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To What Extent does Convergence Explain the Slowdown in Potential Growth of the CEE Countries Following the Global Financial Crisis?

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Abstract

The paper estimates a simple growth model with time-varying cross-country fixed effects on a panel of high-income countries and decomposes changes in potential growth into convergence, movements in the steady state determinants, global TFP growth and labor force growth in order to investigate the sources of potential growth slowdown in CEE following the global financial crisis. Convergence is found to explain about 40% of the slowdown, the other main drivers being falling investment to GDP ratio and the TFP component. Further decomposition of investment and TFP demonstrates that domestic and external factors each account for 25-30% of the slowdown.

Keywords: Convergence, potential growth, decomposition, TFP, investment, CEE.

JEL: O43, O47.

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1. Introduction

Following the global financial crisis of 2008-09, the economic recovery in major advanced economies has been very sluggish – GDP growth rates did not match those observed during previous recoveries, even though the recession was deeper (Figure 1). As a result, most of the economies took a considerable amount of time to reach the pre-crisis GDP per capita levels (Figure 2). Despite GDP remaining well below the pre-crisis trend, in most of the countries the unemployment rate has already returned to the pre-crisis level (Figure 3), suggesting that the sluggish recovery was associated with a slowdown in potential GDP growth.

Studies confirm this hypothesis (e.g. Ball 2014), but the causes behind the slowdown are subject to debate. Some argue that declines in trend output are typical for severe recessions (Haltmaier 2013, Martin et al. 2014), especially if they are associated with financial crises (Reinhart and Rogoff 2014). For others, long-term factors, not necessarily connected with the Great Recession, are to blame. Gordon (2016) claims that the era of groundbreaking innovations is over, while Summers (2014) blames the long-term decline in natural interest rates that, while monetary policy is limited by the zero lower bound, results in secular stagnation. Growth accounting studies view productivity (TFP) growth slowdown and sluggish investment as main culprits (e.g. Cette et al. 2016), lending some credence to both long-run, supply-side explanations and short-run, demand-side hypotheses.

Figure 1 GDP in fixed PPPs in G7 countries from the start of a recession (index, onset of a recession = 100)

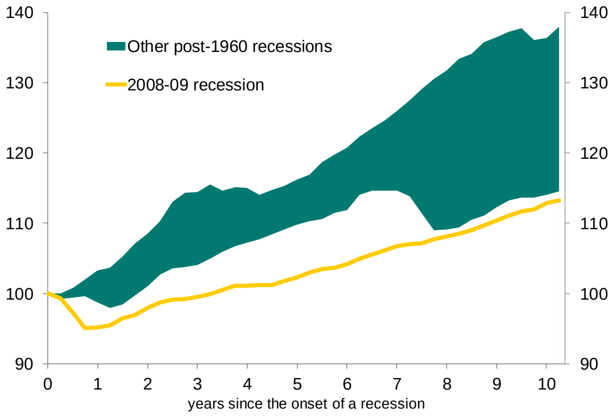
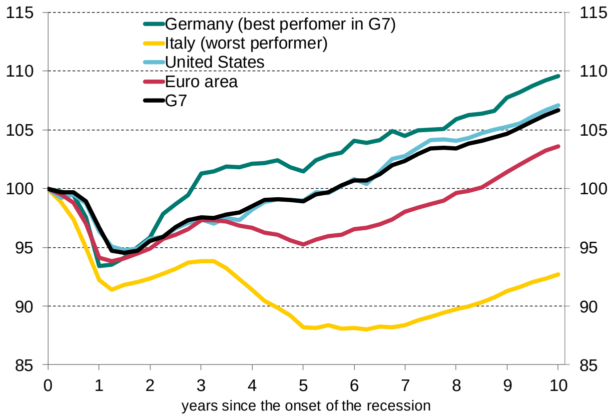


Figure 2 GDP per capita in fixed PPPs in chosen G7 countries and the euro area since the start of the global financial crisis (index, onset of the crisis = 100)



Recession is defined as fall in seasonally adjusted GDP lasting at least one quarter.
Source: Own calculations based on OECD data.

In Central and Eastern Europe, the slowdown in potential growth has been even more pronounced than in advanced economies (Figure 4). Growth accounting studies attribute it to a decline in TFP growth and capital accumulation, similarly as in advanced economies (Podpiera et al. 2017), suggesting that the ultimate drivers could be the same. This is not necessarily the case, however. Brada and Slaveski (2012) claim that growth in CEE was "unnaturally" high in the pre-crisis period due to a large inflow of capital and dynamic growth in foreign demand driven by the accession to the EU and the global boom. As CEE economies are small and open, potential growth could also be driven by developments abroad, especially in the euro area (Bartlett and Prica 2016), though this strand of literature has thus far focused more on reaction to shocks, rather than potential growth (Keppel and Prettner 2015, Hájek and Horvath 2016).

Figure 3 Fall in the unemployment rate (solid line, LHS, pp) vs deviation of GDP from the pre-crisis trend (dashed line, RHS, %) in G7 since the pre-crisis trough in the unemployment rate

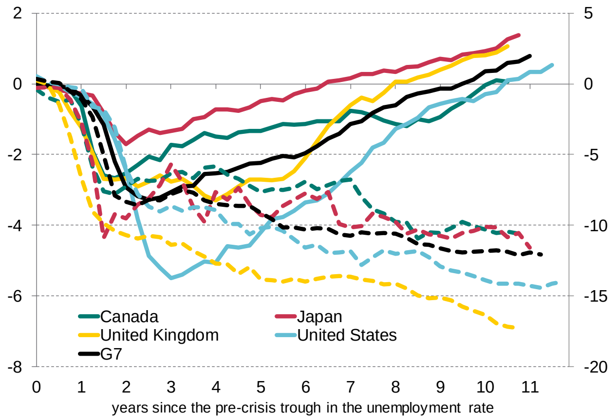
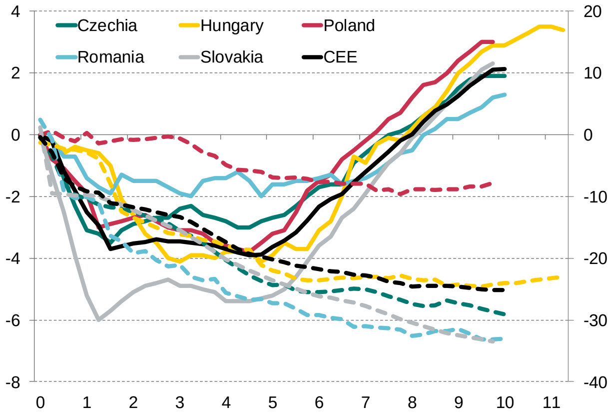


Figure 4 Fall in the unemployment rate (solid line, LHS, pp) vs deviation of GDP from the pre-crisis trend (dashed line, RHS, %) in CEE since the pre-crisis trough in the unemployment rate



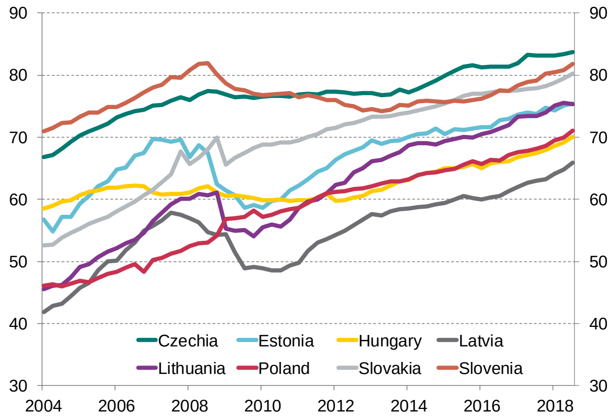
Unemployment rate for people aged 15 and over; pre-crisis trend in GDP computed between 2001Q2 and 2008Q2 (last quarter of expansion to last quarter of expansion) for G7 and between 2000Q4 and 2008Q2 for CEE. CEE countries are former Eastern bloc countries currently belonging to the EU: Estonia, Latvia, Lithuania, Poland, Czechia, Slovakia, Hungary, Romania, Bulgaria, Slovenia and Croatia.
Source: Own calculations based on OECD and Eurostat data.

There is, however, another factor largely omitted from the above-mentioned literature that might explain potential growth slowdown in CEE – convergence. A very large body of literature has proven that convergence is an important driver of growth in the world in general (i.a. Barro 1991, Mankiw et al. 1992, Levine and Renelt 1992, Islam 1995, Barro 1996, Caselli et al. 1996, Sala-i-Martin 1996, Sala-i-Martin 1997, Sala-i-Martin et al. 2004) and in CEE in particular (i.a. Matkowski and Próchniak 2007, Rapacki and Próchniak 2009, Cavenaile and Dubois 2011, Próchniak 2011, Próchniak and Witkowski 2013a). Thus, as GDP per capita in CEE is increasing relative to the euro area (Figure 5), we would expect the catch-up process to weaken, and growth to slow down.

Against this background, the primary aim of this paper is to investigate to what extent convergence explains the slowdown in potential growth of CEE countries following the global financial crisis. Additionally, the goal is to distinguish between domestic and global sources of the slowdown.

To this end, a simple Solow-style growth model in the spirit of Mankiw, Romer and Weil (1992) is estimated on a panel of high income countries. Inspired by Islam (2003) and Di Liberto et al. (2008), country-specific fixed effects are estimated separately for each of the sample subperiods in order to control for potential shifts in the determinants of TFP. Several econometric approaches are tested; however, due to shortcomings of these approaches and a failure to reject the hypothesis that explanatory variables are exogenous, simple fixed effects estimator is used in the baseline specification. Estimation results are subsequently used to decompose changes in the rate of potential growth into convergence, movements in the steady state variables (investment into physical and human capital, labor force growth, TFP level), changes in the labor force and global TFP growth.

Figure 5 GDP per capita PPP relative to the euro area (%)



Source: Own calculations based on OECD data.

Convergence is found to play a significant role, being responsible for on average about 40% of the slowdown in potential growth between 2007 and 2016 in the CEE countries[2]. At the same time, the contribution of global TFP growth to the slowdown is found to be negligible (3%). Falling investment to GDP ratio and lower TFP explain the remaining part of the decline in potential growth (contributing 34% and 38%, respectively[3]). Human capital turns out to be less important (contribution of 9%) and labor force growth plays a role only in some of the countries (Bulgaria, Croatia, Latvia and Slovenia).

These results are largely robust to using alternative proxies for human capital, augmenting the model with explicit proxies for TFP, limiting the sample to CEE countries and excluding outliers. Convergence and investment to GDP ratio are significant drivers of the potential growth slowdown in virtually any model specification. The role of domestic and global TFP growth is less certain, however, since the model has problems distinguishing between the two. Having said that, most of the robustness checks confirm the baseline results also for these variables.

As steady state determinants such as investment to GDP ratio or the "domestic" TFP component are likely influenced by external developments, separate regressions for the TFP component and the investment to GDP ratio are run to further investigate the role of external factors. Movements in TFP and the investment rate are then decomposed into changes in the included explanatory variables, some of which are classified as external, and others as domestic factors.

[2] This is true when looking at simple country means. If one analyzes GDP PPP-weighted means, the contribution of convergence is higher and close to 55%.

[3] Looking at weighted means, these contributions drop to 27% and 10%, respectively.

The decline in the TFP component is found to be explained on average in 20% by external factors (common trend), while domestic factors (Government Effectiveness index, labor reallocation away from agriculture and population density) increase TFP by about the same amount, offsetting the impact of external factors. However, almost all of the decline in TFP is explained by the fall in investment to GDP ratio, which is decomposed next. The decline in investment rate is on average in 25% explained by external factors (common trend), while domestic factors (labor force growth, government spending, corruption, services to GDP ratio) contribute about 30%. The remaining part has no economic interpretation as it is explained either by time-varying fixed effects or the model residual.

Combining all 3 decompositions together, convergence is found to be the major driver of the CEE potential growth slowdown, accounting on average for about 40% of it. External factors contribute nearly 30% and domestic factors (mostly demographic variables, labor force participation and reallocation of labor away from agriculture) 25%.

This paper is most related to the study by Grela et al. (2017) who estimate a similar equation inspired by the Mankiw-Romer-Weil model on a panel of EU countries, investigate how the speed of convergence varies over time and decompose the post-crisis slowdown in growth. However, they do not derive and discuss this decomposition in detail and do not allow for TFP to vary over time, either globally or domestically. In another related study, Ding and Knight (2009) estimate a slightly adjusted version of the MRW model to decompose differences in growth rates across countries, but not across time.

Apart from the literature on the post-crisis potential growth slowdown and the above studies, this paper is related to two other strands of literature.

