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Abstract

Using a growth accounting exercise based on new estimates of flows of capital and labor services in the Polish economy during the period 1995-2013, we study the consequences of the recent global economic crisis for the observed pace and structure of economic growth in Poland – a converging open economy which itself did not contribute to the breakout of the crisis. We thus provide a supply-side explanation why Poland fared so well during the world economic crisis. According to our results, the exceptional performance of the Polish economy in 2008-10 was an effect of several favorable circumstances. In particular, and unlike other European countries, it recorded both a marked increase in capital deepening and an improvement in workforce composition. We also find that the recent recession has not exerted any significant impact on the efficiency with which economic resources are used for production in Poland.

Keywords: growth accounting, Poland, world economic crisis, real convergence

JEL codes: E2, O4.

1. Introduction

The world economic crisis, which broke out in 2007-08, turned out to be deeper and last longer than any other post-war recession. It originated in the financial system of the US economy and immediately affected the level of economic activity worldwide. However, after the initial common response, the economic routes of many countries diverged. Some of them grew relatively quickly out of the recession, whereas in some others (notably several European countries) the underlying structural weaknesses were revealed, increasing the length and depth of the recession. Poland was among the countries that suffered *least* from the world economic crisis, and it was even often mentioned as an *exception* among its European peers – in particular, the only one which recorded positive GDP growth in 2009.

The objective of this paper is to provide a supply-side explanation for Poland's exceptional performance during the world economic crisis. Its consequences for 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 labor services. Based on these new estimates, we also construct an empirical measure of output adjusted for capacity utilization (henceforth, CU-adjusted output).

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 paper is complementary to a range of papers investigating the economic impacts of the crisis from the perspective of demand factors and policy response (e.g. Nabli 2011; Berkmen et al. 2012) or pre-crisis variables (e.g. Dominguez, Hashimoto and Takatoshi 2012; Frankel and Saravelos 2012; Lane and 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. 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, in consequence, an ever increasing loss 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 Furceri and Mourougane (2012) and ECB (2011).

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-labor 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, labor 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 recognized 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 labor market (as opposed to investment outlays) to be an important factor behind the sharp decline in TFP and a somewhat less pronounced decrease in labor productivity. An increase in the capital-labor ratio was due to falling hours and was accompanied by rising labor quality driven by disproportionate job losses on the side of low-skilled workers. Steindel (2009) and Borio, Disyatat and Juselius (2013) 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 the crisis on potential output in Central and Eastern European (CEE) countries is, on the other hand, extremely scarce. The only paper 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. 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

[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-labor 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).

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 its outbreak itself, and because it has managed to maintain positive GDP growth rates throughout the whole crisis period.

Our main contribution is to identify the supply-side factors behind this exceptional development. Using a growth accounting approach, we decompose Poland's GDP growth into the shares of labor, capital and TFP, and discuss the supply-side determinants of `potential' (i.e. CU-adjusted) output growth. Importantly, following the pioneering work of Jorgenson and Griliches (1967) and especially Fernald (2012a,b), 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 analyze the cyclical pattern of the composition components of factor inputs and assess their role in smoothing the recent recession. Finally, having corrected the Solow residual for capacity utilization and factor composition, we construct a relatively 'pure' measurement of TFP which allows us to carry out a precise calculation of its contribution to GDP growth during and after the crisis.[2]

We demonstrate that Poland's resilience to the crisis was not only due to a demand stimulus that resulted i.a. from a decrease in labor income taxes, exchange rate depreciation or loosening of monetary policy, 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 labor reallocation effect *despite* a lack of significant adjustment in total hours worked, and (iii) TFP growth did not slow down markedly. While some of these effects could also be observed in other countries during the crisis, the

[2] Having in mind the discussion on the role of ICT capital for the US economy (e.g. Jorgenson and Stiroh, 2000), we also assess its importance for our calculations as a robustness check.

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 the recent recession seems not 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 2008-10 was largely an effect of a range of favorable 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 real convergence processes.

The remainder of the paper 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 labor, respectively, carefully distinguishing between the stocks and flows of services. In Section 5 we construct the Solow residual and TFP. 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 analyzed variables. In Section 9 we study the consequences of the world economic crisis for the pace and structure of Poland's GDP growth. Section 10 concludes.

2. Method

Our empirical method is a slight modification of the growth accounting framework proposed by Fernald (2012a,b). We carry out a series of decompositions of the aggregate production function, which is assumed to exhibit constant returns to scale[3], as in:

$$Y = TFP \cdot F(Util_K \cdot K(K_1, K_2, \dots),\ Util_L \cdot L(L_1, L_2, \dots)),$$

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 labor L. Each of these two inputs is itself an aggregate of a few capital or labor types, differing in their marginal productivity. Flows of capital and labor services are assumed to be proportional but not equal to their stocks. The (time-varying) coefficients of proportionality are the capital and labor utilization rates, denoted as $Util_K$ and $Util_L$, respectively. The aggregate production function is augmented with a Hicks-neutral technological change component, total factor productivity TFP.

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

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

where the growth rate of the capital input (services provided by capital) is given by $\hat{K} = c_1^K\hat{K}_1 + c_2^K\hat{K}_2 + \cdots$, the growth rate of labor (labor services) is $\hat{L} = c_1^L\hat{L}_1 + c_2^L\hat{L}_2 + \cdots$, and $\widehat{Util} = \alpha\widehat{Util_K} + (1-\alpha)\widehat{Util_L}$ is the weighted average of capital and labor utilization rates. In accordance with the generality of the above Törnquist 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

[3] Although sometimes criticized (e.g. Ray and Desli 1997; Zofio 2007), the CRS assumption is frequently used by macroeconomists as a reasonable approximation of the true production process because in studies based on firm-level or sector-level data, one often finds returns to scale to be close to constant *on average*. This applies to Poland as well (see Gradzewicz and Hagemejer 2007).

L_i in L, α is the capital's share of GDP.[4] 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 labor 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 $K_{raw} = K_1 + K_2 + \cdots$ and the raw sum of hours worked as $L_{raw} = L_1 + L_2 + \cdots$, we shall define the *composition component* of capital and labor, respectively, as $\hat{Q}_K = \hat{K} - \hat{K}_{raw}$ and $\hat{Q}_L = \hat{L} - \hat{L}_{raw}$. Hence, the composition components 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 labor 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 labor composition component may rise due to an increase of the share of people with tertiary education in the workforce.

Having backed out the contribution of increases in capital and labor services to GDP growth, we are left with the *Solow residual*, which can be further decomposed into two components: the relative change in *capacity utilization* and a pure measure of *TFP growth*:

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

Hence, both the Solow residual and TFP growth can be viewed as differences between appropriate measures of output and inputs growth, in line with the voluminous productivity analysis literature (see e.g., Kumbhakar and Lovell, 2000; ten Raa and Mohnen, 2002). The Solow residual is conceptually different from TFP growth in our approach only insofar as the former includes changes in capacity utilization rates in its input growth component whereas the latter does not. Finally, due to being a residual component, TFP growth is also the term where all possible

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[4] The capital's share of GDP is computed based on annual data on GDP, 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 labor in the same proportion as in the rest of the economy. In Poland, the capital income share has exhibited a sharp increase in 2001-04 (from approx. 31% to 39%) after which it has remained roughly constant at the elevated level until 2013.

`other factors' show up: measurement error, time-varying markups, variation in inventories, etc.

From simple algebra we obtain that labor 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 labor services per hour worked plus the Solow residual:

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

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

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

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 utilization.

Needless to say, all above (supply-side) decompositions rest on the usual set of neoclassical assumptions. Firms in our setup are requested to maximize 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 labor; yet, for the measurement to be consistent, these markups ought to be constant over time.

