 2008 by 1.5 pp. on average. This should not necessarily be taken as evidence for a negative impact of the crisis, though: CU-adjusted TFP growth in Poland actually decreased already when comparing the transition period 1996–2004 to the 2004–2008 boom, and this downward trend only continued afterwards. It turns out that the earlier period before the EU accession, marked by Poland's gradual structural and economic transition, has been characterised by relatively most rapid improvement in the (disembodied) technology component of GDP. Later, in the course of the country's real convergence with the EU, this source of growth has seemed to be the first to dry up. A tentative conclusion would be that the world economic crisis has neither strengthened nor reversed the medium-run downward trend in TFP dynamics in Poland, driven by the productivity convergence process.[14]

Naturally, there is a range of caveats which must be kept in mind when interpreting our results. First, it may simply be too early to say if the world economic crisis has really affected Poland's growth potential. There have been multiple confounding effects which might have affected our decomposition exercise, in particular in relation to the demand side of the economy. Second, there may exist an important long-term channel of impact which has not been accounted for (owing to our decomposition method): the crisis might have increased permanent unemployment. Third, our analysis abstracts from a few valid notions which we simply lump in the TFP (residual) component, but which may be important for assessing Poland's growth prospects in the coming years: (i) whether we are approaching a 'middle income trap' (Aiyar, Duval, Puy, Wu, & Zhang, 2013) precluding further convergence due to e.g. long-lived patterns of specialisation in international trade; (ii) low levels of social trust (Zak & Knack, 2001) and social capital (Beugelsdijk & Smulders, 2003), with comparable outcomes; and (iii) inefficient institutions (as captured e.g. by the World Bank's *Doing Business* index) leading to technical inefficiency in production (Acemoglu & Robinson, 2012; Hall & Jones, 1999). Finally, the aggregative character of our approach makes it silent on the issues related to the sectoral structure of the Polish economy. Threats to growth potential in converging economies such as Poland may arise due to, among others, a low share of high-tech industry and service sectors in the creation of total value added, low technology content of exports, low R&D intensity, and a skills mismatch, due to which unemployment may turn out stubbornly high despite the objective improvements in educational attainment.

10. Conclusion

Complementary to the associated literature, the current article has provided a focused *supply-side* explanation for Poland's uninterrupted growth performance during the last two decades. The key advantage of our analytical approach lies with the provision of new and arguably more precise calculations of flows of capital and labour services, capacity utilisation, and CU-adjusted total factor productivity (TFP) growth in Poland in the period 1996–2013.

Among many other quantitative conclusions, our results suggest that the recent recession has not exerted any significant impact on the efficiency with which economic resources are being used for production purposes in Poland. This corresponds with narrative descriptions found in the associated literature, e.g. OECD (2010), that the exceptional performance of the Polish economy in 2008–2010 was largely a positive coincidence, an effect of a range of favourable circumstances rather than a result of any particular anti-crisis policy adopted by the local authorities. For instance, unlike other European countries, it recorded both a marked increase in capital deepening (partly due to the inflows of EU funds) and an improvement in workforce composition. It is also likely that the world economic crisis has neither strengthened nor reversed the medium-run downward trend in TFP dynamics in Poland, driven by the productivity convergence process. Therefore, our results do not suggest that the local economic policy be extended (or not) to other countries.

There is a range of issues which could be addressed with similar frameworks as ours. For example, comparing Poland to other countries of the region as well as to the group of highly developed countries of the OECD, for which one would have to calculate methodologically comparable measures, would be a natural extension. The key question remains, however, *why* has Poland witnessed this exact pattern of supply-side developments which we have just documented (in particular, the gradual decline in the pace of TFP growth). To provide a satisfactory answer to this point, one ought to use firm-level data, though.