The first strand develops methods of growth decomposition that in some way account for convergence. Kumar and Russell (2002) develop a non-parametric (DEA) method of decomposing labor productivity growth into components stemming from technological progress at the frontier, technological catch-up and production factor accumulation. Technological catch-up is often associated with convergence – however, it is convergence only in terms of TFP, while convergence in terms of other production factors is attributed to factor accumulation. Having noted that, it is unsurprising that catch-up is found to play a very marginal role in economic growth (Henderson and Russell 2005). In another study, Wong (2007) develops a channel decomposition approach, which enables him - by combining growth accounting with ad-hoc growth regressions in the spirit of Barro (1996) - to estimate whether convergence runs more through factor accumulation or TFP catch-up. He does not compute the contribution of convergence to GDP growth, though.

The second – and very rich - strand of literature discusses convergence of CEE and transition economies. The vast majority of studies confirm the presence of convergence between CEE and Western Europe (EU-15), both unconditional (Matkowski and Próchniak 2007, Rapacki and Próchniak 2009) and conditional on other growth determinants (Borys et al. 2008, Próchniak 2011, Próchniak and Witkowski 2013a, Próchniak and Witkowski 2013b, Próchniak and Witkowski 2014a, Colak 2015, Grela et al. 2017). In both cases the speed of convergence seems to have accelerated before and slowed down after the crisis, while the average speed of conditional convergence is estimated to be close to or above the "iron law" of 2%. Using spatial econometrics techniques does not affect these conclusions materially (Fischer and Stirbock 2006, Crespo-Cuaresma et al. 2014, Próchniak and Witkowski 2014b). However, if one allows for separate convergence "clubs" within the EU, CEE countries do not converge to the same steady state using the same production function as the EU-15 (Cavenaile and Dubois 2011, Borsi and Metiu 2015).

Against this background, my main contribution to the literature is the development of a method that enables the calculation of the contribution of convergence (as well as the contribution of movements in the steady state determinants) to changes in potential growth rate, while at the same calculating the relative role of domestic and external factors in determining potential growth.

The paper is structured as follows: in section 2, I discuss the choice of the modelling framework, lay out the theoretical model and the estimation framework as well as derive the decomposition method – all for the main growth model. Section 3 discusses the econometric issues and the estimation methods, while section 4 describes the data. Section 5 presents the estimation results and section 6 shows the results of the decomposition. Section 7 provides robustness checks. Section 8 discusses the role of domestic and external factors in explaining the CEE potential growth slowdown, presents the TFP and investment rate regressions and the decompositions of these variables. Finally, section 9 discusses the limitations of the study and concludes.

2. Framework

The most straightforward way of decomposing GDP growth is by the means of growth accounting, from which one obtains the contributions of TFP, capital accumulation, labor and, potentially, human capital (see e.g. Fernald 2014 for a modern application). However, for small, open and converging CEE economies analyzed here, such a decomposition is not very informative as potential growth in these economies is driven not only by investment and domestically generated improvements in efficiency, but also convergence and potential growth abroad. The most widely used alternative approach - the Kumar-Russel (2002) production frontier DEA method - additionally allows for the computation of global TFP growth and TFP catch-up. Convergence stemming from capital accumulation continues to be abstracted from, however. One could also use the Wong's (2007) channel decomposition approach to estimate the full impact of convergence. This method is heavily dependent on an arbitrary choice of variables to be included in growth regressions, though, and does not allow to account for the impact of the external environment on growth.

Against this background, I propose a relatively new method of growth decomposition. A natural starting point is the Solow model, which, in its essence, is a model of convergence to the steady state. Mankiw, Romer and Weil (1992) derive an estimable, out-of-steady-state – and thus accounting for convergence – version of the Solow model augmented with human capital. Islam (1995) applies the cross-country MRW model to panel data. The panel data version of this model controls for a common trend in TFP growth, thus providing a rough proxy for the impact of external factors on growth. In this paper the Islam (1995) model is adjusted to allow for shifts in TFP levels across time and the growth decomposition is developed from this adjusted version of the model.

It should be stressed here that convergence I refer to in this paper is conditional convergence – convergence of a given economy to its steady state – and not absolute convergence. Though in practice these two are likely to coincide, they do not necessarily need to – it is possible that a given economy converged in absolute terms, but at the same time its steady state determinants improved and the distance to its steady state remained roughly the same – as a result, the contribution of conditional convergence to potential growth remained similar. Thus, the research question in this paper can be rephrased in the following way: did absolute convergence observed in CEE countries coincided with conditional convergence and thus had a negative impact on potential growth? If so, what is this impact?

2.1 Model

The out-of-steady-state version of the Mankiw, Romer and Weil (1992) human capital-augmented Solow model takes the following form (for derivation see Appendix 1):

$$ln\left(\frac{Y}{L}\right)_t = e^{-\lambda t} ln\left(\frac{Y}{L}\right)_0 + \left(1-e^{-\lambda t}\right)\frac{\alpha}{1-\alpha-\beta} ln\, i + \left(1-e^{-\lambda t}\right)\frac{\beta}{1-\alpha-\beta} ln i_h + \left(1-e^{-\lambda t}\right)\frac{\alpha+\beta}{1-\alpha-\beta} ln(n+g^A+\delta) + \left(1-e^{-\lambda t}\right) lnA_0 + g^A t$$

Where $\frac{Y}{L}$ is GDP per labor force, λ – speed of convergence, i – investment in physical capital to GDP ratio; i_h - investment in human capital to GDP ratio, n – labor force growth; g^A – steady state TFP growth; δ – depreciation rate, α – elasticity of output with respect to physical capital; β – elasticity of output with respect to human capital, A – TFP.

Islam (1995) rewrites the MRW model as a panel data specification:

$$ln\left(\frac{Y}{L}\right)_{i,t} = e^{-\lambda(t-\tau)} ln\left(\frac{Y}{L}\right)_{i,\tau} + \left(1-e^{-\lambda(t-\tau)}\right)\frac{\alpha}{1-\alpha-\beta} ln i_{i,t} - \left(1-e^{-\lambda(t-\tau)}\right)\frac{\alpha+\beta}{1-\alpha-\beta} ln\left(n_{i,t}+g^A+\delta\right) + \left(1-e^{-\lambda(t-\tau)}\right)\frac{\beta}{1-\alpha-\beta} ln i_{h_{i,t}} + \left(1-e^{-\lambda(t-\tau)}\right)\ln(A_{i,0}) + g_t^A\left(t-e^{-\lambda(t-\tau)}\tau\right)$$

Where t is the current period and τ is the previous period. In our application we use annual data, thus the Islam model takes the following form:

$$ln\left(\frac{Y}{L}\right)_{i,t} = e^{-\lambda}ln\left(\frac{Y}{L}\right)_{i,t-1} + \left(1-e^{-\lambda}\right)\frac{\alpha}{1-\alpha-\beta}lni_{i,t} - \left(1-e^{-\lambda}\right)\frac{\alpha+\beta}{1-\alpha-\beta}ln\left(n_{i,t}+\mathrm{g}^{\mathrm{A}}+\delta\right) + \left(1-e^{-\lambda}\right)\frac{\beta}{1-\alpha-\beta}lni_{h_{i,t}} + \left(1-e^{-\lambda}\right)\ln(A_{i,0}) + g_t^A(t-e^{-\lambda}(t-1))$$

In the empirical application, the $ln\left(n_{i,t}+\mathrm{g}^{\mathrm{A}}+\delta\right)$ variable is constructed assuming that $\mathrm{g}^{\mathrm{A}}+\delta$ is constant and equal to 0.07.

Islam (1995) shows this can be interpreted as a dynamic panel data model:

$$ln\left(\frac{Y}{L}\right)_{i,t} = \gamma ln\left(\frac{Y}{L}\right)_{i,t-1} + \theta_1 lni_{i,t} + \theta_2 ln\left(n_{i,t}+\mathrm{g}^{\mathrm{A}}+\delta\right) + \theta_3 lni_{h_{i,t}} + \mu_i + \eta_t + \varepsilon_{i,t}$$

Where $\gamma = e^{-\lambda}$, $\theta_1 = \left(1-e^{-\lambda}\right)\frac{\alpha}{1-\alpha-\beta}$, $\theta_2 = -\left(1-e^{-\lambda}\right)\frac{\alpha+\beta}{1-\alpha-\beta}$, $\theta_3 = \left(1-e^{-\lambda}\right)\frac{\beta}{1-\alpha-\beta}$, $\mu_i = \left(1-e^{-\lambda}\right)\ln(A_{i,0})$, $\eta_t = g_t^A(t-e^{-\lambda}(t-1))$ and $\varepsilon_{i,t}$ is an idiosyncratic error term.

The main disadvantage of the above model is the assumption that steady state TFP levels are constant relative to other countries as they are estimated with country-specific fixed effects μ_i. Islam (2003) and Di Liberto et al. (2008) estimate the model on two subsequent samples showing that this assumption is in general violated – countries and regions tend to catch up in terms of TFP. This might be relevant especially for CEE countries that have been importing technologies from abroad on a large scale since the economic transition started in 1990.

Given the above, I extend the model by including separate country-specific fixed effects μ_a, μ_b and μ_c for 3 subperiods: 1990s (1991-2000), pre-crisis (2001-2008) and post-crisis (2009-2016):

$$ln\left(\frac{Y}{L}\right)_{i,t} = \gamma ln\left(\frac{Y}{L}\right)_{i,t-1} + \theta_1 lni_{i,t} + \theta_2 ln\left(n_{i,t}+\mathrm{g}^{\mathrm{A}}+\delta\right) + \theta_3 lni_{h_{i,t}} + \mu_{a_{i,1991-2000}} + \mu_{b_{i,2001-2008}} + \mu_{c_{i,2009-2016}} + \eta_t + \varepsilon_{i,t}$$

This allows me to account – in a rather crude way – for shifts in country-specific determinants of TFP. At the same time, time fixed effects are retained, describing the common (global) component of TFP growth.

2.2 Decomposition

Estimation results obtained from the above model are subsequently used to decompose changes in potential growth since the pre-crisis peak. First note that $\eta_t = g_t^A(t-e^{-\lambda}(t-1))$, which gives the following expression for the global TFP growth g_t^A:

$$g_t^A = \frac{\eta_t}{t-\gamma(t-1)}$$

Deriving the expression for convergence is a bit more complicated. First recall that the model's steady state can be expressed as follows:

$$ln\left(\frac{Y}{L}\right)_{i,t}^{ss} = \frac{\alpha}{1-\alpha-\beta} lni_{i,t} - \frac{\alpha+\beta}{1-\alpha-\beta} ln\left(n_{i,t} + \mathrm{g^A} + \delta\right) + \frac{\beta}{1-\alpha-\beta} lni_{h_{i,t}} + \ln(A_{i,0}) + g_t^A t$$

Therefore, the deviation from the steady state is equal to:

$$\begin{aligned} & ln\left(\frac{Y}{L}\right)_{i,t}^{ss} - ln\left(\frac{Y}{L}\right)_{i,t} \\ &= -e^{-\lambda} ln\left(\frac{Y}{L}\right)_{i,t-1} + e^{-\lambda}\frac{\alpha}{1-\alpha-\beta} lni_{i,t} - e^{-\lambda}\frac{\alpha+\beta}{1-\alpha-\beta} ln\left(n_{i,t} + \mathrm{g^A} + \delta\right) \\ &+ e^{-\lambda}\frac{\beta}{1-\alpha-\beta} lni_{h_{i,t}} + e^{-\lambda}\ln(A_{i,0}) + g_t^A e^{-\lambda}(t-1) \end{aligned}$$

Taking into account that $1 - e^{-\lambda} \approx \lambda$ and $e^{-\lambda} \approx 1 - \lambda$, growth stemming from convergence in period t is approximately equal to[4]:

$$\begin{aligned} & \frac{\lambda}{1-\lambda}\left(ln\left(\frac{Y}{L}\right)_{i,t}^{ss} - ln\left(\frac{Y}{L}\right)_{i,t}\right) \\ &\approx \left(e^{-\lambda} - 1\right)\left(\frac{Y}{L}\right)_{i,t-1} + \left(1 - e^{-\lambda}\right)\frac{\alpha}{1-\alpha-\beta} lni_{i,t} \\ &- \left(1 - e^{-\lambda}\right)\frac{\alpha+\beta}{1-\alpha-\beta} ln\left(n_{i,t} + \mathrm{g^A} + \delta\right) + \left(1 - e^{-\lambda}\right)\frac{\beta}{1-\alpha-\beta} lni_{h_{i,t}} \\ &+ \left(1 - e^{-\lambda}\right)\ln(A_{i,0}) + g_t^A (t-1)\left(1 - e^{-\lambda}\right) \end{aligned}$$