Finally, please note that there is a range of issues which are not accounted for in the above decomposition. First of all, we are silent on the question 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:

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

where $\widetilde{K}_{i,t}$ 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:

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

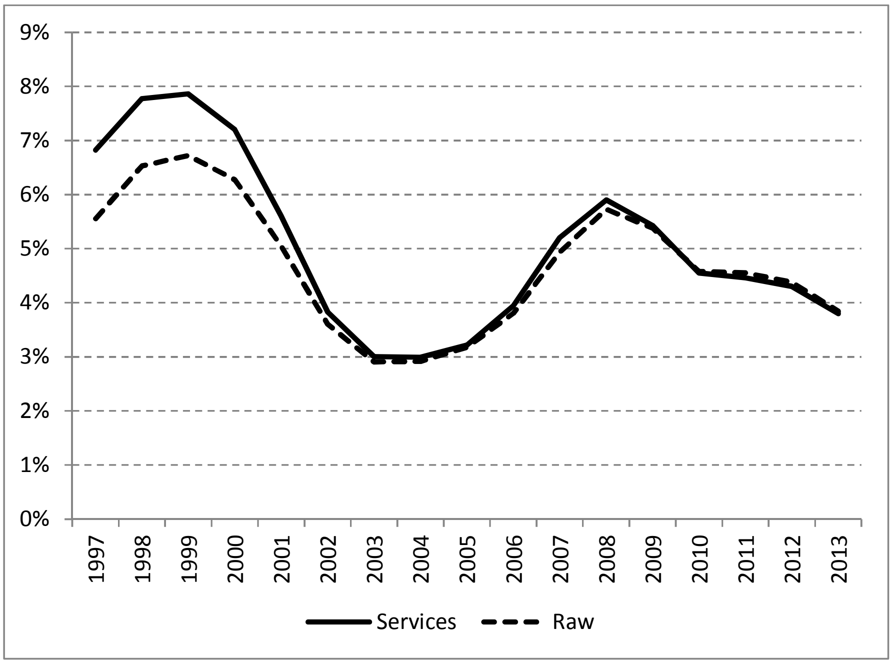
where $P_{i,t}$ is the purchase (investment) price for capital i, $E_t \pi_{i,t+1}$ is the expected rate of price appreciation for capital type i between the current and next period, whereas r_t stands for the nominal interest rate, normalized such that the total capital income share coincides with the one reported in the national accounts.[5] 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, the service measure will grow at a faster rate than the raw aggregate obtained as a simple sum if capital growth is concentrated primarily in the highly compensated types.

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, which additionally reports several robustness checks, including the role of information and communication technologies (ICT).

Figure 1 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.

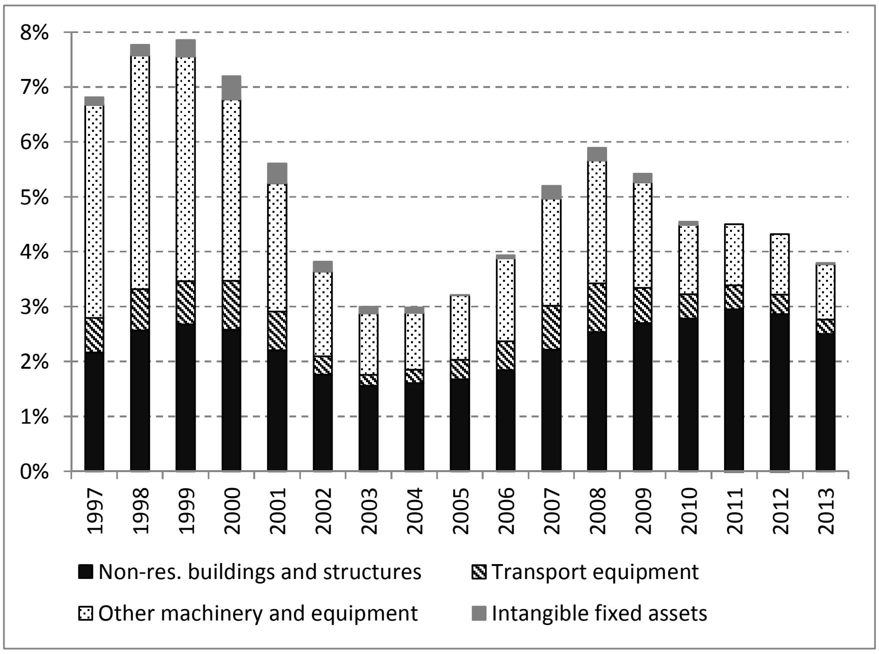
[5] More precisely, the nominal interest rate solves the following equation: $\alpha_t P_t Y_t = \sum_i \left(r_t + \delta_i - E_t \pi_{i,t+1}\right) P_{i,t} K_{i,t}$, where α_t is the capital share according to the national accounts and $P_t Y_t$ is nominal GDP at factor prices.

Figure 1. Capital input growth



Source: own calculations.

Figure 2. Decomposition of capital services growth



Source: own calculations.

The contributions of individual capital types to aggregate capital services growth are presented in Figure 2. Over the analyzed 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 twelve 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, 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. Labor 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 labor productivity of the same persons across sectors which tend to be stubbornly persistent due to slow and inefficient labor relocation.

As a consequence, ongoing changes in the composition of the labor 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 for data sources and details). This allows us to draw a clear distinction between raw measures of the labor input (employment, hours worked) and our main variable of interest: the actual flow of labor services, corrected for the differences in labor productivity across employees and workplaces.

More precisely, our approach to capturing changes in labor composition follows Bell, Burriel-Llombart and Jones (2005). It is based on the estimation of means for each of the considered groups of workers.[6] Similarly to the capital input, growth rates of the composition-adjusted labor 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 labor compensation. The growth rate of the unadjusted ('raw') labor input $\hat{L}_t^{raw}$ – the total number of hours worked – is a sum of the employment growth rate $\hat{L}_t$ (the extensive margin) and the growth rate of average working hours in the economy $\hat{\bar{H}}_t$ (the intensive margin). Thus, the relationship between changes in the aggregate labor input, the raw number of

[6] Fernald (2012a,b) 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 labor composition is the same as ours, though.

hours worked, and the labor composition component ('quality' of hours worked) is as follows:

$$\hat{Q}_t = \hat{L}_t - \hat{L}_t^{raw} = \hat{L}_t - \hat{\hat{H}}_t - \hat{E}_t.$$

Using the properties of the Törnquist index, we further decompose the labor composition component $\hat{Q}_t$ into contributions of each of the considered labor force characteristics (educational attainment, age, gender, sector). For example, the partial 'education-specific' index of labor productivity, capturing the differences between groups according to their educational attainment but ignoring all other dimensions of worker heterogeneity, is computed as:

$$\hat{Q}_t^{Edu} = \hat{L}_t^{Edu} - \hat{L}_t^{raw}.$$

Since the current study singles out four distinct labor 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 labor force productivity decompositions. For example, the second-order index capturing the joint contribution of education and age could be calculated as follows:

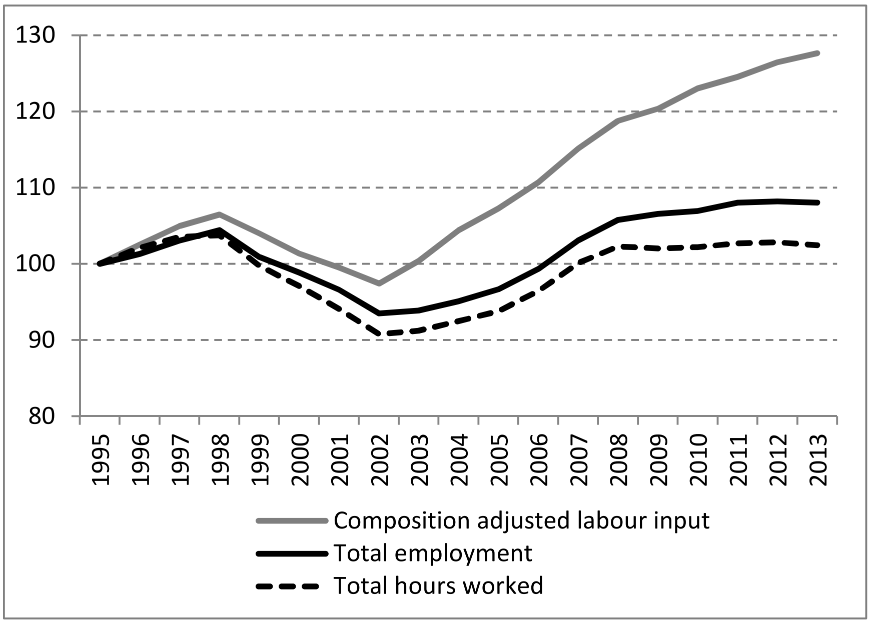
$$\hat{Q}_t^{Edu,Age} = \hat{L}_t^{Edu,Age} - \hat{L}_t^{raw} - \hat{Q}_t^{Edu} - \hat{Q}_t^{Age}.$$

We find that a large majority (72%) of variance of the labor 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 point of annual change.

Our results imply that 'raw' measures of the labor input, which assume homogeneity of employees and disregard any changes in the composition of the labor force, lead to a significant underestimation of aggregate labor input growth (Figure 3). Crucially, we find that the divergence is particularly pronounced after 2002, and that the cumulative effect of labor 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 2012. In 2013 it was actually 8.0% higher than in 1995. Due to the gradual decline in the average number of hours worked per worker in the economy, the dynamics of the 'raw' labor input becomes even less impressive throughout the period 1999-2013. 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 labor, 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 labor service flows 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 labor composition component confirms that without the correction, our estimates of the total labor input would have been heavily biased downwards.