Notes

1. Similar results emerge from the work of Oulton and Sebastiá-Barriel (2013) who focus on banking crises and find significant negative level effects working through the capital–labour ratio. They also find that banking crises have a permanent negative effect on the employment ratio (due to either higher unemployment or lower participation rates).
2. Próchniak and Witkowski (2013) and Witajewski-Baltvilks (2016) have carried out interesting studies on the sources of growth and convergence in the region, but without the focus on cyclical changes in capacity utilisation and input composition.
3. Having in mind the discussion on the role of ICT capital for the US economy (e.g. Jorgenson & Stiroh, 2000), we also assess its importance for our calculations as a robustness check.
4. Although sometimes criticised (e.g. Ray & Desli, 1997; Zofio, 2007), the CRS assumption is frequently used by macroeconomists as a reasonable approximation of the true production process because (a) CRS is implied by the standard replication argument (Barro & Sala-i-Martin, 2004); (b) returns to scale are found to be approximately constant on average in macroeconomic data (see e.g. Growiec, Pajor, Górniak, & Prędki, 2015); and (c) in studies based on firm-level or sector-level data, one also often finds returns to scale to be close to constant on average. This applies to Poland as well (see Gradzewicz & Hagemejer, 2007).
5. See Hulten (2009) for a broad overview of growth accounting methods.
6. Ideally, the decomposition could feature specific utilisation rates for each of the n capital and m labour types. Such data are, however, not available.

7. The capital share of GDP is computed based on annual data on GDP at factor prices, gross operating surplus, total compensation of employees and gross mixed income. We assume that mixed income of proprietors is split into the remuneration of capital and labour in the same proportion as in the rest of the economy. In Poland, the capital income share has exhibited a sharp increase in 2001–2004 (from approx. 31% to 39%) after which it has remained roughly constant at the elevated level until 2013.
8. More precisely, the nominal interest rate solves the following equation: $\alpha_t P_t Y_t = \sum_i \left(r_t + \delta_i - E_t \pi_{i,t+1}\right) P_{i,t} K_{i,t}$, where α_t is the capital share according to the national accounts and $P_t Y_t$ is nominal GDP at factor prices.
9. Fernald (2012a, 2012b) uses a different approach for this purpose. Following Aaronson and Sullivan (2001), he estimates wages in groups of workers by relying on wage regressions. His method of aggregation and thus the calculation of the changes in labour composition is the same as ours, though.
10. If the capital–output ratio (one of the 'great ratios' in macroeconomics) tends to a constant in the long run, then TFP growth first translates one-to-one to output growth, in line with $\hat{Y} = \alpha \hat{K} + (1 - \alpha)\hat{L} + \widehat{Util} + \hat{A}$, and then triggers capital accumulation which restores the equilibrium capital–output ratio. In the current decomposition, all such 'induced' capital accumulation is attributed to TFP growth whereas the role of capital accumulation is limited to the extent it outpaces output growth.
11. Naturally, the role of TFP becomes even larger if we calculate it according to the modified formula that corrects for an endogenous response of capital accumulation to technological progress.
12. As mentioned before, the level of the 'output gap' is just the log of the index of factor utilisation rates.
13. In accordance with our results, Marelli, Signorelli, and Tyrowicz (2012) find that during the recent crisis, increases in labour productivity were observed in four countries only (Hungary, Spain, Belgium and Poland), but only in the latter two was this increase accompanied by increasing employment. Those two countries experienced a relatively mild recession. Our contribution shows that, at least in the case of Poland, this fact can be partially attributed to the countercyclicality of labour composition and strong capital deepening.
14. For evidence of productivity convergence in Poland, i.e. a negative relationship between productivity growth and the distance to technology frontier, see e.g. Kolasa (2008).
15. This indicator – of capacity utilisation in the manufacturing industry – is the only indicator of capacity utilisation with a long history provided by the GUS. Given the fact that the patterns of cyclical volatility in industry, construction and market services in Poland are markedly different (Gradzewicz, Growiec, Hagemejer, & Popowski, 2010), we have decided not to replace the (admittedly imperfect) NBP Quick Monitoring Survey indicator with the GUS one, but rather to backcast it.
16. This assumption is supported with a model-based rationale by Basu et al. (2006).

Disclosure statement

No potential conflict of interest was reported by the authors. The views expressed here are those of the authors and have not been endorsed by Narodowy Bank Polski.

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Appendix 1. Capital

Data sources

To calculate disaggregated capital stocks using the perpetual inventory method we need asset-specific data on real investment, depreciation rates and initial stocks. The Eurostat database provides a breakdown of gross fixed capital formation into six asset types, of which we use the following four: other (i.e. non-residential) buildings and structures, transport equipment, other machinery and equipment, and intangible fixed assets. The asset specific depreciation rates are taken from Fraumeni (1997) and summarised in Table A1. We take a real time series of investment, evaluated at base 2005 prices.