In terms of estimated parameters, the same expression looks in the following way:

$$\begin{aligned} & \frac{\lambda}{1-\lambda}\left(ln\left(\frac{Y}{L}\right)_{i,t}^{ss} - ln\left(\frac{Y}{L}\right)_{i,t}\right) \\ &\approx (\gamma - 1)\left(\frac{Y}{L}\right)_{i,t-1} + \theta_1 lni_{i,t} - \theta_2 ln\left(n_{i,t} + \mathrm{g^A} + \delta\right) + \theta_3 lni_{h_{i,t}} + \mu_{a_{i,1991-2000}} \\ &+ \mu_{b_{i,2001-2008}} + \mu_{c_{i,2009-2016}} + \frac{\eta_t}{t - \gamma(t-1)}(t-1)(1-\gamma) \end{aligned}$$

One can note that this is simply the remaining part of growth in period t, other than global TFP growth g_t^A and the model residual $\varepsilon_{i,t}$:

$$\Delta ln\left(\frac{Y}{L}\right)_{i,t} = \frac{\lambda}{1-\lambda}\left(ln\left(\frac{Y}{L}\right)_{i,t}^{ss} - ln\left(\frac{Y}{L}\right)_{i,t}\right) + g_t^A + \varepsilon_{i,t}$$

However, steady state determinants vary over time and so does the steady state. Hence, growth stemming from convergence changes not only because of "pure" convergence, but also because of movements in the steady state. One can decompose "total" convergence into "pure" convergence assuming constant steady state determinants and steady state movements

[4] Dividing by $1 - \lambda$ is necessary since GDP per worker level in period t already includes convergence that took place in that period.

against the benchmark period. In my case this benchmark period is the last pre-crisis year - 2007:

$$\frac{\lambda}{1-\lambda}\left(ln\left(\frac{Y}{L}\right)_{i,t}^{ss}-ln\left(\frac{Y}{L}\right)_{i,t}\right)=\frac{\lambda}{1-\lambda}\left(ln\left(\frac{Y}{L}\right)_{i,t}^{ss}-ln\left(\frac{Y}{L}\right)_{i,2007}^{ss}\right)+\frac{\lambda}{1-\lambda}\left(ln\left(\frac{Y}{L}\right)_{i,2007}^{ss}-ln\left(\frac{Y}{L}\right)_{i,t}\right)$$

Where:

$\frac{\lambda}{1-\lambda}\left(ln\left(\frac{Y}{L}\right)_{i,t}^{ss}-ln\left(\frac{Y}{L}\right)_{i,2007}^{ss}\right)=\theta_1(lni_{i,t}-lni_{i,2007})+\theta_2(\ln(n_{i,t}+\mathrm{g^A}+\delta)-\ln(n_{i,2007}+\mathrm{g^A}+\delta))+\theta_3(\ln i_{h_{i,t}}-\ln i_{h_{i,2007}})+\mu_{a_{i,1991-2000}}+\mu_{b_{i,2001-2008}}+\mu_{c_{i,2009-2016}}-\mu_{b_i}$: steady state movements

$\frac{\lambda}{1-\lambda}\left(ln\left(\frac{Y}{L}\right)_{i,2007}^{ss}-ln\left(\frac{Y}{L}\right)_{i,t}\right)=(\gamma-1)ln\left(\frac{Y}{L}\right)_{i,t-1}+\theta_1 lni_{i,2007}-\theta_2 ln(n_{i,2007}+\mathrm{g^A}+\delta)+\theta_3 lni_{h_{i,2007}}+\mu_{b_i}+\frac{\eta_t}{t-\gamma(t-1)}(t-1)(1-\gamma)$: convergence

Furthermore, the model explains (potential) GDP per worker, while we are interested in overall (potential) GDP. Therefore, one might also add labor force growth (n_t) to the decomposition and further divide it into working age population growth (n_t^{pop}) and the contribution from labor force participation $(n_t-n_t^{pop})$.

As a result, one obtains the full decomposition of potential GDP growth g_t:

$$g_t=\frac{\lambda}{1-\lambda}\left(ln\left(\frac{Y}{L}\right)_{i,t}^{ss}-ln\left(\frac{Y}{L}\right)_{i,2007}^{ss}\right)+\frac{\lambda}{1-\lambda}\left(ln\left(\frac{Y}{L}\right)_{i,2007}^{ss}-ln\left(\frac{Y}{L}\right)_{i,t}\right)+g_t^A+n_t^{pop}+(n_t-n_t^{pop})+\varepsilon_{i,t}$$

Where:

$\frac{\lambda}{1-\lambda}\left(ln\left(\frac{Y}{L}\right)_{i,t}^{ss}-ln\left(\frac{Y}{L}\right)_{i,2007}^{ss}\right)=\theta_1(lni_{i,t}-lni_{i,2007})+\theta_2(\ln(n_{i,t}+\mathrm{g^A}+\delta)-\ln(n_{i,2007}+\mathrm{g^A}+\delta))+\theta_3(\ln i_{h_{i,t}}-\ln i_{h_{i,2007}})+\mu_{a_{i,1991-2000}}+\mu_{b_{i,2001-2008}}+\mu_{c_{i,2009-2016}}-\mu_{b_i}$: steady state movements

$\frac{\lambda}{1-\lambda}\left(ln\left(\frac{Y}{L}\right)_{i,2007}^{ss}-ln\left(\frac{Y}{L}\right)_{i,t}\right)=(\gamma-1)ln\left(\frac{Y}{L}\right)_{i,t-1}+\theta_1 lni_{i,2007}-\theta_2 ln(n_{i,2007}+\mathrm{g^A}+\delta)+\theta_3 lni_{h_{i,2007}}+\mu_{b_i}+\frac{\eta_t}{t-\gamma(t-1)}(t-1)(1-\gamma)$: convergence

$g_t^A=\frac{\eta_t}{t-\gamma(t-1)}$: global TFP growth

n_t^{pop}: working age population growth

n_t: labour force growth

$\varepsilon_{i,t}$: model residual.

Steady state movements might be further decomposed into the ones stemming from the changes in the investment to GDP ratio, labor force growth, investment in human capital and the steady state TFP level, as demonstrated by the equation describing steady state movements.

In practice, however, the model is not able to fully distinguish between the contributions of convergence and global TFP growth to GDP growth as an increase in a time fixed effect is equivalent to an increase in country-specific fixed effects for all countries. For the same reason, the model does not fully distinguish between movements in "domestic" TFP level and global TFP growth. As a result, one cannot interpret the above decomposition in absolute terms, i.e. it cannot be said that convergence is responsible for X% of potential growth or that it adds Y pp to potential growth. The decomposition can only be used for comparison between given points in time, i.e. it can be said that convergence contributes to growth Z pp less in 2015 than in 2007. This is not a problem for this study, however, since the comparison of potential growth drivers between different points in time (now vs pre-crisis) is precisely what I want to do.

Hence, I compare the contributions to potential growth of all factors between 2016 (the last observation in the sample) and 2007 to obtain contributions from each factor to the post-crisis growth slowdown:

$$g_{2016} - g_{2007} = \frac{\lambda}{1-\lambda}\left(\left(\frac{Y}{L}\right)^{ss}_{i,2016} - \left(\frac{Y}{L}\right)^{ss}_{i,2007}\right) + \frac{\lambda}{1-\lambda}\left(\left(\frac{Y}{L}\right)^{ss}_{i,2007} - \left(\frac{Y}{L}\right)_{i,2016}\right) - \frac{\lambda}{1-\lambda}\left(\left(\frac{Y}{L}\right)^{ss}_{i,2007} - \left(\frac{Y}{L}\right)_{i,2007}\right) + (g^A_{2016} - g^A_{2007}) + (n^{pop}_{2016} - n^{pop}_{2007}) + \left(n_{2016} - n_{2007} - n^{pop}_{2016} + n^{pop}_{2007}\right) + (\varepsilon_{i,2016} - \varepsilon_{i,2007})$$

This allows me to answer the question to what extent convergence explains the slowdown in potential growth. To some degree, by looking at changes in global TFP growth I am also able to say what is the contribution of global factors to the slowdown.

3. Estimation Methods

Traditional fixed effects estimator generates a downward bias on a lagged dependent variable in a dynamic setting (Nickell 1981). Arellano-Bond (1991) difference GMM and Blundell-Bond (1998) system GMM that instrument the lagged dependent variable with its further lags (the difference equation with levels and the level equation with differences) are the most popular ways to deal with this problem.

However, these methods have their own issues. Difference GMM performs poorly when the dependent variable is close to a random walk (the coefficient on lagged dependent variable is close to 1) as past levels contain little information about the future changes in the dependent variable and thus the instruments are weak (Blundell and Bond 1998; Roodman 2009a). This is very likely to be the case in our specification – if the speed of convergence matches the commonly assumed rate of 2%, the coefficient on the lagged dependent variable is 0.98 – very close to 1.

System GMM solves this problem by simultaneously estimating the level equation instrumented with first differences. However, it does so under an additional assumption that the initial distance from the steady state is uncorrelated with fixed effects. If this assumption is not fulfilled, instruments are correlated with the error term, which voids them invalid. The assumption can be tested with the difference-in-Sargan test (Roodman 2009b).

Moreover, these methods are designed for "small T, large N" samples as GMM instruments are growing quadratically with the time dimension of the panel (Roodman 2009a). Having too many instruments can cause overfitting of endogenous variables – instruments fail to expunge endogenous components of instrumented variables, biasing coefficient estimates. It also weakens the Hansen test for validity of the instrument set and the above-mentioned difference-in-Sargan test (Roodman 2009b).

The rule of thumb is that the number of instruments should not exceed the number of units N, and ideally it should be significantly smaller than that (Roodman 2009a). In my sample T (27) is relatively large compared to N (47). Moreover, the number of instruments is additionally increased by the introduction of time-varying cross-country fixed effects. As a result, it significantly exceeds N even if the number of lags is limited and/or the instruments are "collapsed", that is each lag is treated as one instrument instead of creating separate instruments for each time period (Roodman 2009b). As a consequence, the results of Hansen and the difference-in-Sargan tests are not reliable, while the results of the Sargan test are also unlikely to be reliable due to heteroskedasticity. Therefore, to investigate whether the exclusion restriction holds, I add instruments as additional regressors to the specification and test for their joint significance with the F-test (Baum et al. 2007).

Instrument lags are chosen based on the Arellano-Bond autocorrelation test (if residuals are autocorrelated up to a given order, only further lags are used as instruments) and in such a way that the results remain "stable" and "sensible" – that is they are similar to the specification with more instruments and the coefficient on the lagged dependent variable is close to the expected range (between the fixed effect and pooled OLS estimates).

Dynamic panel data models can also be estimated with methods that correct the bias of the fixed effects estimator. Contrary to GMM, these methods fare better in "large T" samples as the fixed effects bias is decreasing with the rising time dimension (Bruno 2005). I use the estimator developed by Bruno (2005), which can be easily implemented in Stata with the xtlsdvc command.

Endogeneity of explanatory variables is another potential problem with my specification. In particular, human capital is very likely to be affected by the GDP per capita level as in richer countries parents are more likely to be able to afford to pay for their children's education. Reverse causality might also exist for investment (very poor countries cannot afford to invest, while rich countries have abundant capital and do not need to invest that much), labor supply (via substitution and income effects) and population growth (rich countries tend to have lower population growth).

The easiest way to deal with endogeneity is to instrument explanatory variables with their lags. This can be done either within a panel data IV model (where levels are instrumented with levels or differences) or difference/system GMM (where differences are instrumented with levels and levels with differences). In the latter case making explanatory variables endogenous exacerbates problems with instrument proliferation and the Hansen test cannot be used to check whether the exclusion restriction for these instruments holds. Therefore, the restriction is checked by adding instruments as additional regressors to the specification and testing them for joint significance with the F-test. I run the Hansen test and the above test to see which specification and which instrument set fulfil the exclusion restriction. Subsequently, I test the explanatory variables for endogeneity with the endogeneity test (Baum et al. 2007) to see whether the instrumental variable approach is necessary.

Alternatively, one can use external instruments. Ultimate causes of growth, and in particular institutional factors, are natural candidates for instruments. However, their exogeneity is questionable – they might affect GDP also via TFP, which is not explicitly included in the model (other than via fixed effects), and may themselves be subject to reverse causality (richer countries tend to have better institutions). Moreover, there are no objective measures of institutions, which gives rise to measurement error and amplifies reverse causality (richer countries get higher institutional ratings simply because they are richer).

Age structure of the population is another potential source of instrumental variables (Cook 2002). It should have a relatively strong effect on population growth (via the share of women at reproductive age) and tertiary school enrolment (via the share of people aged 20-24), which enters my measure of human capital accumulation. It could also have some effect on investment as population ageing tends to lower saving (due to dissaving by retirees) and thus investment. At the same time, the exogeneity assumption might hold – while GDP level clearly affects population structure via population growth and life expectancy, it does so with a substantial lag, and hence the effect should not be strong in my sample, which covers 26 years.