Figure 3. Cumulative labor input growth (year 1995=100)

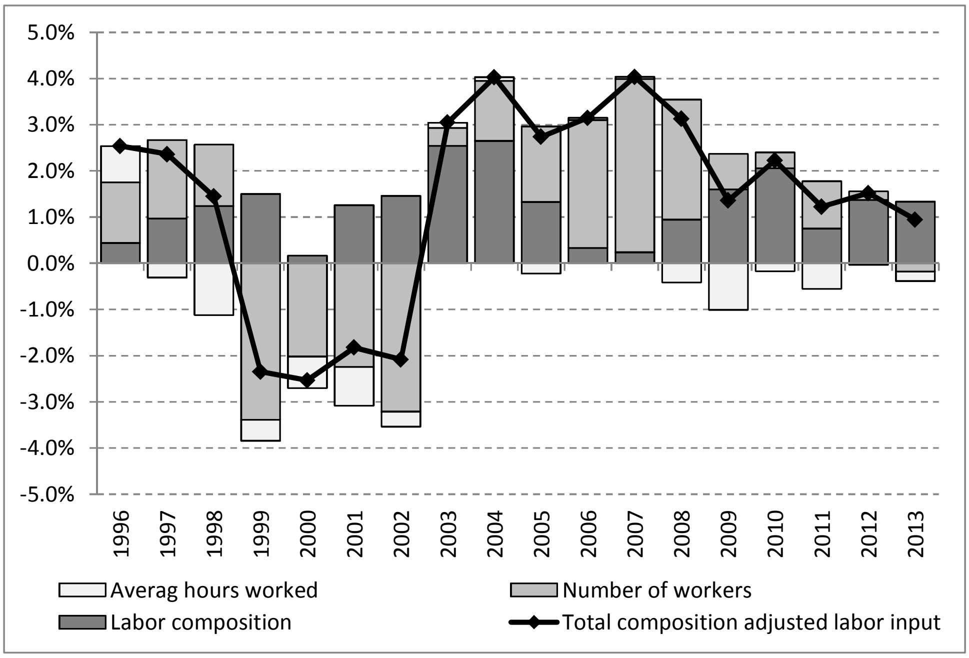


Source: own calculations.

Our next step is to decompose total labor input growth into the contributions of the number of workers, average hours worked per worker, and the labor composition component (Figure 4). We find that changes in employment were the most important factor behind the cyclical variation of the total labor input: employment fluctuated pro-cyclically 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 labor composition was consistently positive in every year of the discussed period, albeit perhaps somewhat counter-cyclical. Most significant increases in the labor input due to improvements in its composition were recorded in 2003-2004 and in 2009-2010.

The partial indexes defined above, such as $\hat{Q}_t^{Edu}$, enable a more detailed decomposition of the factors that are responsible for improvements in labor composition (Figure 5). Our results are very sharp here: the increasing share of employees with better educational attainment (mainly tertiary education) is in fact responsible for the vast majority of changes in labor composition, contributing over 18,6 pp. to the 24,6% total improvement in labor composition over 1995-2013. The second most important factor – sectoral shifts in employment – accounted for about 3 pp. of the total labor composition growth, whereas changes in age and gender composition of employment contributed less than 2 pp.

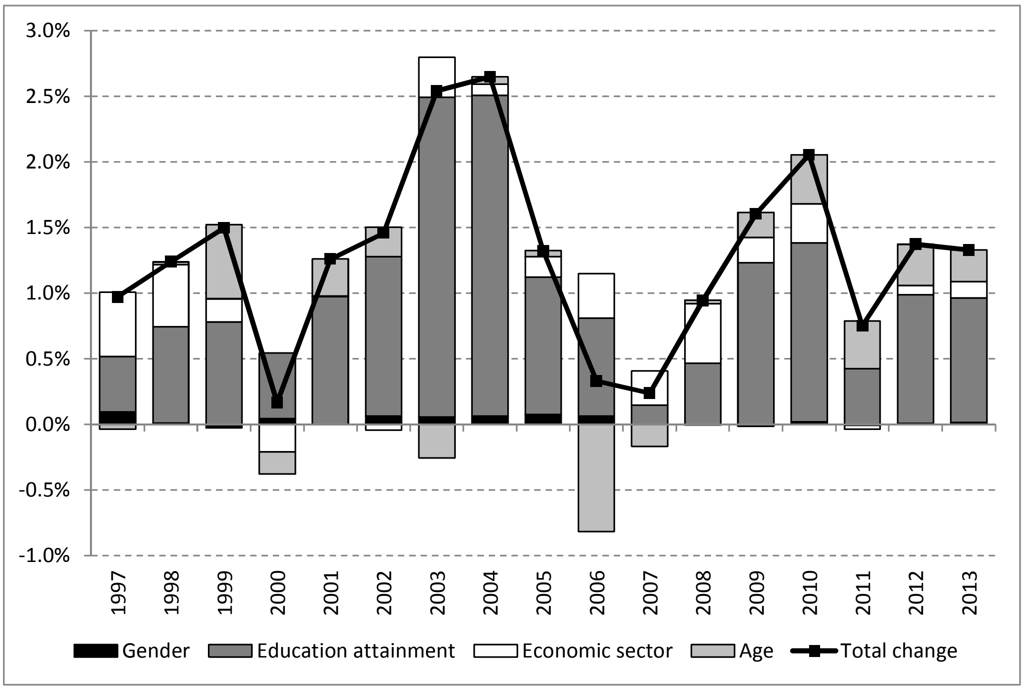
Figure 4. Decomposition of growth in labor services



Source: own calculations.

These results are in line with the only earlier publication in this area that we are aware of, i.e. Bukowski et al. (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.

Figure 5. Breakdown of the labor composition component



Source: own calculations

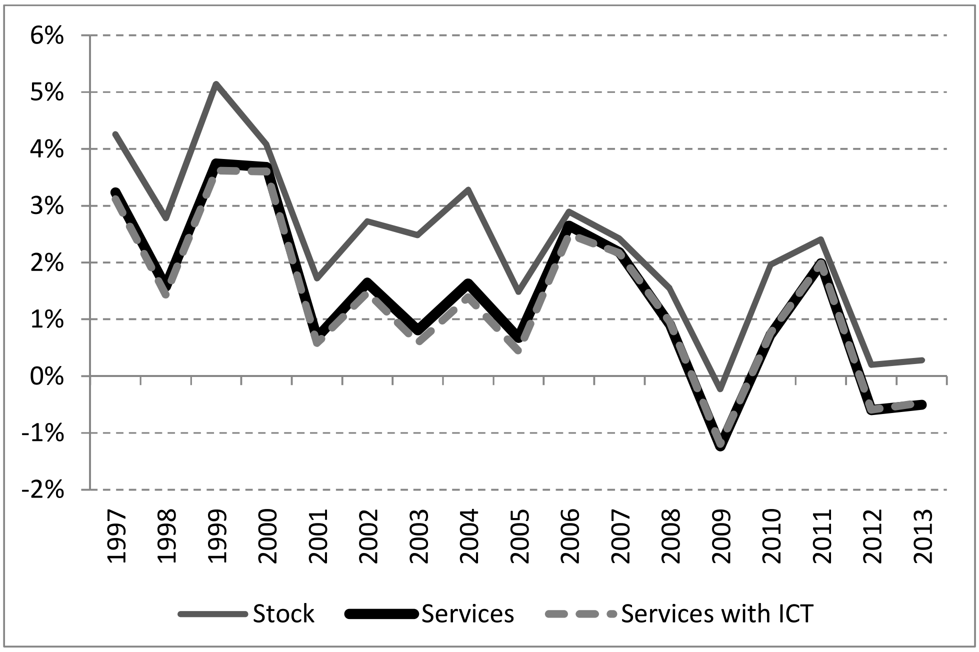
Additionally, we have performed a set of robustness checks, presented in the appendix. These tests include a comparison of our results with their counterparts based on data from the Polish Structure of Earnings Survey; an assessment of the influence of the correction of LFS data after the Census in 2011; 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) labor 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 labor input to economic growth in Poland over the period 1995-2013 was substantially higher than one might assess by looking at its raw 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. Furthermore, the labor composition component also plays an important role in mitigating the pro-cyclical fluctuations of the aggregate labor input.