Estimating initial capital stocks poses a serious challenge, with which we deal in the following steps. As our departure point for assessing the initial stocks for the tangible asset types as of the end of 1995, we use the gross estimates published by Poland's Central Statistical Office (GUS) in 'Fixed Assets in National Economy in 1995'. The net values are obtained by correcting the gross numbers with the average degree of fixed asset consumption, i.e. one minus the net to gross capital stock ratio, also published by the GUS. The next adjustment makes these statistics compatible with the national accounts by a simple rescaling. Finally, we also remove dwellings from total buildings and structures using the data on household sector assets of this type. All three of these adjustments use averages over the period of 2003–2010 (earlier data are not available) and rely on the official annual GUS publications 'Fixed Assets in the National Economy' and 'Statistical Yearbook' for the respective years. As regards the starting point for intangible fixed assets, we use the balanced growth path implication, according to which the value of capital should be proportional to investment, with the proportionality coefficient given by $\left(\delta_i + g_i\right)^{-1}$, where g_i is the average growth rate of investment over the whole sample.

Calculating the user cost additionally requires data on individual asset prices and their expected appreciation. To this end we use asset specific gross fixed capital formation deflators taken from the Eurostat. Following Fernald (2012a), we approximate the expectations with the centred five-year moving averages of actual price changes.

Table A1 Depreciation rates by asset type [%].

	Fraumeni (1997)	Oulton and Srinivasan (2003)
Non-residential buildings and structures	**2.6**	1.1–2.5
Transport equipment	**12.8**	20.6–25
Other machinery and equipment	**10.4**	5.7–13
Intangible fixed assets	**30.0**	22
Computer hardware	31.5	31.5
Computer software	46.0	31.5
Other machinery and equipment, excluding computer. hardware	9.3	13

Source: Fraumeni (1997) and own calculations; numbers in bold are used as baseline.

Robustness checks

Our baseline calculations of capital services are based on several assumptions and approximations. In this section we discuss their effect on our main results.

At least since Jorgenson and Stiroh (2000) it has been argued that accounting for ICT technologies might be important while analysing economic growth in modern economies. Since data on ICT expenditures that are consistent with the Polish national accounts are not available, our baseline variant does not distinguish between computer hardware and standard machinery and equipment, and it also merges computer software with other non-tangible fixed assets.

However, some data on ICT, including computer hardware and software expenditures, can be obtained from the 'Digital Planet' reports published biannually by the World Information Technology and Services Alliance (WITSA). This source has been used before by Piątkowski (2004) to analyse the effect of ICT on economic growth in Poland. The WITSA data are available only in current US dollars. To convert them into real terms we use the relevant US deflators of computer hardware and software investment published by the US Bureau of Economic Analysis. For lack of any data on stocks, we use the balanced growth path assumption discussed above to pin down the 1995 levels. The depreciation rates used in calculations are reported in Table A1.

The effect of accounting for ICT capital is illustrated in Figure A1. The average growth rate of so calculated capital stock is now 5.3%, i.e. slightly larger than under our baseline (5.1%). This difference is mainly driven by the estimates obtained for the beginning and middle of our sample. As from 2006, including ICT capital gives virtually the same outcomes as the baseline variant.

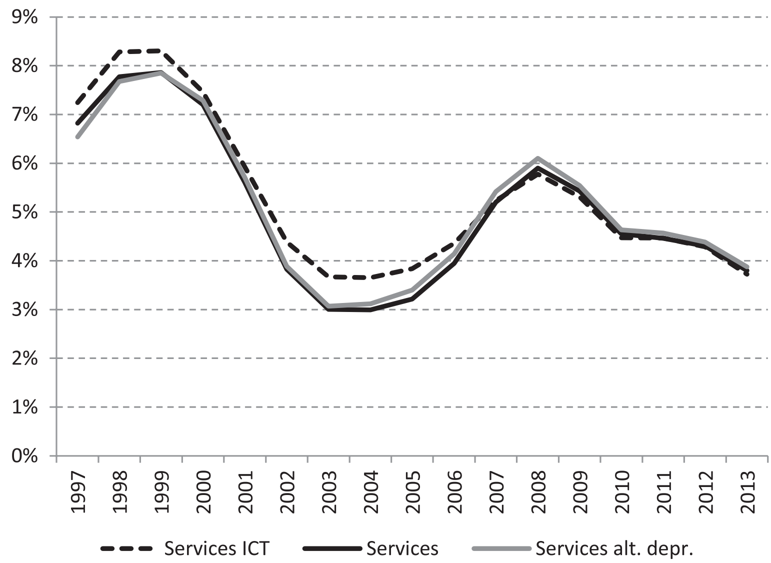

Figure A1 Capital services growth with and without ICT. Source: own calculations.