Having noted the above, I test a wide set of potential institutional and population structure instruments (for details see section 4.2) for exogeneity using the Hansen test for overidentifying restrictions (for the whole set of instruments), the difference-in-Sargan test (for single instruments) and by adding them to the model as explanatory variables. Subsequently, IV redundancy tests are conducted to find weak instruments (Baum et al. 2007). Variables that pass these tests are used as instruments for investment, labor force growth and human capital investment variables. At the end, the endogeneity tests of explanatory variables are conducted to check whether the instrumental variable approach is necessary in the first place (Baum et al. 2007).

Summing up, I run 9 regressions. Firstly, there are 5 regressions assuming explanatory variables are exogenous:

- pooled OLS and fixed effects models (to obtain upper and lower bound for the coefficient on the lagged dependent variable),
- difference and system GMM,
- the bias-corrected fixed effects model.

I choose the best specification out of the fixed effects and difference/system GMM ones (the bias-corrected fixed effects method assumes exogeneity of explanatory variables; Bruno 2005) based on the tests for instrument exogeneity and whether the coefficient on the lagged dependent variable falls into the expected range. This specification is later used as a starting point for 5 regressions assuming explanatory variables are endogenous:

- system GMM with internal instruments for all 3 explanatory variables,
- "optimal" specification with lags as instruments (based on tests for instrument exogeneity and endogeneity of explanatory variables),
- specification with external instruments for all 3 explanatory variables,
- specification which combines internal and external instruments for endogenous variables (as suggested by endogeneity tests).

Difference and system GMM are estimated in one step (as the introduction of time-varying cross-country fixed effects makes it difficult to invert the covariance matrix), with robust standard errors and using orthogonal deviations (in order not to lose observations due to breaks in the data). The bias corrected fixed effects estimator uses Arellano-Bond (1991) estimator to initialize the 1st order bias correction and obtains bootstrap standard errors with 100 repetitions. Panel IV specifications are estimated with TSLS with fixed effects. OLS, fixed effects and panel IV estimators have standard errors clustered by country.

Out of the 9 regressions, the one with best properties based on the tests conducted, the coefficient on the lagged dependent variable and common sense is utilized as the baseline regression in the decomposition and in the robustness checks.

4. Data

4.1 Sample

The model is estimated on an annual panel of 47 high-income countries spanning from 1991 to 2016. High-income countries are on a similar level of development to our economies of interest and thus are likely to have a similar aggregate production function. At the same time, the sample is not limited to CEE countries in order to reap the benefits of a larger sample and capture the truly "global" component of TFP growth with the time fixed effects.

High-income country is defined as a one with GDP per capita PPP above 20 000 international dollars in 2017 according to the IMF. Oil and natural gas exporters, microstates (with less than 300 000 inhabitants) and city states (Singapore and Hong Kong) are excluded from the sample.

The decomposition and further analysis is conducted for broadly-defined CEE countries, i.e. former Eastern bloc countries that currently belong to the EU: Estonia, Latvia, Lithuania, Poland, Czechia, Slovakia, Hungary, Romania, Bulgaria, Croatia and Slovenia (in other words, it is CESEE EU + Baltics).

4.2 Explanatory Variables

Table 1 describes the data used in the estimation.

Table 1. Data

Variable	Construction	Source
$ln\left(\frac{Y}{L}\right)_{i,t}$	HP trend of ln GDP PPP in constant international dollars per labor force	World Bank, own calculations
$lni_{i,t}$	HP trend of ln gross fixed capital formation (% of GDP)	World Bank, own calculations
$n_{i,t}$	Annual growth in HP trend of ln labor force	World Bank, own calculations
$lni_{h\,i,t}$	ln percentage of total population enrolled in tertiary education (percentage of population aged 20-24 times tertiary school enrolment)	World Bank, own calculations

Cyclical fluctuations are removed from the GDP, investment and labor force data using HP filter (using standard λ = 100). This allows me to take advantage of a larger sample and estimate the model on annual data, instead of e.g. 5-year averages (as is often done in literature), without fearing that cyclical fluctuations might distort the results.

Percentage of population enrolled into tertiary education is used as a measure of human capital investment. In the literature, Barro and Lee (2013) data on average years of schooling is most often used instead. However, it is a measure of human capital stock, which can be used only if economies are assumed to be in their steady states. In an out-of-steady-state model a gauge of investment is needed. The fraction of population enrolled in education originally used by Mankiw, Romer and Weil (1992) gauges the fraction of the population that is currently building its human capital stock, and thus constitutes such a measure.

My measure of human capital accumulation takes into account only enrolment into tertiary education. Primary and secondary education enrolment in high-income countries is close to 100% on average, and quite often it even exceeds 100% due to high numbers of repeaters. In such a case, high enrolment might indicate lower quality of education, and hence lower human capital accumulation. Tertiary school enrolment is usually well below 100% and varies more across countries and time. As a result, tertiary education is more strongly (partially) correlated with output per worker in our setup than alternative measures that include other education tiers.

4.3 Instruments

Candidates for instruments come from 3 sources: the Heritage Foundation Index of Economic Freedom, the World Bank Worldwide Governance Indicators and the World Bank World Development Indicators database. From the Index of Economic Freedom, I take 9 out of 12 subindices: property rights, government integrity, tax burden, government spending, business freedom, monetary freedom, trade freedom, investment freedom, and financial freedom. Judicial effectiveness, fiscal health and labor freedom are excluded since they cover only a relatively short sample. This data is available since 1995. From the Worldwide Governance Indicators, I take all 6 indices: Voice and Accountability, Political Stability, Government Effectiveness, Regulatory Quality, Rule of Law, and Control of Corruption. These series are available since 1996, though initially biennially - missing observations are interpolated. The population structure data includes shares in total population by 10-year age groups. The exceptions are children from 0 to 14 and elders above 75. The last variable is a share of women in total population. All the variables are in natural logarithms.

Out of these 24 candidate variables only 8 are retained in the external instruments specification (regression 8) following the tests for exogeneity and relevance described in section 3. For clarity these variables are presented in Table 2. In the specification which combines lags and external instruments and only human capital is endogenous (regression 9 – see section 5 for details) only 3 external instruments are used – these are also listed in Table 2.

Table 2. Instrumental variables

Variable	Construction	Source	Regression
ln_mon_free	ln monetary freedom index	Index of Economic Freedom	8
ln_trade_free	ln trade freedom index	Index of Economic Freedom	9
ln_regul	ln Regulatory Quality index	World Bank Worldwide Governance Indicators	8
ln_pop_0_14	ln share of total population aged 0-14	World Bank	8, 9
ln_pop_15_24	ln share of total population aged 15-24	World Bank	8, 9
ln_pop_25_34	ln share of total population aged 25-34	World Bank	8
ln_pop_35_44	ln share of total population aged 25-34	World Bank	8
ln_pop_45_54	ln share of total population aged 45-54	World Bank	8
ln_pop_65_74	ln share of total population aged 65-74	World Bank	8

5. Estimation Results

The results of regressions which assume explanatory variables are exogenous are shown in Table 3.

The results of pooled OLS and fixed effects regressions suggest that the coefficient on the lagged dependent variable should lie in the range of 0.969-0.986, i.e. the speed convergence is between 1.4% and 3.1%, close to the "iron law" of 2%.

Difference and system GMM do not improve on these results, as the difference GMM estimate is very close to the FE one and system GMM to the pooled OLS one. This suggests that overinstrumentation is indeed an issue as the endogenous component of variation in the lagged dependent variable is not being expunged. At the same time, Sargan test and F-test on instruments as additional regressors clearly show that the exclusion restriction does not hold.

Table 3. Exogenous explanatory variables regressions

	(1) Pooled OLS	(2) FE (baseline)	(3) Difference GMM	(4) System GMM	(5) Bias-corrected FE
L.ln(Y/L)	0.9861***	0.9693***	0.9700***	0.9873***	0.9894***
	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)
ln(i)	0.0329***	0.0270***	0.0270***	0.0262***	0.0456***
	(0.0000)	(0.0009)	(0.0001)	(0.0026)	(0.0000)
ln(n+g+δ)	-0.0283***	-0.0308	-0.0311*	-0.0258**	-0.0320***
	(0.0027)	(0.1231)	(0.0889)	(0.0387)	(0.0003)
$\ln(i_h)$	0.0008	0.0060**	0.0059**	0.0003	0.0007
	(0.8605)	(0.0430)	(0.0296)	(0.9473)	(0.8065)
Time-varying cross-country fixed effects	No	Yes	Yes	Yes	Yes
Time fixed effects	Yes	Yes	Yes	Yes	Yes
Instruments for L.Y/L	-	-	2nd-4th lag	5th-6th lag	-
n	1018	1018	971	1018	1018
N		47	47	47	47
Number of instruments	-	-	182	178	-
Sargan/Hansen test (p-value)	-	-	0.000/1.000	0.000/1.000	-
Difference-in-Sargan test for level equation instruments	-	-	-	1.000	-
Instruments as additional regressors: F-test (p-value)	-	-	0.000	0.000	-

Robust p-values in parentheses
*** p<0.01, ** p<0.05, * p<0.1

On the other hand, the bias corrected fixed effect estimator gives an estimate of the coefficient on the lagged dependent variable which is too high. This estimator seems to have problems dealing with a large number of additional binary explanatory variables in the form of time-varying cross-country fixed effects as estimates vary quite significantly depending on the estimator which initializes the bias correction and the order of the correction (results not shown here).

Based on the above, I choose the fixed effects estimator as the starting point for the regressions with endogenous explanatory variables. While this estimator is biased, the bias is quite well understood and not very large. Moreover, the lack of problems with overinstrumentation enables me to utilize Hansen test when choosing the optimal instrument set, which would not be possible under difference/system GMM.

According to results of the fixed effects specification, all 3 explanatory variables have a significant and expected impact on GDP per worker. The sum of coefficients on investment and human capital is very close to an absolute value of the coefficient on labor force growth, as suggested by the theory. The implied α and β (shares of physical and human capital in

GDP) are 42.4% and 9.4%, respectively[5] - these estimates seem quite sensible[6], further strengthening the case for the use of the FE model. An increase in investment to GDP ratio by 10% (e.g. from 20% to 22%) raises potential growth by an initial 0.27 pp, while steady state output per worker increases by approximately 8.7%.[7] Human capital is of lesser importance – a rise in the share of people enrolled into tertiary education by 10% increases potential growth and steady state output per worker by 0.06 pp and 1.9%, respectively.

The results of the endogenous explanatory variables regressions are shown in Table 4.

The first regression is a system GMM in which explanatory variables (but not the lagged dependent variable) are instrumented with their 2nd and 3rd lags. This equation suffers from instrument proliferation (330 instruments while N = 47) and instrument endogeneity as shown by the Sargan test and the F-test for joint significance of instruments as additional regressors. Using internal instruments, the best specification in terms of instrument exogeneity is an equation in levels instrumented with lagged differences[8] estimated with panel IV methods (TSLS with fixed effects). As investment and labor force growth continue to fail tests for exogeneity of instruments, only the human capital variable is instrumented (regression 7). This specification implies a relatively high speed of convergence of 3.7% and a high – relative to other specifications – role of human capital. However, the endogeneity test shows that human capital can be treated as an exogenous variable (though the p-value is relatively low). Thus, the standard fixed effects regression might be preferable.

In regression 8 explanatory variables are instrumented with 8 institutional and population structure variables that have been found to be exogenous (see section 3 for more detailed discussion of the procedure of instrument choice and section 4.2 for variables used). This specification implies the speed of convergence of 2%, the effects of investment and labor force growth on GDP growth are larger than in other specifications, while human capital has no impact on GDP. However, the regression has disadvantages. Instruments are pretty weak as evidenced by F-tests mostly below the rule of thumb of 10 and the Kleibergen-Paap statistic of only 2.25. Moreover, all the variables are found to be exogenous, therefore they do not need to be instrumented in the first place - the simple fixed effects model is again preferable.

Regression 9 combines differenced lags and external instruments while instrumenting for human capital. Given that in regression 7 human capital is close to being endogenous, it seems worthwhile to test whether adding more instruments might change this result. The 1st stage F-test raises from 11 to 18.7 - the instruments might be regarded as quite strong. Point estimates

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[5] Estimates based on coefficients for investment and human capital.

[6] The sample average of capital share of income is 44% according to the Penn World Tables data - very similar to the implied α.

[7] $y^* = i^{\frac{\alpha(1-\beta)+\alpha\beta}{1-\alpha-\beta}} i\_h^{\frac{\beta(1-\alpha)+\alpha\beta}{1-\alpha-\beta}} (n + g + \delta)^{\frac{-\alpha-\beta}{1-\alpha-\beta}}$ where y^* is steady state output per effective worker. See Mankiw, Romer and Weil (1992) for derivation.