5. Solow residual and TFP growth

Having constructed the measures of capital and labor services, we are in the position to calculate the *Solow residual* and *TFP growth* as defined in Section 2. Figure 6 plots the Solow residual obtained under three different assumptions regarding the measurement of the capital and labor input growth. The bold line represents our baseline version, in which composition effects caused by changes in the makeup of both capital and labor 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 labor inputs. The dashed grey line ('services with ICT') provides an additional robustness check (see the appendix), allowing us to compare these two scenarios with one that capitalizes on the available data on ICT expenditures in Poland.

Figure 6. Solow residual



Source: own calculations

Our calculations allow us to draw several conclusions regarding the role of input composition effects in growth accounting. First, using 'raw' (stock) instead of composition-adjusted measures of capital and labor services leads to a substantial overestimation of the Solow residual, by 0.9 pp. per annum on average. More precisely, looking at the recent recession, we see that in 2006-07 the gap was relatively small (0.3 pp.), then in 2008-2010 it widened up to 1.3 pp., and in 2011 both estimates converge again. Second, accounting for ICT has very little impact on our estimates of the Solow residual – in contrast to the findings for the US economy (Fernald, 2012a).

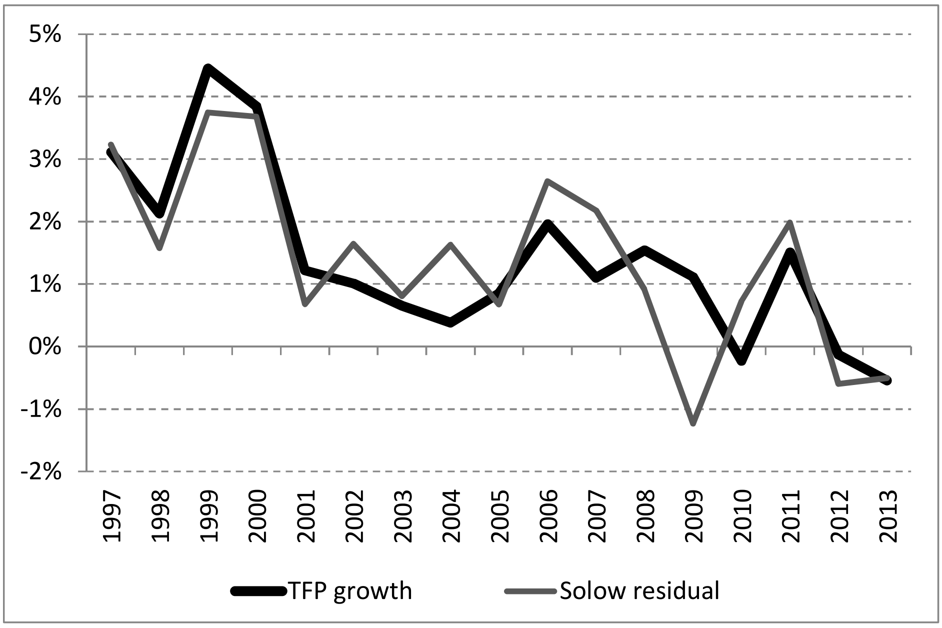
The Solow residual discussed above – although identified with 'observed TFP growth' in numerous other studies, including most of the ones taking a long-run perspective – should not be taken as its literal equivalent, though (e.g., Basu, Fernald and Kimball 2006). The basic reason is that short- to medium-run variation in observed TFP growth can be driven largely by changes in the utilization rate of production factors.

As discussed in Section 2, we have addressed this concern by adjusting the Solow residual with a survey-based measure of capacity utilization, provided by the NBP in its Quick Monitoring Survey. Consistently with the characteristics of this dataset, we depart from Fernald (2012a,b) and apply the utilization rate to capital only. Labor utilization 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 utilization measure and some robustness checks are presented in the appendix.

Since correcting for capacity utilization has no impact on the magnitude of capital and labor composition effects, we proceed directly to the comparison between the Solow residual before and after the adjustment. Both variables are presented in Figure 7. Bearing in mind all the reservations, we refer to the latter measure as *TFP growth*.

Figure 7 shows that adjusting for capacity utilization indeed helps to wipe out some variation in the Solow residual at business cycle frequencies; even then our estimates of TFP growth remain far from smooth, though. In particular, they imply a sudden drop in TFP growth 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 TFP growth, nevertheless it seems that the current behavior of TFP growth remains different than after the crisis of 2000-2002 when the path of TFP growth 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.

Figure 7. Solow residual and TFP growth



Source: own calculations

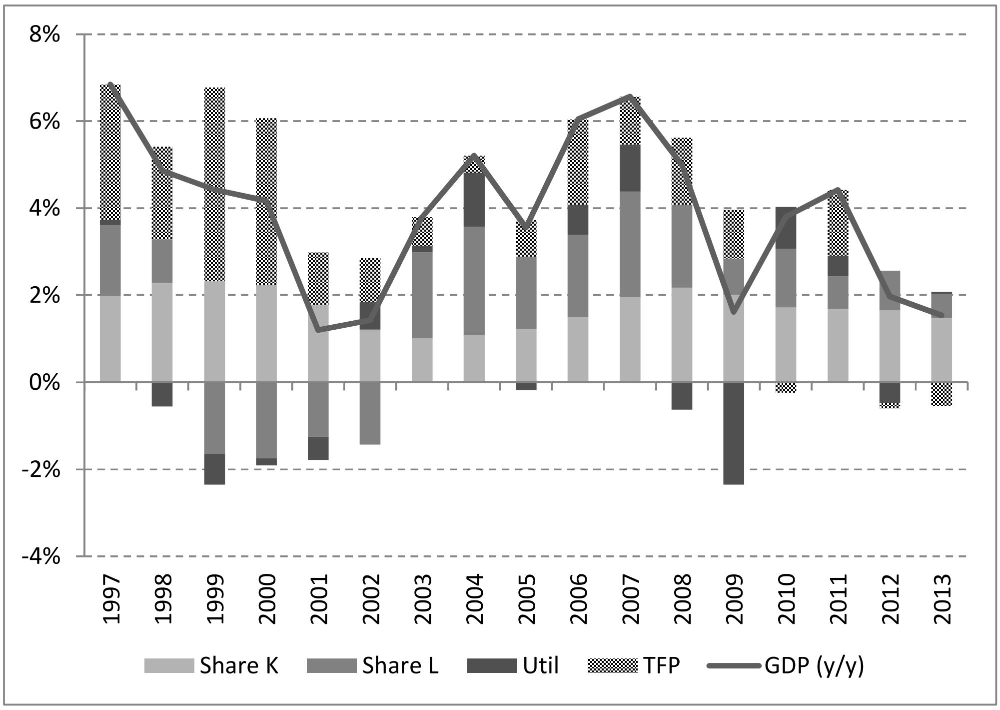
Summarizing all the above-mentioned findings, we conclude that our baseline ("service-based") approach should capture TFP growth more accurately than the other approaches taken in the literature. The main advantage of our approach is that it allows for an *explicit* inclusion of composition effects driven by the changing structure of inputs. The heterogeneity of capital and labor would otherwise be *implicitly* disguised in TFP growth estimates. Since the composition effects are either gradually decreasing over time (capital) or countercyclical (labor), one should take them into account while analyzing the behavior of TFP growth 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 8. As inputs, we use the flows of services of capital and labor (*K* and *L*). We also decompose the Solow residual into the components attributable to capacity utilization (*Util*) and TFP growth.

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 TFP growth have also been consistently positive and often substantial (hiking up to 4 pp. per annum in 1998-2000), whereas the contributions of labor have been also generally positive, but subject to much stronger cyclical volatility.

Figure 8: Contributions to GDP growth in Poland, 1996-2013.