Figure A2 shows the decomposition of capital services growth when ICT capital is taken into account. While the role of computer software turns out to be of rather minor importance, the contribution of computer hardware accumulation was similar to that of transport equipment on average, accelerating growth in the aggregate capital stock especially in the first half of our sample.

The next robustness check is related to the depreciation rates. In our baseline variant, we take them from the US study by Fraumeni (1997). This source is commonly used in growth accounting also for other countries as alternative estimates are very scarce. A notable exception is Oulton and Srinivasan (2003) who report disaggregate depreciation rates by asset types for the UK. As can be seen from Table A1, their estimates differ somewhat from our baseline, suggesting faster depreciation for transport equipment and slower for buildings and non-tangible assets. Given these differences, we check how our main results change once we modify the assumed depreciation rates so that they are closer to Oulton and Srinivasan (2003). More specifically, we increase the depreciation rate for transport equipment to 20% and lower those for buildings and non-tangible assets to 2% and 25%, respectively. As Figure A1 illustrates, growth in total capital services is hardly affected.

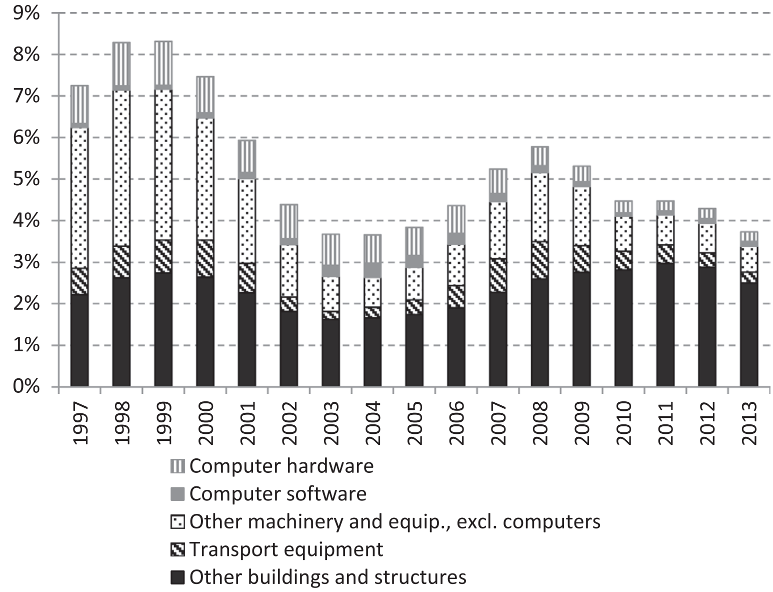

Figure A2 Decomposition of capital services growth – ICT included. Source: own calculations.

One may also argue that applying depreciation rates calculated for advanced economies such as the US or the UK to less developed countries like Poland may be not warranted. However, such a concern does not seem to find strong support from the existing (though scarce) empirical evidence. For example, the average depreciation rate calculated by Schündeln (2013) for manufacturing enterprises in Indonesia does not deviate much from the US-based estimates. Also, the depreciation rates estimated by Oulton and Srinivasan (2003) for the UK do not exhibit any trends, suggesting no clear relationship between the level of economic development and the average service life of capital.

Finally, we discuss two assumptions that we need to make to carry out our calculations, and that can be considered rather restrictive. The first one concerns the initial stock of intangible fixed assets in our baseline variant, and that of computer hardware and software in the variant accounting for the role of ICT. While using a balanced growth relationship in this context might be dubious, it does not actually have significant effects on our main results, except for the initial two or three years. This is because all these capital types depreciate at a relatively fast rate, so the initial stock effect dies out very quickly. The second assumption concerns the way we approximate price expectations. While using a moving average of actual price data might look to be a rather crude proxy, experimenting with various forms of expectation formation (including adaptive expectations or different moving average windows) did not lead to significant differences in our main findings.