[8] Instruments are constructed in GMM-style – missing observations are replaced with 0s – in order not to lose observations.

end up being in between regressions 7 and 8. In particular, the point estimate for human capital is only slightly positive, not very far from the FE estimate (0.034 vs 0.060) and insignificant. As a result, human capital is again found to be exogenous.

Table 4. Endogenous explanatory variables regressions

	(6) Lags GMM	(7) Lags optimal	(8) External instruments	(9) Combined lags and external instruments
L.ln(Y/L)	0.9911***	0.9632***	0.9803***	0.9743***
	(0.0000)	(0.0000)	(0.0000)	(0.0000)
ln(i)	0.0248**	0.0252***	0.0450**	0.0384***
	(0.0136)	(0.0003)	(0.0195)	(0.0000)
ln(n+g+δ)	-0.0385***	-0.0291*	-0.0676**	-0.0465***
	(0.0007)	(0.0882)	(0.0140)	(0.0005)
$\ln(i_h)$	0.0008	0.0140**	-0.0001	0.0034
	(0.8541)	(0.0111)	(0.9870)	(0.4343)
Time-varying cross-country fixed effects	Yes	Yes	Yes	Yes
Time fixed effects	Yes	Yes	Yes	Yes
Instrumented variables	i, ln(n+g+δ), i_h	i_h	i, ln(n+g+δ), i_h	i_h
Instruments	2^{nd}–3^{rd} lags	2^{nd} and 4^{th}-7^{th} lagged differences	Institutions and population structure	Institutions and population structure; 2^{nd}, 5^{th} and 6^{th} lagged differences
Estimation method	System GMM	TSLS FE	TSLS FE	TSLS FE
n	1018	1018	814	845
N	47	47	47	47
Number of instruments	330	-	-	-
Sample	1991-2016	1996-2016	1996-2016	1995-2016
1^{st} stage F-test: ln(i)/ln(n+g+δ)/$\ln(i_h)$	-	-/-/11.05	10.37/5.35/8.41	-/-/18.73
Kleibergen-Paap rk Wald F statistic	-	11.05	2.25	18.73
Sargan/Hansen test (p-value)	0.000/1.000	0.2188/0.8803	0.0150/0.8013	0.0114/0.8861
Instruments as additional regressors: F-test (p-value)	0.000	0.7097	0.9476	0.7498
Endogeneity test: ln(i)/ln(n+g+δ)/$\ln(i_h)$ (p-value)	-	-/-/0.1365	0.9927/0.6005/ 0.9918	-/-/0.2083

Robust p-value in parentheses
*** p<0.01, ** p<0.05, * p<0.1

In conclusion, instrumental variables approaches fail to reject the hypothesis that explanatory variables might be assumed to be exogenous. Therefore, I regard the fixed effects model as my baseline regression and use estimates obtained from this specification in my growth decomposition. I do it bearing in mind that the coefficient on the lagged dependent variable is downward biased, and thus the contribution of convergence to growth is upward biased.

6. Decomposition

The decomposition of potential growth slowdown is shown in Table 5 and Figure 6.

Table 5. Decomposition of potential growth slowdown: 2016 vs 2007 (pp)

	Convergence	Steady state					Global TFP growth	Population growth	Labor force participation	Residual	**Overall slowdown**
		Total	Investment	Labor force growth	Human capital	Domestic TFP					
Bulgaria	0.81	0.90	0.56	-0.28	-0.03	0.64	0.05	0.70	-0.09	-0.20	**2.16**
Croatia	0.24	1.89	0.69	-0.23	-0.12	1.54	0.05	1.09	-0.61	-0.49	**2.16**
Czechia	0.49	0.72	0.32	0.06	0.02	0.31	0.05	1.24	-1.38	0.23	**1.33**
Estonia	0.53	2.07	0.70	-0.07	0.22	1.23	0.05	0.00	0.17	-1.30	**1.52**
Hungary	0.08	1.62	0.35	0.25	0.23	0.78	0.05	0.78	-1.41	-0.56	**0.56**
Latvia	0.77	2.24	0.94	-0.30	0.20	1.40	0.05	0.51	0.10	-1.46	**2.20**
Lithuania	0.93	2.00	0.52	0.34	0.27	0.86	0.05	0.69	-1.40	-0.64	**1.62**
Poland	0.86	-0.20	0.22	-0.01	0.20	-0.61	0.05	1.12	-1.09	0.27	**1.01**
Romania	1.02	1.68	0.30	0.49	0.29	0.59	0.05	-0.46	-0.48	-0.21	**1.60**
Slovakia	0.87	0.21	0.48	0.00	0.14	-0.42	0.05	0.91	-0.91	0.61	**1.73**
Slovenia	0.30	1.19	0.99	-0.44	0.22	0.41	0.05	1.05	-0.06	-0.64	**1.88**
Mean	**0.63**	**1.30**	**0.56**	**-0.02**	**0.15**	**0.61**	**0.05**	**0.69**	**-0.65**	**-0.40**	**1.62**
Weighted mean	**0.72**	**0.74**	**0.36**	**0.08**	**0.17**	**0.13**	**0.05**	**0.76**	**-0.92**	**-0.03**	**1.32**
% of mean	**38.8**	**80.5**	**34.4**	**-1.1**	**9.3**	**37.9**	**2.8**	**43.0**	**-40.3**	**-24.7**	
% of weighted mean	**54.7**	**56.1**	**27.2**	**6.0**	**13.0**	**9.8**	**3.4**	**57.7**	**-69.8**	**-2.2**	

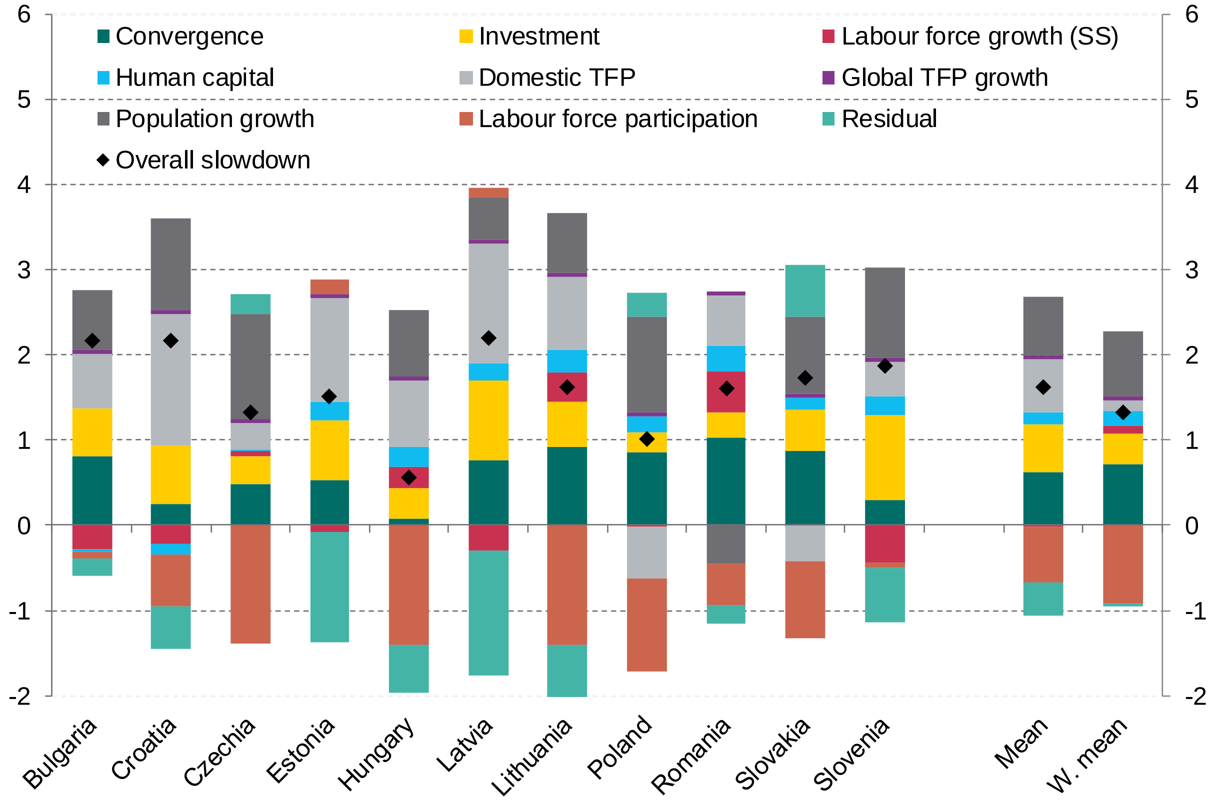
Weighted mean utilizes GDP PPP as weights.

According to HP filter estimates, potential growth of CEE countries slowed down by 1.6 pp on average between 2007 and 2016. All the countries experienced the slowdown, ranging from 0.6 pp in Hungary to 2.2 pp in Latvia.

Convergence was a significant contributor to the slowdown in most of the countries – it decreased potential growth by 0.6 pp on average, ranging from 0.1 pp in Hungary to 1 pp in Romania. Thus, it was on average responsible for 39% of the overall slowdown.

The remaining part of the slowdown was associated with the steady state determinants, and in particular falling investment to GDP ratio and declining “domestic” component of TFP (i.e. the one estimated from time-varying cross-country fixed effects). Both of these factors decreased potential growth by 0.6 pp on average. The decline in investment to GDP ratio was observed in all CEE countries, as its contribution to slowdown ranged from 0.2 pp in Poland to 1 pp in Slovenia. The domestic component of TFP decreased significantly in all the countries but Poland and Slovakia, subtracting as much as 1.5 pp from potential growth in Croatia.

Figure 6 Decomposition of potential growth slowdown: 2016 vs 2007 (pp)



Weighted mean utilises GDP PPP as weights.

Lower working age population growth had a large contribution to the slowdown (0.7 pp on average), which was however offset in most of the countries by labor force participation rising at a faster pace. The exceptions are Bulgaria, Croatia, Latvia and Slovenia where labor force growth slowed down by 0.5-1 pp, depressing potential growth by 0.3-0.6 pp[9].

Other factors – global TFP growth and human capital – played little role. Global TFP growth slowed down already before the crisis, remaining at a similar level afterwards, and hence it had virtually no effect on potential growth 2016 vs 2007 (Figure A.2 in the Appendix). The share of people enrolled into tertiary education fell in all the CEE countries but Bulgaria and Croatia, contributing to the slowdown in potential growth on average 0.15 pp and maximum 0.3 pp in Romania.

Similar conclusions can be reached if one analyzes GDP PPP-weighted mean values, though due to the dominating role of Poland, overall potential growth slowdown and the contributions of investment and especially domestic TFP are somewhat lower. As a result, convergence explains 55% of the overall slowdown.

[9] Lower labor force growth raises steady state output per worker, which partly offsets its negative effect on potential growth.

7. Robustness Checks

The baseline results are largely robust to using alternative proxies for human capital, augmenting the model with explicit proxies for TFP, limiting the sample to CEE countries and excluding outliers.

7.1 Explicit Proxies for TFP

One might attempt to extend the model by adding variables that would explicitly capture a part of the variation in TFP, on the top of the variation already controlled for with time-varying cross-country fixed effects.

Institutional variables that I have gathered as potential instruments for explanatory variables could influence GDP per worker also via TFP. Thus, I test these 15 variables (see section 4.2 for their description) as additional regressors. It turns out that only the Government Effectiveness index from the Worldwide Governance Indicators is robustly statistically significant and influences GDP per worker with an expected sign. This regression is reported in Table 6 as regression 2.

Government Effectiveness has a relatively strong influence on potential output – a 10% increase in the index raises potential growth by 0.25 pp in the first year. The speed of convergence does not materially change, but other coefficients do – both investment and labor force growth have an approximately 50% stronger impact on GDP per worker, while human capital becomes insignificant. Thus, the contribution of declining investment to GDP ratio to potential growth slowdown increases from 0.63 pp on average to 0.85 pp (Table 12 in section 7.3).

There are many potential drivers of TFP other than institutions, however. Among others, Romer (1986, 1990) and his followers see R&D investment and the resulting innovation as the main driver of TFP growth. Incentives to innovate depend i.a. on the sector of activity (they might be stronger in industry than in services), the size of domestic market and access to foreign markets. Lewis (1954) notes that reallocation of labor from agriculture to more productive sectors is an important source of growth in developing countries. Less developed countries might also import technologies and best practices from abroad via foreign direct investment (Borensztein et al. 1998). Free trade might also make it easier to copy technologies from abroad by developing trade links and importing innovative products (Saggi 2002). On the other hand, population ageing might have a negative effect on TFP as individual productivity tends to fall at older age (Skirbekk 2004). Older workers and consumers might also be less willing to introduce and consume innovative products (Laukannen et al. 2007).