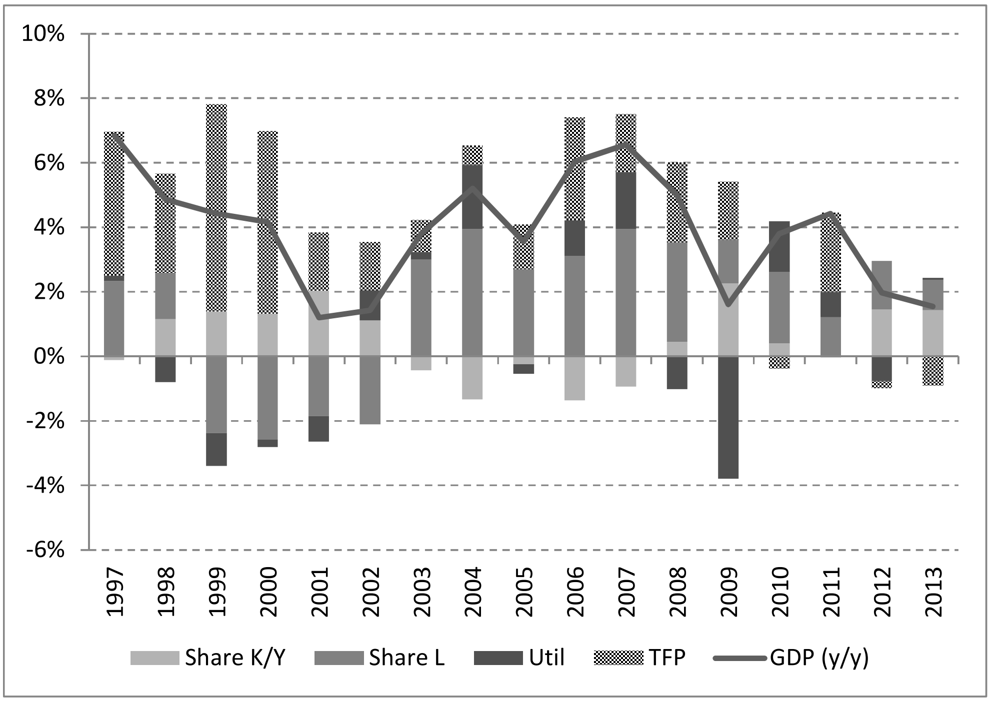
Source: own calculations

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 neighbors 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 Madsen, 2010, 2011). To disentangle these two effects we alternatively decompose output growth according to the following equation:

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

which is just a rearrangement of our baseline formula such that TFP-induced capital deepening is attributed to technological progress.

Figure 9: Contributions to GDP growth in Poland, 1996-2013, alternative decomposition



Source: own calculations

Figure 9 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. Contributions to GDP growth (1996-2013 averages)

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

Source: own calculations

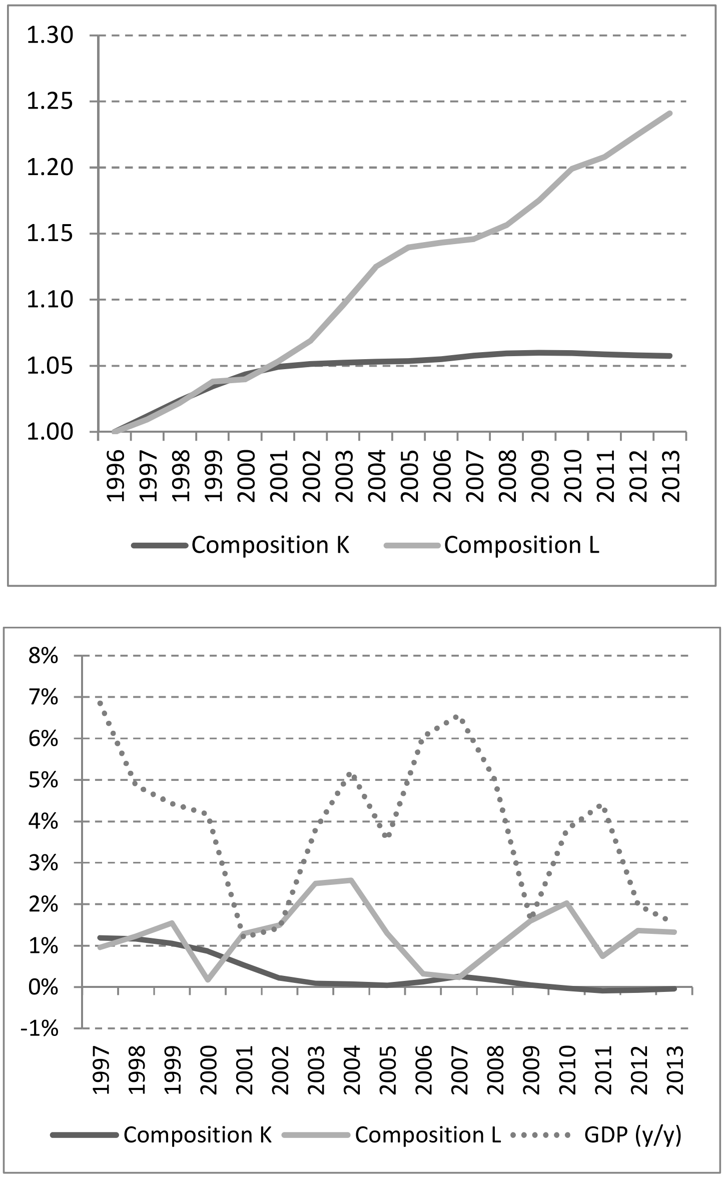
Table 2. Contribution of TFP growth (1996-2013 averages)

		Labor	
		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

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 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 labor 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 labor composition effect was much stronger and has more than compensated that, however, so that in the baseline scenario the contribution of labor 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 utilization rates is small because this variable has exhibited cyclical variability around a constant mean value.

Figure 10. Labor and capital composition components (index 1996=100 and growth rates)



Source: own calculations

The residual contribution to GDP growth – by construction – comes from changes in 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, 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 labor is measured as the raw number of hours worked.[7] The reason is that in such a case, all changes in labor composition, in particular the effects of the upward trend in educational attainment, are shifted in the accounting procedure from the labor component to TFP growth. Given that human capital is naturally embodied in workers, we therefore view it vital to augment the measure of labor services with the composition component as we do in our baseline scenario.

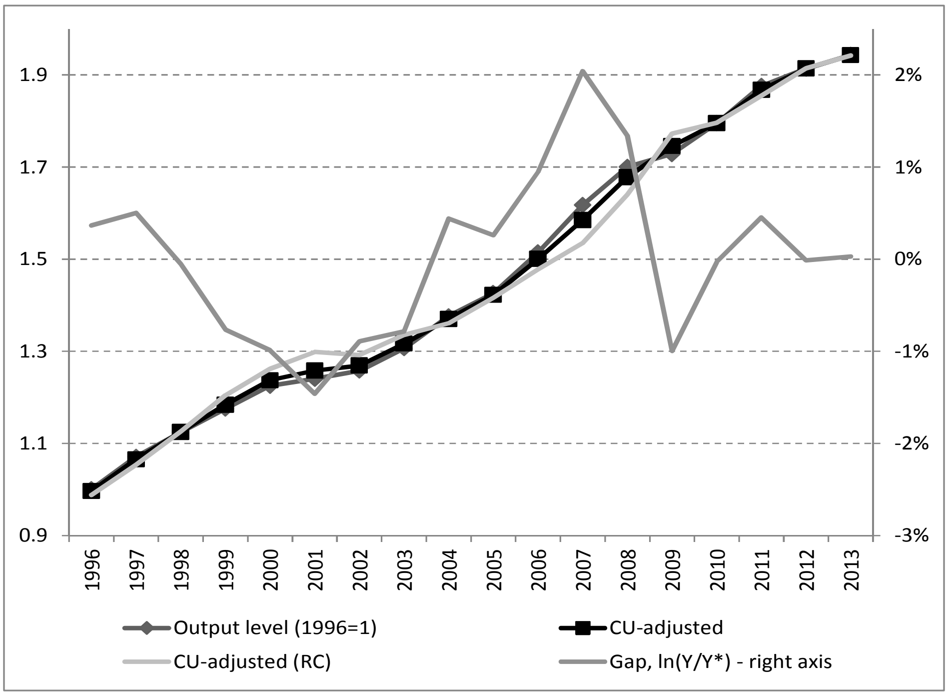
To put these discrepancies in a dynamic perspective, in Figure 10 we present the time paths of capital and labor composition effects, both as growth rates and level indices. This figure serves as another illustration why capital composition effects play a relatively minor role when compared to labor 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 labor 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 labor composition component grew (cumulatively) by as much as 24.1%.

[7] 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.

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 utilization. The results for the period 1996-2013 are presented in Figure 11. 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[8] has been strongly procyclical (positive in expansions, negative in downturns), but its magnitude reached at most 2% of GDP (in 2007).

Figure 11. Actual and CU-adjusted output in Poland, and the "output gap"



Source: own calculations

Returning to the starting point of the current paper – the discussion on the lasting consequences of the world economic crisis for the Polish real economy – our results indicate that these have been essentially non-existent. Even though during the outbreak of the crisis in 2008-09, the economy indeed recorded a sharp decline in

[8] As mentioned before, the level of the "output gap" is just the log of the index of factor utilization rates.

capacity utilization, this fall was partly due to capacity over-utilization during the preceding boom period, and it was then followed by a quick rebound. 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 2000-02. 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.