Appendix 2. Labour

Data

In order to calculate the disaggregated labour input, stratified by different groups that are assumed to have different productivity levels, we need a data source that would represent employment in the whole economy and allow us to select specific groups. The Polish Labour Force Survey (LFS), which we use as our baseline, is likely the best choice in this respect, but as a robustness check we also compare this dataset with the Structure of Earnings Survey. In both cases, average hours worked and labour productivity will be measured separately for each of 4×10×2×3 = 240 groups listed in Table A2.

Table A2 Heterogeneity of employees included in the analysis – categories.

	Categories	
Feature	Number	Labels
Educational attainment	4	Tertiary, secondary, basic vocational, basic
Age	10	Five years age groups: 15–19, … , 60–64, 65+
Gender	2	Male, female
Economic sector	3	Agriculture, industry, services

Source: Own calculations.

Productivity of individual employees is difficult to measure. The key identifying assumption made in this article is that the average level of labour productivity in each of the worker groups is reflected in their remuneration (total labour cost). Only net wages are provided in LFS data, though. Using them directly would distort the results because income taxes are progressive in Poland. For this reason, we have decided to recode the individual net wages from LFS data into individual labour costs (before tax) using the available information on the tax wedge and its components. These auxiliary data are publicly available for each of the analysed years 1995–2013.

Let us also emphasise that our analysis covers total employment in the economy, including both self-employed persons and employees. It is assumed that labour productivity of persons whose wages and labour costs are not observed is equal to that of persons with analogous features who receive wages.

Additionally, we note that after the National Census 2011, the GUS has corrected Poland's population estimates and also introduced a new definition of population in the LFS, endowing it with a system of weights which are expected to adjust the population estimates for the effects of migration. In this article we use these weights, which are readily available since 2010, as well as a backward correction of the previous LFS weights, prepared by Saczuk (2014). This allows us to account for the impact of emigration on employment estimates before the year 2010.

Robustness checks

Even though our baseline results are based on LFS data, the Structure of Earnings Survey (SES) can be considered as an alternative source of data for the estimation of 'quality-adjusted' labour input. The main advantage of that survey is that it provides detailed information about the random sample of 400,000–600,000 workers, including their personal characteristics, wages and hours worked reported by the interviewed companies. It is a bi-annual survey carried out since 2004; before that it was collected irregularly by the GUS. As opposed to the LFS, the SES does not represent the total economy: it only includes firms over nine employees, and only very few firms from the agricultural sector completed the survey.

The estimated impact of changes in employment composition by age, gender and educational attainment (Figure A3) on GDP growth is generally weaker when identified with SES rather than LFS data. This discrepancy can either be a result of (a) inferior coverage of the population with SES data, (b) the fact that we cannot take sectoral shifts in employment into consideration when using these data, or (c) relatively smaller variation of wages in the SES. Specifically, it may differently tackle the issue of the actual vs. reported variability of compensation per hour worked across different types of workers (referring, e.g. to both civil law contracts and the shadow economy). Reassuringly, at least since 2001 the dynamics of the labour compensation component inferred from both data sources are roughly parallel, though.

As mentioned above, employment estimates used in this article are based on the new, backward corrected LFS data that better include migration in the population estimates (Saczuk, 2014). That is why in comparison to official employment growth rates, published before, our figures are lower in the period 2005–2008 and then slightly higher in 2009–2010 (Table A3). The corrected estimates of employment

Figure A3 Impact of labor composition on GDP growth – LFS vs. SES. Source: own calculations.

are also closer to the estimates of employment included in the national accounts, which are based largely on the reports from enterprises. The main difference between national accounts data and LFS data lies with population growth rates in 2009 and 2010. According to the national accounts, employment decreased by 1.8% in 2009 but then recovered by 2.4% in 2010. The LFS measure of employment, used here, increased by 0.8% in 2009 and then by 0.3% in 2010. Furthermore, the national accounts estimates do not provide consistent data on the total number of hours worked in the economy, while these can readily be calculated using LFS data. The influence of changes in average hours worked on the final aggregate of labour service flows was particularly strong during the initial phase of the previous slowdown in 1998, and in 2009 when total hours worked decreased despite increasing employment.

As far as our other corrections to the raw data are concerned, the differences in results arising due to our calculation of (before-tax) labour costs instead of net wages were relatively minor, with the exception of the period 1999–2004 when proportionally higher costs of better paid workers, together with the increase in their share in employment, boosted the volume of the total labour input. Adding more reliable information about the number of immigrants after Census 2011 decreased not only the estimates of total employment but also adversely influenced the composition of the population, lowering the annual growth of the adjusted labour input by an additional 0.1–0.2 pp.