Table 6. Regressions with explicit proxies for TFP

	(1) Baseline	(2) Government Effectiveness	(3) Government Effectiveness + exports/GDP
L.ln(Y/L)	0.9693***	0.9673***	0.9614***
	(0.0000)	(0.0000)	(0.0000)
ln(i)	0.0270***	0.0413***	0.0572***
	(0.0009)	(0.0002)	(0.0001)
ln(n+g+δ)	-0.0308	-0.0463***	-0.0532***
	(0.1231)	(0.0011)	(0.0002)
ln(i_h)	0.0060**	0.0018	0.0037
	(0.0430)	(0.5781)	(0.2166)
ln Government Effectiveness		0.0255***	0.0250***
		(0.0032)	(0.0036)
ln exports/GDP			0.0298**
			(0.0103)
Time-varying cross-country fixed effects	Yes	Yes	Yes
Time fixed effects	Yes	Yes	Yes
Instrumented variables	-	-	-
Instruments	-	-	-
n	1018	823	823
N	47	47	47
Sample	1991-2017	1996-2017	1996-2017
1st stage F-test: ln(i)/ln(n+g+δ)/ln(i_h)	-	-	-
Kleibergen-Paap rk Wald F statistic	-	-	-
Sargan/Hansen test (p-value)	-	-	-
Instruments as additional regressors: F-test (p-value)	-	-	-
Endogeneity test: ln(i)/ln(n+g+δ)/ln(i_h) (p-value)	-	-	-

Robust p-value in parentheses
** p<0.05, * p<0.1

I try to control for the above-mentioned factors. As measures of R&D investment, I use R&D expenditure as a % of GDP and the number of R&D researchers per million people. To account for potential differences in TFP growth resulting from different sectoral structure of the economy, I include the shares of industry and services in GDP. Since GDP is clearly endogenous, population density and total population are my gauges of domestic market size. Access to foreign markets is measured with exports to GDP ratio, bearing in mind that regulatory aspects of trade openness have already been captured by the trade freedom index, while geographical aspects (such as distance to main trading partners and territory size) are captured by fixed effects. Reallocation of labor is measured with the change in the share of people employed in agriculture, while FDI is simply FDI net inflows as a % of GDP. Finally, population ageing is captured by an average age of the workforce. All variables but FDI and changes in employment in agriculture are expressed in natural logarithms and the cyclical component is removed from FDI and exports/GDP data using HP filter.

Out of all these variables, only exports to GDP ratio is statistically significant and enters with an expected sign. The regression including this variable together with the Government Effectiveness index is reported in Table 6 as regression 3.

Exports to GDP ratio is highly significant and has a relatively strong impact on output per worker – a 10% increase in the ratio raises potential growth by 0.3 pp in the first year. Implied speed of convergence increases to 3.9% and so does the size of coefficients for investment and labor force growth. At the same time, the impact of Government Effectiveness on potential growth stays roughly the same.

The introduction of new variables and their high impact on the results warrants analyzing the potential growth decomposition for all the countries separately (the mean contributions for all specifications, including this one, are reported in section 7.3). The alternative decomposition is calculated based on the results of regression 3 and presented in Table 7 and Figure 7.

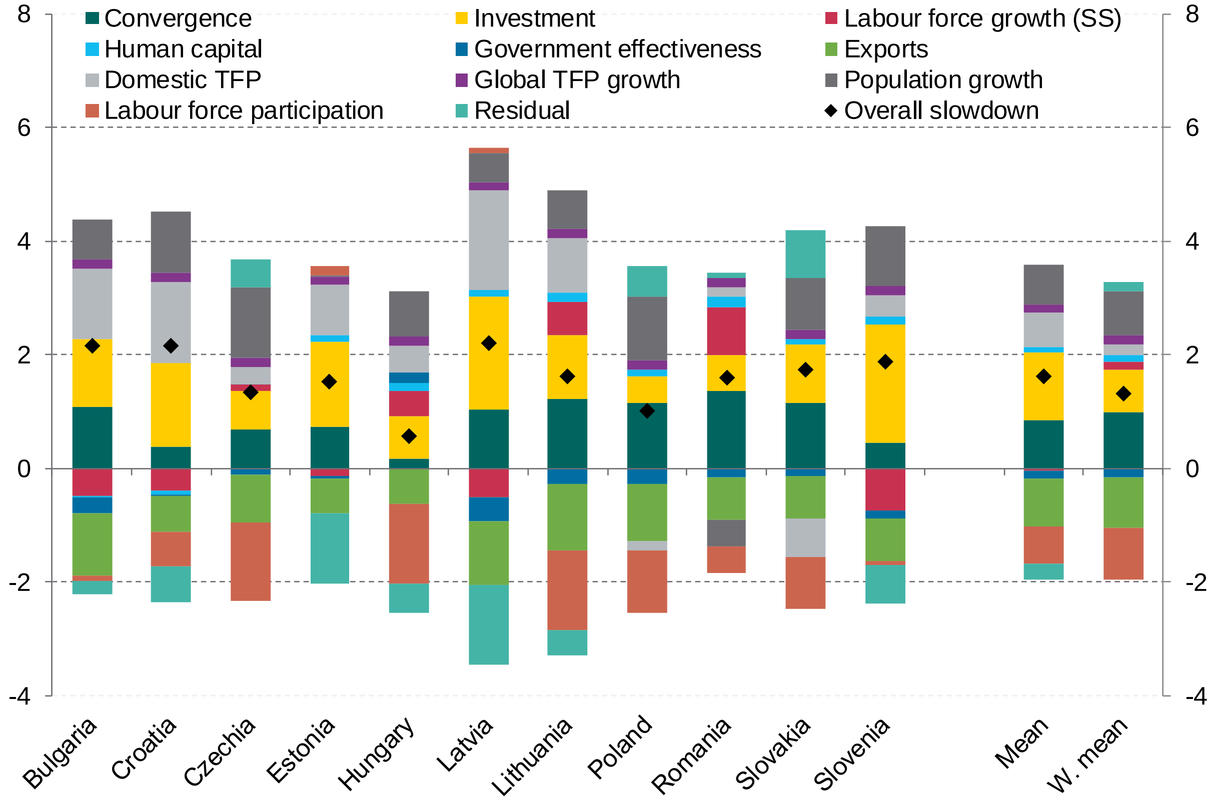
Table 7. Decomposition of potential growth slowdown – augmented specification (pp, 2016 vs 2007)

		Steady state											
	Convergence	Total	Investment	Labor force growth	Human capital	Government Effectiveness	Exports/ GDP	Domestic TFP	Global TFP growth	Population growth	Labor force participation	Residual	**Overall slowdown**
Bulgaria	1.09	0.54	1.20	-0.49	-0.02	-0.29	-1.10	1.24	0.16	0.70	-0.09	-0.23	**2.16**
Croatia	0.38	1.79	1.47	-0.39	-0.07	-0.02	-0.63	1.43	0.16	1.09	-0.61	-0.64	**2.16**
Czechia	0.68	0.15	0.69	0.11	0.01	-0.11	-0.84	0.30	0.16	1.24	-1.38	0.49	**1.33**
Estonia	0.73	1.70	1.49	-0.13	0.13	-0.04	-0.63	0.87	0.16	0.00	0.17	-1.24	**1.52**
Hungary	0.18	1.37	0.75	0.43	0.15	0.20	-0.62	0.47	0.16	0.78	-1.41	-0.52	**0.56**
Latvia	1.03	1.81	2.00	-0.52	0.12	-0.41	-1.13	1.74	0.16	0.51	0.10	-1.41	**2.20**
Lithuania	1.23	1.37	1.11	0.60	0.17	-0.28	-1.16	0.95	0.16	0.69	-1.40	-0.44	**1.62**
Poland	1.15	-0.85	0.47	-0.02	0.12	-0.26	-1.01	-0.17	0.16	1.12	-1.09	0.52	**1.01**
Romania	1.35	0.92	0.65	0.84	0.18	-0.16	-0.75	0.17	0.16	-0.46	-0.48	0.10	**1.60**
Slovakia	1.16	-0.45	1.03	0.00	0.09	-0.13	-0.76	-0.68	0.16	0.91	-0.91	0.86	**1.73**
Slovenia	0.44	0.96	2.10	-0.75	0.14	-0.14	-0.75	0.37	0.16	1.05	-0.06	-0.68	**1.88**
Mean	**0.86**	**0.85**	**1.18**	**-0.03**	**0.09**	**-0.15**	**-0.85**	**0.61**	**0.16**	**0.69**	**-0.65**	**-0.29**	**1.62**
Weighted mean	**0.98**	**0.17**	**0.76**	**0.14**	**0.11**	**-0.16**	**-0.88**	**0.21**	**0.16**	**0.76**	**-0.92**	**0.17**	**1.32**
% of mean	**53.0**	**52.5**	**72.8**	**-1.8**	**5.7**	**-9.2**	**-52.8**	**37.7**	**9.8**	**43.0**	**-40.3**	**-17.9**	
% of weighted mean	**74.0**	**13.2**	**57.7**	**10.4**	**8.0**	**-12.2**	**-66.4**	**15.6**	**12.0**	**57.7**	**-69.8**	**12.9**	

Weighted mean utilizes GDP PPP as weights.

Since the implied speed of convergence is higher (3.9% vs 3.1%), the contribution of convergence increases from 0.63 pp on average to 0.86 pp, explaining more than a half (53%) of the slowdown. Significantly higher coefficient on investment more than doubles the contribution of declining investment to GDP ratio to the slowdown – now it is 1.2 pp on average and in Slovenia even 2.1 pp. As the coefficient on labor force growth goes up, the positive effects of lower labor growth on per worker output now almost entirely offset the negative effects on overall output.

Figure 7 Decomposition of potential growth slowdown – augmented specification (pp, 2016 vs 2007)



Weighted mean utilises GDP PPP as weights.

Significantly higher contributions of convergence and investment are offset by an increasing exports to GDP ratio, which added to growth from 0.6 pp in Hungary to 1.2 pp in Lithuania, and to a lesser extent by increasing government effectiveness, which improved potential growth in all the countries but Hungary, the contributions ranging from close to 0 in Croatia to 0.4 pp in Latvia. The contributions of human capital, global TFP growth and domestic TFP (the latter on average) do not change materially. Thus, it seems that additional variables not so much help explain developments in TFP, but rather help correct the omitted variable bias for the speed of convergence, investment and labor force growth.

While augmenting the model changes some of the quantitative conclusions, qualitatively the message remains the same – convergence was one of the main contributors to the slowdown alongside falling investment to GDP ratio and domestic TFP, while global TFP growth played little to no role.

7.2 CEE Sample

Instead of estimating the model on the sample of high income countries, one can focus only on the CEE countries. In such a case, parameter estimates better reflect the aggregate production functions of CEE countries. However, the time fixed effect can no longer be interpreted as global TFP growth – now it is a common component of TFP growth in CEE. Therefore, one cannot estimate the impact of global factors on potential growth in CEE.

The results of the regression on the CEE sample are shown in Table 8 as regression 2.

Table 8. Regressions on the CEE sample and after excluding outliers

	(1) Baseline	(2) CEE sample
L.ln(Y/L)	0.9693***	0.9503***
	(0.0000)	(0.0000)
ln(i)	0.0270***	0.0236
	(0.0009)	(0.1832)
ln(n+g+δ)	-0.0308	-0.0552**
	(0.1231)	(0.0132)
$ln(i_h)$	0.0060**	-0.0014
	(0.0430)	(0.8454)
Time-varying cross-country fixed effects	Yes	Yes
Time fixed effects	Yes	Yes
n	1018	252
N	47	11

Robust p-value in parentheses
*** p<0.01, ** p<0.05, * p<0.1

The implied speed of convergence raises to 5%, in line with some of the previous literature that finds convergence in CEE to be faster than in Western Europe (Próchniak and Witkowski 2013a, Próchniak and Witkowski 2014a). The coefficient on investment is very similar, though understandably less precisely estimated, while the effect of labor force growth on output per worker grows significantly. At the same time, human capital becomes insignificant and the point estimate is even slightly negative.

Thus, the contribution of convergence to slowdown raises significantly (to 78%; Table 12) at the cost of investment, human capital and especially domestic TFP. Common component of TFP growth contributes 0.36 pp to the slowdown, which further decreases the contribution of domestic TFP (which contributes positively to growth, adding 0.45 pp on average).

7.3 Alternative Proxies for Human Capital Accumulation

Out of my explanatory variables, the choice of proxy for human capital is most disputable. Thus, it seems worthwhile to investigate whether this choice significantly affects the results.

I check 3 alternative proxies for human capital. The first one includes secondary education on the top of tertiary education, the second one attempts to control for the quality of education by taking into account PISA test results, and the third one is Barro-Lee mean years of schooling. The details of variable construction are provided in Table 9.