8. Cyclical properties of inputs

In Section 6 we have assessed the relative contribution of each of the production inputs as well as capacity utilization and 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.

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***
Labor	Services	0.52**	1.46	0.67***
	Raw	0.62***	1.48	0.68***
Utilization		0.41*	1.67	-0.01
Solow residual		0.67***	0.63	0.30
TFP		0.44**	0.57	0.56***

Note: * p<0.1, ** p<0.05, *** p <0.01

Source: own calculations

First, 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, labor 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 labor services measure is somewhat less procyclical than raw hours worked, in line with the finding that the labor composition component varies countercyclically.

Third, the capital utilization rate is procyclical, highly variable, and exhibits essentially no autocorrelation. The Solow residual inherits some properties of capacity utilization, albeit it is significantly *less* variable than GDP. 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 labor 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 labor composition effect is countercyclical. This result is consistent with our finding that labor 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.

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

Note: * p<0.1, ** p<0.05, *** p <0.01

Source: own calculations

9. Impact of the world economic crisis

Having analyzed 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 (2008-09) and four years immediately following the crisis. These results are useful for answering 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 5. Why has Poland been the 'green island' in 2009?

Output	Capital (raw)	Composition K	Labor (raw)	Composition L	Utilization rate	Solow residual	TFP
1.62%	5.24%	0.05%	-0.25%	1.59%	-6.16%	1.14%	2.12%

Source: own calculations

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, the annual growth rate was actually reasonably large here, amounting to 1.6%. Our decomposition exercise, summarized in Table 5, elucidates that this number was driven largely by rapid capital accumulation, improvements in labor composition and TFP growth, accompanied by just a tiny adjustment of employment, and was only counteracted by an abrupt decline in the capacity utilization rate.

In fact, 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 labor input (total hours worked) has been more than compensated by labor 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 labor input, Table 6 compares our data for Poland with the calculations for other countries available in the KLEMS database (O'Mahony and 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 labor 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 labor input was relatively mild and caused only by the decrease in average hours per worker (see also Figure 4). It needs to be mentioned that in the period before the crisis Poland experienced a huge positive labor composition effect (due to mass higher education) that contributed to on average 0.8pp. 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 1pp.[9]

Table 6. Comparison of contributions of labor input to value added growth

	Contribution of hours worked to value added growth (percentage points)		Contribution of labor 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)

Turning to capital accumulation, Figure 12 shows that the inflow of structural funds from the EU (including the cohesion funds) was an important source of investment funding in Poland. In fact, almost 5% of total investment in 2007-2008 was financed from this source. As the EU programs focus mainly on longer-term projects, they contributed positively to the continuation of capital deepening at the outset of the crisis. Their share has even increased since 2009, but it has not compensated for the decrease in private gross fixed capital formation. Overall, the

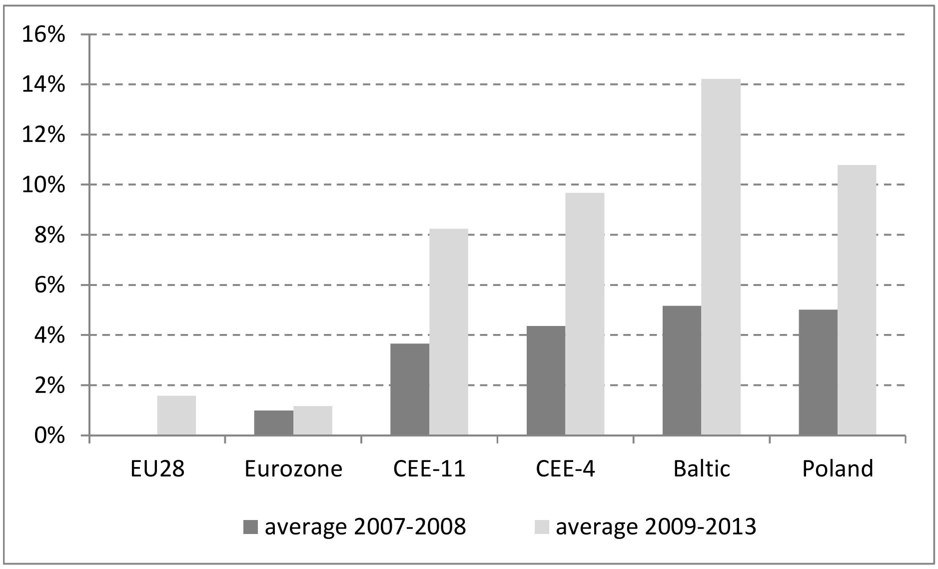
[9] In accordance with our results, Marelli et al. (2012) find that during the recent crisis, increases in labor productivity were observed in 4 countries only (Hungary, Spain, Belgium and Poland), but only in the latter two was this increase accompanied by increasing employment. Those two countries 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 labor composition and strong capital deepening.

EU funds helped sustain high investment demand in Poland during the times of financial market turmoil and drying commercial credit supply, contributing positively to capital accumulation.

The share of EU-funded investment in total investment was higher in Poland than in other CEE-4 countries (Czech Republic, Slovakia and Hungary) or the CEE-11 (all new EU member states) group, although lower than in the Baltic countries. Additionally, and unlike in many countries in the region, the flow of UE funds to Poland during that period was very stable after 2008, positively affecting the confidence of the enterprise sector.

Has the world economic crisis impacted Poland's growth potential in the *following* years? As argued intuitively above and as shown quantitatively in Table 7, our 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 2004-08 than the subsequent decline: CU-adjusted output growth in 2008-13 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.

Figure 12. Flow of structural funds financed via EU Budget in percent of total GFCF



Source: Eurostat

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 robustness check (making a different assumption regarding capacity utilization, see the appendix). The result is even more striking here: there was an *increase* in CU-adjusted output growth after 2008.

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

	Output	CU-adjusted output	CU-adjusted output (RC)	Solow residual	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

We observe a continued downward trend in the pace of Poland's TFP growth, though. The average TFP growth rate fell after 2008 by 1.5 pp. on average. This should not necessarily be taken as sufficient evidence for a negative impact of the crisis: TFP growth in Poland actually decreased already when comparing the transition period 1996-2004 to the 2004-08 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 characterized 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 real convergence processes.

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 the prospects for Poland's potential output growth. There have been multiple confounding effects which might have affected our decomposition exercise. 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 potential output growth in the coming years: (i) whether we are approaching a "middle income trap" (Aiyar et al. 2013) precluding further convergence due to e.g. long-lived patterns of specialization in international trade, (ii) low levels of social trust (Zak and Knack 2001) and social capital (Beugelsdijk and Smulders 2003), with comparable outcomes, (ii) inefficient institutions (as captured e.g., by the World Bank's *Doing Business* index) leading to technical inefficiency in production (Hall and Jones 1999; Acemoglu and Robinson 2012). Finally, the aggregative character of our approach makes it silent on the issues related to the sectoral structure of the Polish economy. Threats to potential output growth 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 objective improvements in years of schooling.

10. Conclusion

Complementary to the associated literature, the current paper has provided a focused *supply-side* explanation for Poland's exceptional growth performance during the world economic crisis. The key advantage of our analytical approach lies with the provision of new and arguably more precise calculations of flows of capital and labor services, capacity utilization, and total factor productivity (TFP) growth in Poland in the period 1996-2013. Our results imply 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, and the exceptional performance of the Polish economy in 2008-10 was largely a positive coincidence, an effect of a range of favorable circumstances. For instance, unlike other European countries, it recorded both a marked increase in capital deepening and an improvement in workforce composition. It is likely that the world economic crisis has neither strengthened nor reversed the medium-run downward trend in TFP dynamics in Poland, driven by real convergence processes.

There is a range of issues which could be addressed with similar frameworks as ours. Redoing the analysis with quarterly series – which, given data scarcity, requires a few additional cumbersome assumptions – could improve our understanding of the cyclical variation of capital and labor composition as well as residual TFP growth. 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 also 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.

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Appendix

A.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 summarized in Table A.1 below. We take 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 these three 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 $(\delta_i + g_i)^{-1}$, 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 centered five-year moving averages of actual price changes.