Finally, we also note that the method of decomposition of the labour force used here assumes that relative differences in wages among the selected groups are updated every year. However, it could also be interesting to analyse how the labour composition component and our services measure of the total labour input would change if wage differences remained at a constant level, taken from one particular year (Figure A4). The results of such an analysis suggest that the results would, in most cases, remain similar. Taking into consideration only the labour cost differences observed at the end of the sample (year 2012) or at the beginning of the sample (year 1995) leads to a fall in the implied level of the cumulated labour input by about 3–7 pp. below the baseline, though.

Appendix 3. Capacity utilisation and TFP

In our growth accounting exercise, we adjust the Solow residual using a survey-based measure of capacity utilisation. Raw data for this measure come from the NBP Quick Monitoring Survey, which is conducted on a quarterly basis on a sample of (currently more than 1300) non-financial enterprises representing all sections of the economy according to the NACE-equivalent Polish Classification of Activity (excluding farming, fishing and forestry), both public and non-public sectors, and both SMEs and large corporations.

Table A3 Comparison of alternative measures of labour services.

	Baseline LFS with migration adjustment, calculations using labour costs			LFS without migration adjustment (data before 2012)		National accounts estimates*	Calculations on net wages
Year	Employment	Total hours	Labour services	Employment	Labour services	Employment	Labour services
1996	1.3	2.1	2.5	1.2	2.4	0.9	2.5
1997	1.7	1.4	2.4	1.4	2.8	3.8	2.3
1998	1.3	0.2	1.4	1.2	2.4	2.6	1.4
1999	−3.4	−3.8	−2.3	−3.0	−2.5	−3.5	−2.5
2000	−2.0	−2.7	−2.5	−2.6	−2.4	−2.7	−2.5
2001	−2.2	−3.1	−1.8	−2.2	−1.1	−0.6	−1.9
2002	−3.2	−3.5	−2.1	−3.0	−1.0	−2.5	−2.1
2003	0.4	0.5	3.0	0.6	3.0	−0.5	2.2
2004	1.3	1.4	4.0	1.3	3.8	−0.3	3.1
2005	1.6	1.4	2.7	2.3	4.0	1.1	2.7
2006	2.8	2.8	3.1	3.3	3.7	1.7	3.1
2007	3.8	3.8	4.0	4.3	4.6	4.1	4.0
2008	2.6	2.2	3.1	3.6	3.7	4.8	3.1
2009	0.8	−0.2	1.4	0.4	1.1	−0.7	1.3
2010	0.3	0.2	2.2	0.1	1.8	−0.2	2.2
2011	1.0	0.5	1.2	0.6	−0.2	1.3	1.2
2012	0.2	0.1	1.5	0.2	1.5	−0.6	1.5
2013	−0.2	−0.4	0.9	−0.2	1.5	−1.1	0.9

*Excluding agriculture to avoid inconsistencies caused by past corrections of employment in agricultural sector.;
Source: Own computations.

Figure A4 Labor services – the effect of wage changes. Source: own calculations.

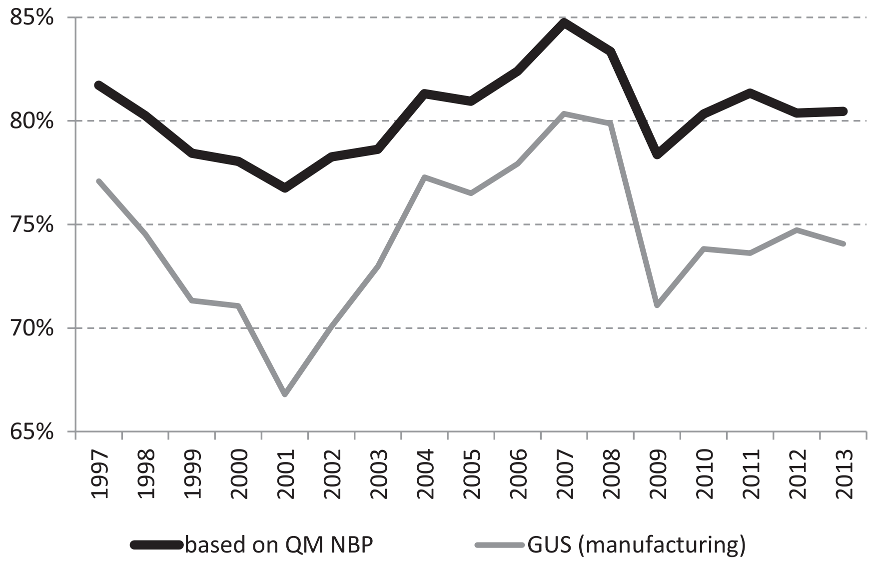

Figure A5 Capacity utilization. Source: own calculations.