Table 9. Alternative proxies for human capital

Regression	Human capital variable construction	Comments	Source
Baseline	ln percentage of total population enrolled in tertiary education (percentage of population aged 20-24 * tertiary school enrolment)		World Bank, own calculations
Including secondary education	ln percentage of total population enrolled in secondary and tertiary education (percentage of population aged 15-19 * secondary school enrolment + percentage of population aged 20-24 * tertiary school enrolment)		World Bank, own calculations
Quality-corrected	ln percentage of total population enrolled in tertiary education times PISA reading score (percentage of population aged 20-24 * tertiary school enrolment * interpolated PISA reading score/500)	PISA scores are available triennially since 2000 – missing observations interpolated after 2000 and assumed to equal the 2000 score before 2000	World Bank, OECD PISA, own calculations
Barro-Lee	ln interpolated mean years of schooling	Barro-Lee data up to 2010, Wittgenstein's projections after 2010; both are available at 5 year intervals – missing observations are interpolated	Barro-Lee (2013), Wittgenstein Centre for Demography and Global Human Capital, own calculations

Regression results are provided in Table 10.

Table 10. Regressions with alternative proxies for human capital accumulation

	(1) Baseline	(2) Including secondary education	(3) Quality-corrected	(4) Barro-Lee
L.ln(Y/L)	0.9693***	0.9735***	0.9631***	0.9743***
	(0.0000)	(0.0000)	(0.0000)	(0.0000)
ln(i)	0.0270***	0.0292***	0.0323***	0.0283***
	(0.0009)	(0.0014)	(0.0012)	(0.0003)
$\ln(n+g+\delta)$	-0.0308	-0.0323	-0.0306	-0.0282
	(0.1231)	(0.1383)	(0.1353)	(0.1841)
$\ln(i_h)$	0.0060**	-0.0033	0.0069**	-0.0064
	(0.0430)	(0.5271)	(0.0218)	(0.4999)
Time-varying cross-country fixed effects	Yes	Yes	Yes	Yes
Time fixed effects	Yes	Yes	Yes	Yes
n	1018	996	972	1171
N	47	47	45	47

Robust p-value in parentheses
** p<0.05, * p<0.1

The inclusion of secondary education renders the human capital variable insignificant, and the point estimate turns negative. At the same time, other point estimates increase, which results in a somewhat lower contribution of convergence to potential growth slowdown, while the contribution of domestic TFP increases (Table 12). Quality correction has very little influence on the human capital coefficient, but slightly increases the implied speed of convergence and the coefficient on investment. These differences, however, stem almost exclusively from the sample change (2 countries and 56 observations fewer; results not reported). Lastly, the Barro-Lee mean years of schooling variable is insignificant, while the point estimate is visibly negative. As a result, the implied speed of convergence decreases.

The results confirm that the share of people enrolled into tertiary education seems to be the best proxy for human capital in this sample. Alternative measures are either insignificant with counterintuitively negative point estimates (secondary education and the Barro-Lee measures) or have virtually no influence on the estimates while limiting the sample (quality-corrected). At the same time, the impact of human capital on GDP per worker is very sensitive to the choice of proxy, and thus the baseline result should not be overly trusted. Having said that, the choice of human capital proxy has little influence on the main conclusions of the study as the role of human capital is limited in virtually all specifications (Table 12).

7.4 Outliers

Baseline estimates might also be influenced by outlying observations. This seems likely as the sample includes economies going through transition (CEE countries in the 1990s), severe crisis (e.g. Argentina, Greece) and large boom and bust cycles (Baltic countries before and during the global financial crisis), which heavily influenced not only the cyclical components, but also the trend components of variables used in the regression. Moreover, the division into subperiods (for the cross-country fixed effect) is somewhat arbitrary and might create outliers within these subperiods.

To investigate whether this is indeed the case, I use the Cook's D statistic – a very popular way of detecting influential observations. The observations above the standard threshold of 4/n are excluded from the sample. The results of the regression without outliers are shown in Table 11 as regression 2.

Almost 70 observations are excluded, but all 47 countries are still in the sample. The implied speed of convergence remains virtually unchanged, but the size of other coefficients decreases somewhat, especially for labor force growth. As a result, the contributions of investment and human capital (and labor force growth for some countries) decrease, which is offset by higher contribution from domestic TFP (Table 12).

The results are very similar if one excludes outliers in alternative ways – either by using DFITS statistic (Belsley et al. 1980) or by excluding observations with residuals more than 2 standard deviations away from 0 (results not reported).

However, excluding only some of the observations for a given country is similar to cherry picking, and makes the estimates of domestic TFP unrealistic. Therefore, as an alternative, I exclude from the sample non-CEE countries that have at least 2 observations with Cook's D above the standard threshold. For CEE countries, I exclude only observations up to 2000 if at least two of them exceed the threshold, so that I am able to estimate domestic TFP shifts between pre-crisis and post-crisis. The results are presented in Table 11 as regression 3.

Table 11. Regressions on the CEE sample and after excluding outliers

	(1) Baseline	(3) Outliers	(4) Outliers v2
L.ln(Y/L)	0.9693***	0.9700***	0.9642***
	(0.0000)	(0.0000)	(0.0000)
ln(i)	0.0270***	0.0189***	0.0153*
	(0.0009)	(0.0009)	(0.0579)
ln(n+g+δ)	-0.0308	-0.0127	-0.0056
	(0.1231)	(0.2273)	(0.6476)
$\ln(i_h)$	0.0060**	0.0043**	0.0049**
	(0.0430)	(0.0136)	(0.0253)
Time-varying cross-country fixed effects	Yes	Yes	Yes
Time fixed effects	Yes	Yes	Yes
n	1018	949	872
N	47	47	41

Robust p-value in parentheses
*** p<0.01, ** p<0.05, * p<0.1

6 countries are excluded – Argentina, Greece, Ireland, Luxembourg, Panama and Uruguay – and observations up to 2000 are excluded for Bulgaria and Romania. These are indeed mostly countries experiencing severe crises (Argentina, Greece), with unreliable GDP data (Ireland) or peculiar structure of the economy (Luxembourg). Altogether, almost 150 observations are excluded. The implied speed of convergence raises somewhat, and the size of coefficients for investment and labor force growth falls even further, the latter becoming only slightly negative and highly insignificant. As a result, the contribution of convergence to potential growth slowdown goes up slightly to 42%, while the contribution of investment falls further to 20%.

Summing up, the main conclusions of the study are qualitatively robust to excluding outliers – convergence remains a significant driver of the potential growth slowdown alongside falling investment to GDP ratio and domestic TFP.

7.5 Robustness of Potential Growth Decomposition

It is also worth looking in more detail into how the decompositions of potential growth slowdown in CEE change between different specifications. For brevity, I present only mean results, without analyzing each country separately. Results for each country separately are shown only for the specification augmented with Government Effectiveness and exports to GDP ratio (see section 7.2). The mean contributions for all the specifications are presented in Table 12.

Table 12. Decomposition of potential growth slowdown – mean contributions across all specifications (pp, 2016 vs 2007)

	Convergence	Steady state							Global TFP growth*	Population growth	Labor force participation	Residual
		Total	Investment	Labor force growth	Human capital	Government Effectiveness	Exports/ GDP	Domestic TFP				
Baseline	**0.63**	**1.30**	**0.56**	**-0.02**	**0.15**	**-**	**-**	**0.61**	**0.05**	**0.69**	**-0.65**	**-0.40**
Difference GMM	0.86	0.56	0.55	-0.02	0.15	-	-	-0.13	0.56	0.69	-0.65	-0.40
System GMM (exogenous)	0.63	-0.39	0.54	-0.01	0.01	-	-	-0.92	1.72	0.69	-0.65	-0.39
Bias-corrected FE	0.35	1.13	0.94	-0.02	0.02	-	-	0.19	0.53	0.69	-0.65	-0.43
Lags GMM	0.45	0.11	0.51	-0.02	0.02	-	-	-0.40	1.46	0.69	-0.65	-0.32
Lags optimal	1.00	0.66	0.52	-0.02	0.35	-	-	-0.19	0.47	0.69	-0.65	-0.56
External instruments	0.14	2.24	0.93	-0.04	0.00	-	-	1.36	-0.46	0.69	-0.65	-0.35
Lags and external instruments	0.65	1.23	0.79	-0.03	0.09	-	-	0.38	0.10	0.69	-0.65	-0.40
Secondary education	0.54	1.22	0.60	-0.02	-0.08	-	-	0.72	0.05	0.69	-0.65	-0.24
Quality-corrected human capital	0.71	1.28	0.66	-0.02	0.16	-	-	0.47	-0.02	0.69	-0.65	-0.40
Barro-Lee human capital	-0.15	3.58	0.58	-0.02	0.04	-	-	2.98	-1.59	0.69	-0.65	-0.27
Government Effectiveness	0.63	1.27	0.85	-0.03	0.04	-0.15	-	0.56	-0.03	0.69	-0.65	-0.30
Government Effectiveness + exports/GDP	0.86	0.85	1.18	-0.03	0.09	-0.15	-0.85	0.61	0.16	0.69	-0.65	-0.29
CEE sample*	1.27	-0.03	0.49	-0.03	-0.04	-	-	-0.45	0.36	0.69	-0.65	-0.02
Outliers	0.58	1.37	0.39	-0.01	0.11	-	-	0.88	-0.01	0.69	-0.65	-0.37
Outliers v2	0.68	1.17	0.32	0.00	0.12	-	-	0.74	-0.04	0.69	-0.65	-0.24
Mean	**0.61**	**1.10**	**0.65**	**-0.02**	**0.08**	**-0.15**	**-0.85**	**0.46**	**0.21**	**0.69**	**-0.65**	**-0.34**
% of mean	**37.8**	**67.6**	**40.0**	**-1.2**	**4.7**	**-9.2**	**-52.6**	**28.5**	**12.6**	**42.7**	**-40.1**	**-20.7**

* For the CEE sample, the column „Global TFP growth" shows the contribution of common component of TFP growth in the CEE countries rather than the global component.

Overall, the results of the decomposition are quite robust to the use of other specifications - mean contributions from all specifications are quite close to the baseline results. For convergence the contribution is virtually identical, the contribution of investment goes up by about 0.1 pp and for human capital it falls by 0.07 pp. The contribution of domestic TFP decreases by 0.15 pp, which is offset by an increase in global TFP's contribution by 0.16 pp.

Looking closer, the results confirm that the model has problems distinguishing between domestic and global TFP. This is particularly visible for specifications estimated with system GMM, external instruments and Barro-Lee human capital – the global TFP component and the domestic TFP component jump significantly and in opposite directions between subsamples, which results in their high and opposite contributions to potential growth slowdown. These jumps in domestic TFP affect also the steady state level, and thus the contributions of convergence to growth slowdown.

Taking away these 4 extreme cases, the contribution of convergence ranges from 0.35 pp in the bias-corrected fixed effects specification to 1.27 pp in the CEE sample, while the contribution of investment ranges from 0.3 pp to 1.2 pp – therefore, both factors significantly and robustly contributed to the potential growth slowdown. The contribution of labor force growth remains negligible, while the contribution of human capital is small in all specifications but the one which instruments human capital with its lags (Lags optimal).

The contribution of domestic TFP is positive and relatively large in most of the specifications, while that of global TFP growth is mostly close to 0, though these results should not be overly trusted. The notable exception here is the difference GMM regression, which despite giving very similar point estimates of explanatory variables as the baseline regression, implies that global TFP growth contributed 0.5 pp to the slowdown and the contribution of domestic TFP was close to 0.

8. External vs Domestic Factors

Global TFP trend is found to have contributed little to the post-crisis slowdown in potential growth. However, the time fixed effect is only a very rough proxy for the impact of external factors on growth - other model variables might also be driven by economic developments abroad. In particular, domestic TFP and investment to GDP ratio in small open CEE economies might depend on TFP and growth among its closest economic partners.

In this section I run additional regressions, decompose movements in domestic TFP and investment to GDP ratios, and combine these findings with the baseline results to estimate the impact of external vs domestic causes behind the CEE potential growth slowdown.

8.1 Domestic TFP

As mentioned above, TFP growth might include not only domestic and purely global components, but also reflect regional developments in the closest proximity of the economy – a given country is likely to copy technology, organization of production and management practices primarily from its closest economic partners – either via foreign trade or foreign direct investment.

To investigate whether this is indeed the case, I regress domestic TFP levels (expressed in natural logarithms) obtained from the baseline regression on the TFP level among the trading partners. The latter variable is computed as the ln TFP level estimated from the baseline regression weighted by the each country's share in each country's foreign trade turnover (imports + exports). Only countries from the sample are taken into account when computing shares in foreign trade. Data on foreign trade is taken from the World Bank WITS TradeStat database.