Table A.1. 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 eq., excl. comp. hardware	9.3	13

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

Robustness checks

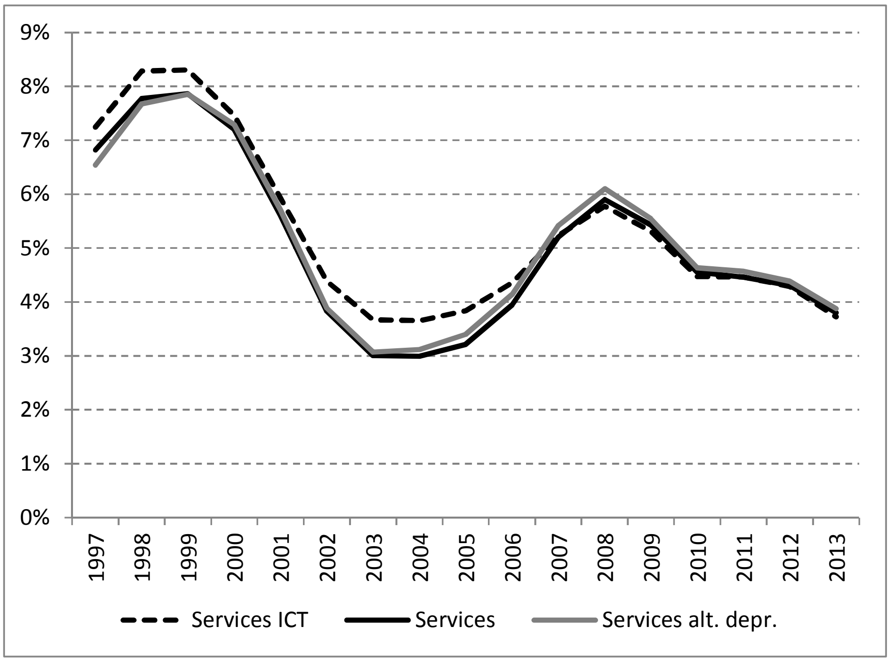
Our baseline calculations of capital services are based on several assumptions and approximations. In this section we discuss their effect on our main results.

At least since Jorgenson and Stiroh (2000) it has been argued that accounting for ICT technologies might be important while analyzing 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 nontangible 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 analyze 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 U.S. 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 A.1.

The effect of accounting for ICT capital is illustrated in Figure A.1. 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 A.1. Capital services growth with and without ICT

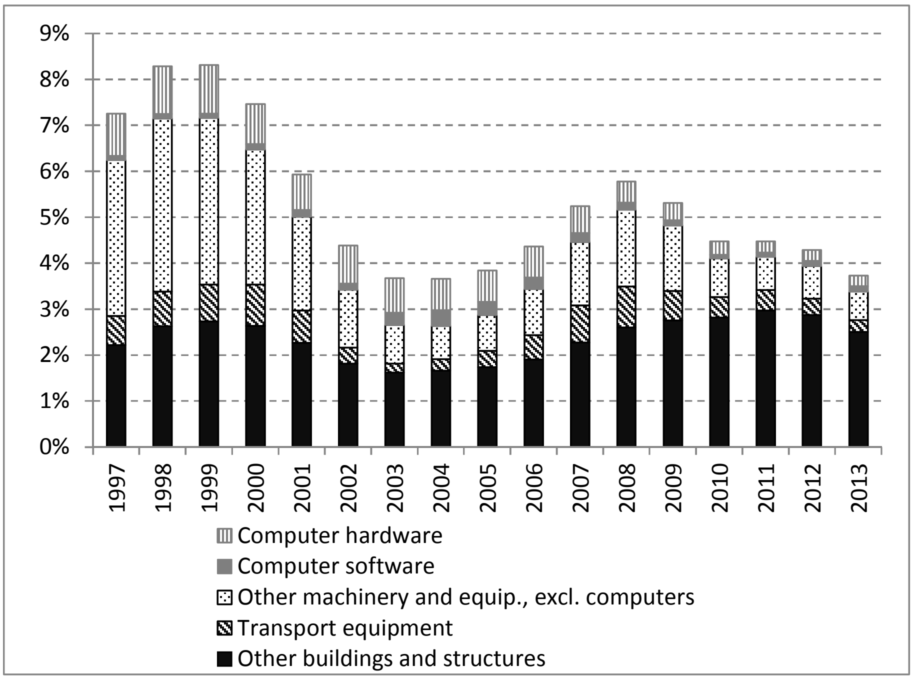


Source: own calculations.

Figure A.2 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 U.S. 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 A.1, 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 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 A.1 illustrates, growth in total capital services is hardly affected.

Figure A.2. 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 as 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.

A.2. Labor

Data

In order to calculate the disaggregated labor 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 labor productivity will be measured separately for each of 4*10*2*3=240 groups listed in Table A.2.

Table A.2. Heterogeneity of employees included in the analysis – categories.

Feature	Categories	
	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 paper is that the average level of labor productivity in each of the worker groups is reflected in their remuneration (total labor 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 labor costs (before tax) using the available information on the tax wedge and its components. These auxiliary data are publicly available for each of analyzed years 1995-2013.

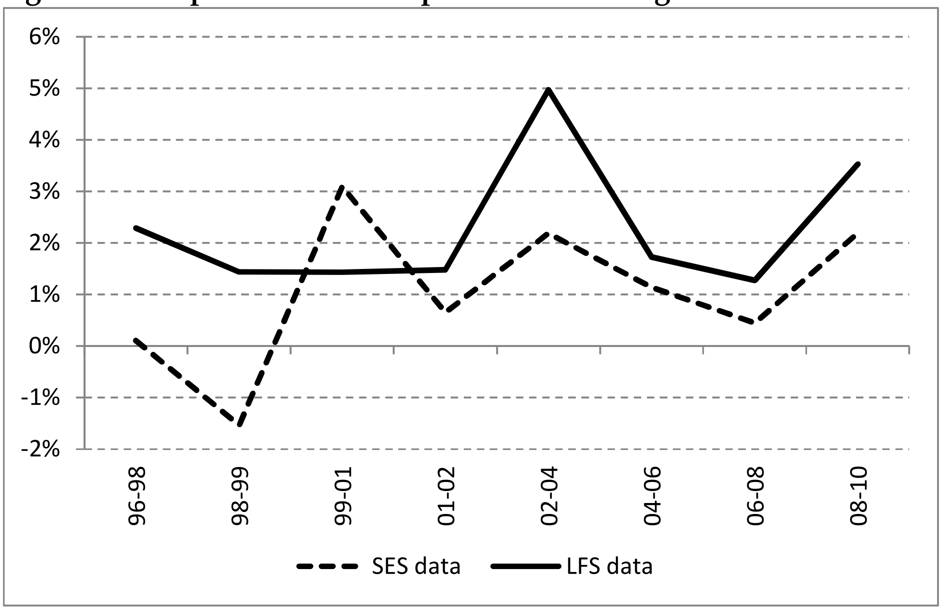
Let us also emphasize that our analysis covers total employment in the economy, including both self-employed persons and employees. It is assumed that labor productivity of persons whose wages and labor costs are not observed is equal to the one of persons with analogous features who receive wages.

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 paper we use these weights, which are readily available since 2010, as well as a backward correction of the previous LFS weights, prepared by Saczuk (2013). 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" labor input. The main advantage of that survey is that it provides detailed information about the random sample of 400-600 thousands of 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 9 employees, and only very few firms from the agricultural sector completed the survey.

Figure A.3. Impact of labor composition on GDP growth – LFS vs. SES.



Source: own calculations

The estimated impact of changes in employment composition by age, gender and educational attainment (Figure A.3) 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 labor compensation component inferred from both data sources are roughly parallel, though.

As mentioned above, employment estimates used in this paper are based on the new, backward corrected LFS data that better includes 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 A.3). The corrected estimates of employment 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 labor 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) labor 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 labor 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 labor input by an additional 0.1-0.2 pp.