Based on these data, we calculate seasonally adjusted arithmetic means of capacity utilisation for four sectors: industry, construction, trade and transport, and other market services. Next, we aggregate the data in the cross-sectional and quarter-to-year dimensions using Eurostat data on seasonally adjusted gross value added as weights. Due to the lack of NBP Quick Monitoring data for the years 1997–1999, we also run an auxiliary regression on the GUS indicator of capacity utilisation in the manufacturing industry[15] and backcast our data for this period. Both series are presented in Figure A5.

While calculating CU-adjusted TFP growth we make two additional assumptions regarding capacity utilisation:

- Taking into account that non-market services and agriculture, forestry and fishing generate about 15–20% of total gross value added, we assume that capacity utilisation in these sectors is constant across time and equal to the average level of capacity utilisation in 1999–2011 for the market part of the economy (80.2%). Because the share of the residuals sector in total gross value added is relatively small, the proposed assumption has relatively little impact on our results (e.g. we obtain very similar estimates of CU-adjusted TFP growth if we assume that capacity utilisation in the residual sector were constantly equal to e.g. 100%).
- Since we use labour data obtained from the Labour Force Survey (LFS) we assume that labour utilisation is already (directly) included in the way we measure the labour input. As a result only the capital input is adjusted for capacity utilisation. If we additionally adjusted labour for capacity utilisation, we would observe strongly countercyclical behaviour of CU-adjusted TFP growth, i.e. negative dynamics in years 2002–2004 when GDP growth accelerated from 1.4% to 5.2% and, most strikingly, a big peak in 2009 when Poland's economy was hit by the international crisis. We claim that these counterintuitive findings would result from (erroneously) adjusting labour for capacity utilisation *twice*. Actually, in our data, in 2009 the number of workers slightly increased but the number of hours worked per worker significantly dropped, reflecting decreasing labour utilisation. Thus any additional correction for decreasing labour utilisation would have artificially pushed up CU-adjusted TFP growth above our baseline estimates. This phenomenon is shown as robustness check RC#1 in Figure A6.

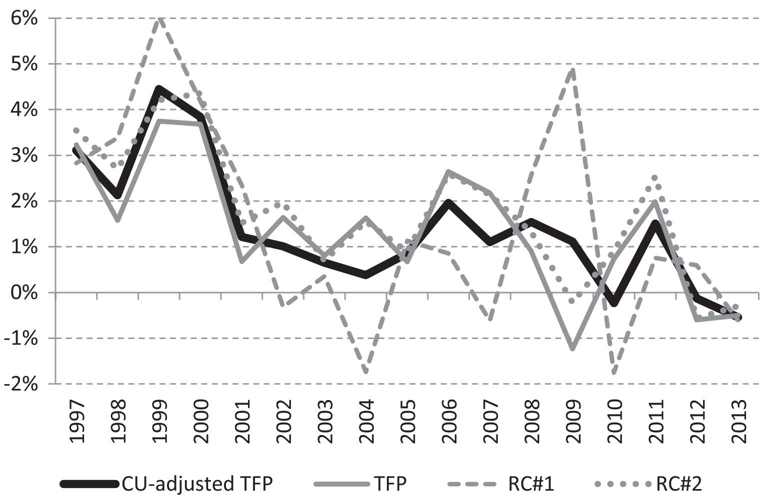

Figure A6 CU-adjusted TFP under different assumptions regarding capacity utilization. Source: own calculations.

As a further robustness check and for a direct comparison with Fernald (2012a), we also present (RC#2 in Figure A6) our estimates of CU-adjusted TFP growth in Poland following Fernald's original identifying assumption that both capital and labour utilisation are proportional to hours worked per worker.[16] It seems, however, that this procedure fails to sufficiently differentiate TFP from its utilisation-adjusted variant.