Table A.3. Comparison of alternative measures of labor services

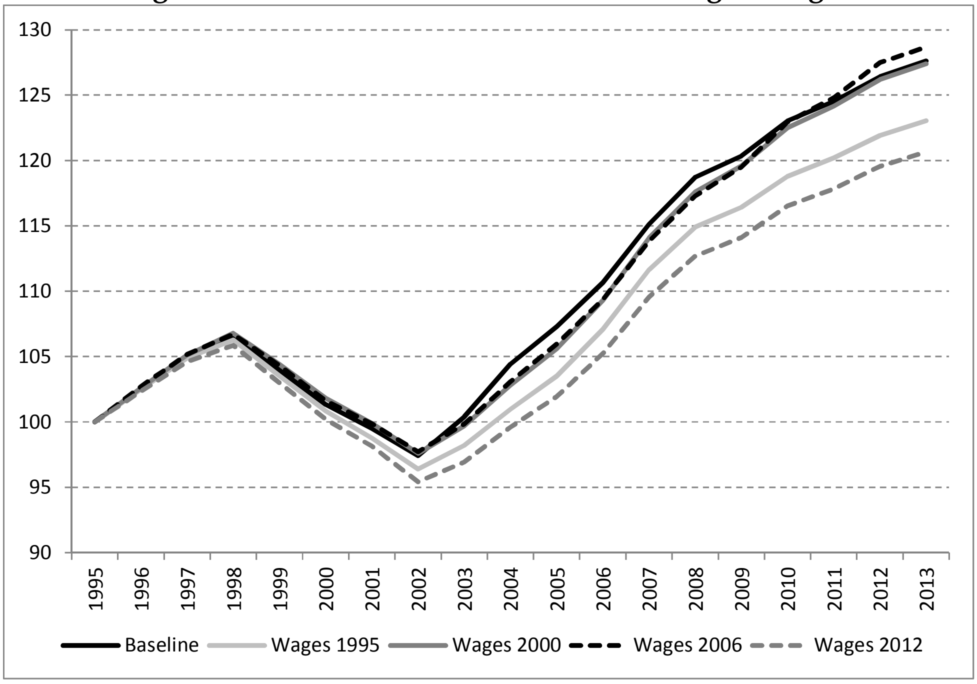
Year	Baseline LFS with migration adjustment, calculations using labor costs			LFS without migration adjustment (data before 2012)		National accounts estimates*	Calculations on net wages
	Employment	Total hours	Labor services	Employment	Labor services	Employment	Labor services
1996	1.3	2.1	2.5	1.2	2.4	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		0.9

*Excluding agriculture to avoid inconsistences caused by past corrections of employment in agricultural sector

Source: own computations.

Finally, we also note that the method of decomposition of the labor force used in the current paper assumes that relative differences in wages among the selected groups are updated every year. However, it could also be interesting to analyze how the labor composition component and our services measure of the total labor input would change if wage differences remained at a constant level, taken from one particular year (Figure A.4). The results of such an analysis suggest that the results would, in most cases, remain similar. Taking into consideration only the labor 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 labor input by about 3-7 pp. below the baseline, though.

Figure A.4. Labor services – the effect of wage changes

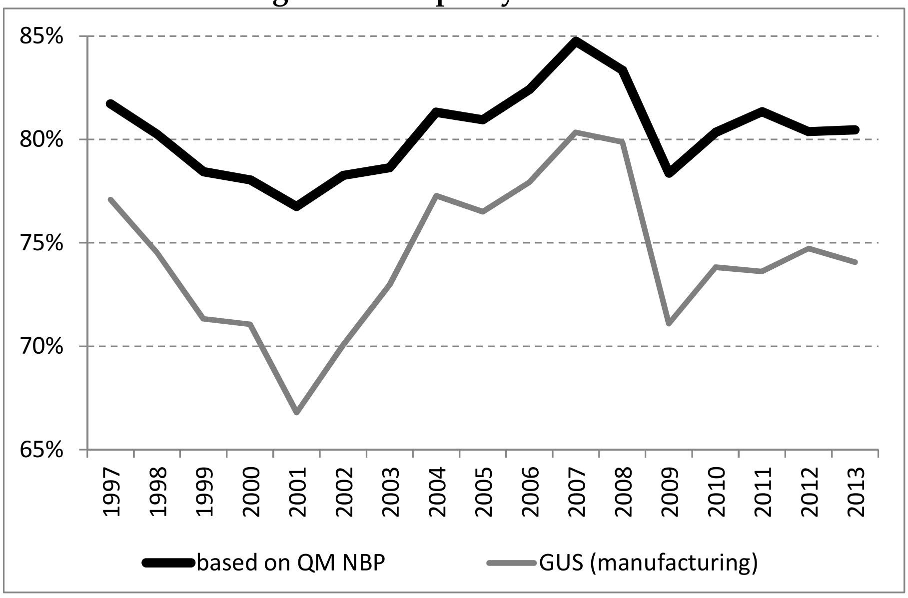


Source: own calculations

A.3. Capacity utilization and TFP

In our growth accounting exercise, we adjust the Solow residual using a survey-based measure of capacity utilization. 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.

Figure A.5. Capacity utilization



Source: own calculations

Based on these data, we calculate seasonally adjusted arithmetic means of capacity utilization 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 utilization in the manufacturing industry[10] and backcast our data for this period. Both series are presented in Figure A.5.

While calculating TFP growth we make two additional assumptions regarding capacity utilization:

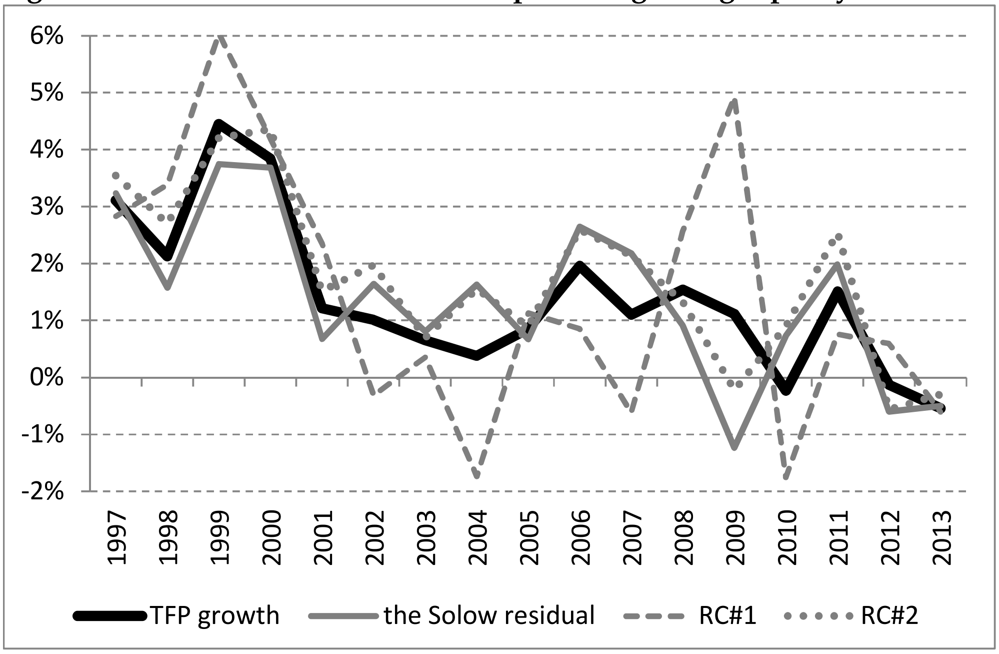
- Taking into account that non-market services and agriculture, forestry and fishing generate about 15-20% of total gross value added, we assume that capacity utilization in these sectors is constant across time and equal to the average level of capacity utilization in 1999-2011 for the market part of the economy (80,2%). Because the share of these 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 TFP growth if we assume that capacity utilization in the residual sector were constantly equal to e.g. 100%).
- Since we use labor data obtained from the Labor Force Survey (LFS) we assume that labor utilization is already (directly) included in the way we measure the labor input. As a result only the capital input is adjusted for capacity utilization. If we additionally adjusted labor for capacity utilization, we would observe strongly countercyclical behavior of TFP growth, i.e., negative TFP dynamics in years 2002-2004 when GDP growth accelerated from 1,4% to 5,2% and, most strikingly, a big peak of TFP growth in 2009 when Poland's economy was hit by the international crisis. We claim that these counterintuitive findings would result from (erroneously) adjusting labor for capacity utilization *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 labor utilization. Thus any additional correction for decreasing labor utilization would have artificially pushed up TFP growth above our baseline estimates of TFP growth. This phenomenon is shown as robustness check RC#1 in Figure A.6.

As a further robustness check and for a direct comparison with Fernald (2012a), we also present (RC#2 in Figure A.6) our estimates of TFP growth in Poland following

[10] This indicator – of capacity utilization in the manufacturing industry – is the only indicator of capacity utilization with 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 et al., 2010), we have decided not to replace the (admittedly imperfect) NBP Quick Monitoring Survey indicator with the GUS one, but rather to backcast it.

Fernald's original identifying assumption that both capital and labor utilization are proportional to hours worked per worker.[11] It seems, however, that this procedure fails to sufficiently differentiate the Solow residual from TFP growth.

Figure A.6. TFP under different assumptions regarding capacity utilization



Source: own calculations

[11] This assumption is supported with a model-based rationale by Basu, Fernald and Kimball (2006).

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