As candidates for control variables, I use investment to GDP ratio and human capital investment from the baseline regression (as the implementation of new technology usually requires investment in physical capital, while higher human capital should make innovation easier), potential external instruments described in subsection 4.3 - institutional variables from the Index of Economic Freedom and World Bank Worldwide Governance Indicators, and population age structure variables – as well as other potential drivers of TFP described in subsection 7.2, such as i.a. R&D investment, population density, industry to GDP ratio, or exports to GDP ratio. Since domestic TFP is estimated for 3 subperiods (1991-2000, 2001-2008, 2009-2016), all variables are averaged over these 3 periods, shrinking the time series dimension of the panel to T=3. The regression also includes the time trend to capture common movement in TFP.

Eventually 5 variables that enter the regression with an expected sign and sufficiently low p-value are included in the model on the top of foreign TFP: the Government Effectiveness index, labor reallocation (change in the share of people employed in agriculture), population density, exports to GDP ratio, and investment to GDP ratio. The model is estimated using the same method as the baseline regression, i.e. the fixed effects estimator. The regression results are shown in Table 13.

Foreign TFP has no statistically significant impact on domestic TFP; however, p-value is relatively low and the point estimate is economically relevant – a 1% rise in foreign TFP raises domestic TFP by 0.88%. At the same time, labor reallocation is highly statistically significant and economically relevant – a 1 pp fall in the share of people employed in agriculture raises TFP by 0.7% as employees move to more productive sectors. The impact of government effectiveness and investment to GDP ratio on TFP is also highly significant and quite strong – a 10% rise in either of these variables increases TFP by 0.45% and 0.28%, respectively. Similarly, a 10% rise in population density raises TFP by 0.3%, perhaps due to agglomeration effects and stronger incentives to innovate. Finally, exports to GDP ratio is not statistically significant, but its p-value remains relatively low – the point estimate suggests a 10% rise in trade openness raises TFP by 0.11%.

Table 13. Domestic TFP regression

	(1) FE
ln foreign TFP	0.8823
	(0.1599)
Labor reallocation	-0.0072***
	(0.0009)
ln population density	0.0306*
	(0.0602)
ln Government Effectiveness	0.0447**
	(0.0127)
ln(i)	0.0283**
	(0.0102)
ln exports/GDP	0.0112
	(0.1659)
Time fixed effects	Yes
n	130
N	46
R-squared	0.3877

Robust p-value in parentheses
*** p<0.01, ** p<0.05, * p<0.1

The decomposition of the TFP's contribution to the CEE potential growth slowdown into the variables included in the TFP regression is straightforward. First note that the TFP model can be concisely written as follows:

$$\mu_{i,t} = \varphi x_{i,t} + \omega_i + \kappa_t + \varepsilon_{i,t}$$

Where μ is ln domestic TFP, x is a vector of explanatory variables, including foreign TFP and control variables, φ is a vector of model parameters, ω and κ are cross-country and time fixed effects, respectively, and ε is an error term.

Next recall that domestic TFP's contribution to the slowdown is simply a difference between time-varying fixed effects, i.e. ln domestic TFP levels. Hence, the TFP's contribution to the slowdown can be decomposed in the following way:

$$\mu_{c_{i,2009-2016}} - \mu_{b_{2001-2008,}} = \varphi(x_{i,2009-2016} - x_{i,2001-2008}) + (\kappa_{2009-2016} - \kappa_{2001-2008}) + (\varepsilon_{i,2009-2016} - \varepsilon_{i,2001-2008})$$

The shift in domestic TFP is explained by changes in explanatory variables, the common time trend and a residual.

The results of the decomposition are presented in Table 14 and Figure 8.

Table 14. Decomposition of domestic TFP's contribution to potential growth slowdown: 2016 vs 2007 (pp)

	Foreign TFP	Government Effectiveness	Labor reallocation	Population density	Exports/GDP	Investment/ GDP	Global TFP	Residual	**Overall contribution**	External factors
Bulgaria	0.16	-0.51	0.33	0.17	-0.42	0.59	0.16	0.15	**0.64**	0.33
Croatia	0.07	-0.04	0.19	0.19	-0.24	0.73	0.16	0.47	**1.54**	0.24
Czechia	-0.36	-0.20	0.11	-0.08	-0.32	0.34	0.16	0.66	**0.31**	-0.20
Estonia	0.25	-0.08	0.20	0.13	-0.24	0.74	0.16	0.06	**1.23**	0.41
Hungary	-0.27	0.37	0.23	0.11	-0.23	0.37	0.16	0.05	**0.78**	-0.11
Latvia	0.13	-0.73	0.74	0.35	-0.42	0.99	0.16	0.17	**1.40**	0.29
Lithuania	0.05	-0.50	1.02	0.36	-0.44	0.55	0.16	-0.34	**0.86**	0.21
Poland	-0.24	-0.46	0.07	0.01	-0.38	0.23	0.16	-0.01	**-0.61**	-0.08
Romania	-0.05	-0.29	-1.01	0.18	-0.28	0.32	0.16	1.57	**0.59**	0.12
Slovakia	-0.16	-0.23	-0.08	-0.03	-0.29	0.51	0.16	-0.30	**-0.42**	0.00
Slovenia	-0.01	-0.24	-1.70	-0.07	-0.28	1.04	0.16	1.51	**0.41**	0.16
Mean	**-0.04**	**-0.27**	**0.01**	**0.12**	**-0.32**	**0.58**	**0.16**	**0.36**	**0.61**	**0.13**
Weighted mean	**-0.16**	**-0.29**	**-0.08**	**0.07**	**-0.33**	**0.38**	**0.16**	**0.39**	**0.13**	**0.00**
% of mean	**-6.5**	**-43.3**	**1.6**	**19.7**	**-52.5**	**95.0**	**26.9**	**59.2**		**20.4**
% of weighted mean	**-126.8**	**-223.1**	**-64.4**	**50.4**	**-255.6**	**291.5**	**127.6**	**300.4**		**0.8**

Weighted mean utilizes GDP PPP as weights.

The contribution of foreign TFP to the growth slowdown is on average close to zero (under GDP PPP-weighted mean even negative), thus on average CEE trading partners did not experience lower TFP growth than advanced economies as a whole. The average contribution hides cross-country differences, however – in Czechia, foreign TFP *increased* potential growth by as much as 0.36 pp, while in Estonia the contribution was negative and amounted to 0.25 pp. At the same time, the average TFP level declined following the crisis, thus the global component contributed 0.16 pp to the potential growth slowdown, which amounts to 27% of the domestic TFP's contribution and 10% of the total slowdown.

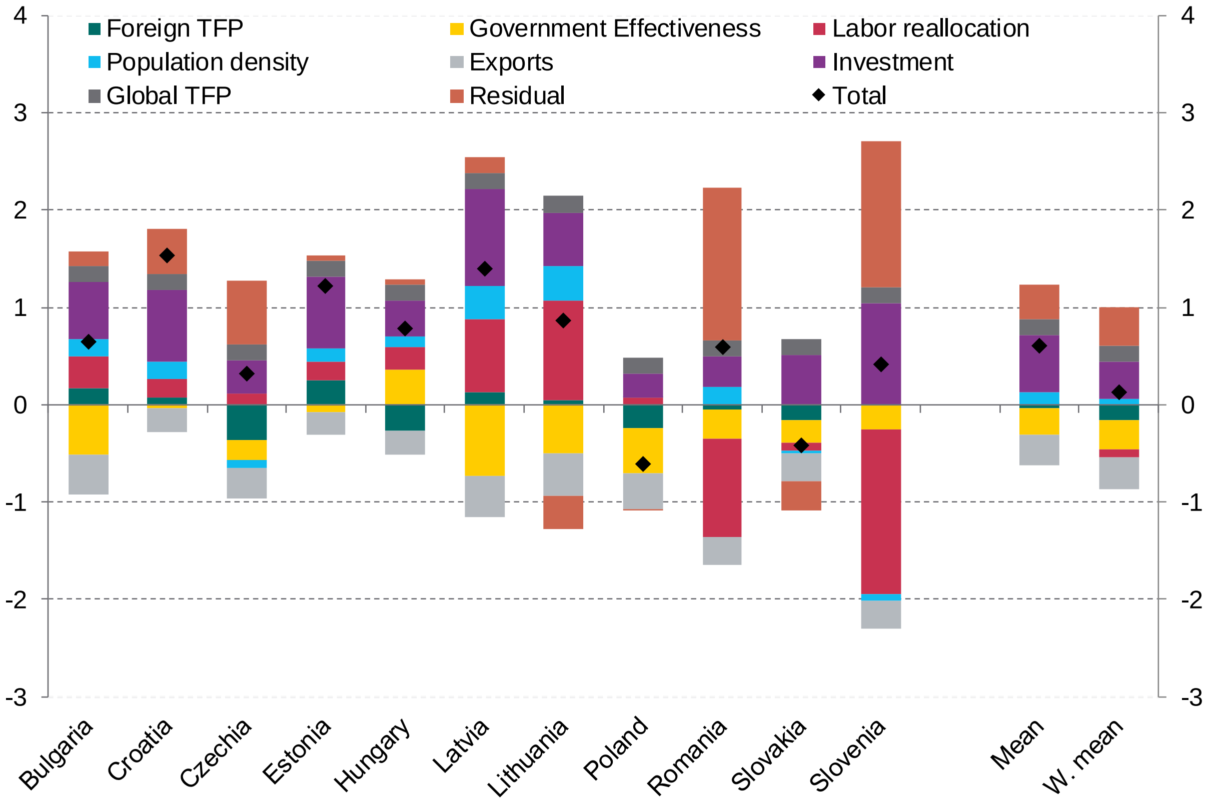
Among other factors, improving government effectiveness and increasing exports to GDP ratios contributed towards a rise in potential growth by 0.27 pp and 0.32 pp on average, respectively[10]. These contributions are offset by the falling investment to GDP ratios, which subtracted 0.58 pp from TFP growth and thus are responsible for 95% of the decline in domestic TFP. In most of the countries the outflow of labor from agriculture slowed down, decreasing potential growth. However, in Slovenia and Romania it accelerated rapidly, increasing potential growth by as much as 1.7pp[11] – as a result, the average contribution of labor reallocation to the fall in domestic TFP is virtually zero. Some of the countries – in

[10] This is roughly in line with the results of the specification in which Government Effectiveness and exports/GDP enter the main equation (see subsection 7.2 and Table 12).

[11] These contributions are probably exaggerated though, as they are mirrored by a negative contribution to domestic TFP of as a similar size from the model residual.

particular Baltic countries – saw a decline in total population, primarily due to emigration. As a result, population density declined and contributed to the fall in TFP by 0.12 pp on average.

Figure 8. Decomposition of domestic TFP's contribution to potential growth slowdown: 2016 vs 2007 (pp)



Weighted mean utilizes GDP PPP as weights.

Summing up, external factors identified in the TFP regression explain only about 20% of the decline in "domestic" TFP following the crisis, contributing 0.13 pp to the potential growth slowdown. However, most of the decline in TFP can be explained by falling investment to GDP ratios, which – as mentioned earlier – could also be driven by external factors.

8.2 Investment

In small open CEE economies, which produce to a large extent for exports, investment should depend on economic developments abroad. There is also a series of global phenomena, such as falling relative price of capital (Appendix Figure A.1), automation, or higher economic uncertainty after the crisis (Baker et al. 2016) that could have contributed to falling investment rates across the globe.

To investigate to what extent these external factors contributed to a decline in investment rates in CEE following the crisis, I regress investment rates (in natural logarithms) on trade-weighted potential growth abroad, which is a proxy for the expansion potential of CEE export markets. The foreign potential growth variable is constructed in an analogous way to foreign

TFP – potential growth (total, not per capita) among trading partners is weighted with shares in each country's foreign trade turnover (exports + imports) taking into account only the countries present in the sample. Data on foreign trade comes from the World Bank WITS TradeStat database. Additionally, the model includes time fixed effects to capture any global trends that influence investment rates across all the countries.

The candidates for control variables are first and foremost institutional and population age structure variables which are used as potential instruments for investment in the main regression of this paper (see subsection 4.3 for details). Some of the potential drivers of TFP described in subsection 7.2 are also used as candidate variables – the industry to GDP and services to GDP ratios might influence investment as industrial companies tend to require more physical capital; better access to foreign markets (proxied by exports to GDP ratio and average tariffs) might spur investment to expand in these markets; openness to foreign capital might attract direct investment (FDI inflows). Other explanatory variables from the main regressions – labor force growth and human capital investment – are also used as potential controls. They might act either as substitutes (implying a negative relationship) or complements in the production process (investment usually needs to be accompanied by a rise in employment, including that of skilled labor, and vice versa).

The model also includes lagged investment rate as the dependent variable is persistent, and time-varying cross-country fixed effects to capture any other time-varying domestic factors. Eventually, the following control variables that enter the regression with an expected sign and sufficiently low p-value are included in the regression: ln labor force growth, ln government spending index, ln control of corruption index, ln services to GDP ratio, and a full group of population age structure variables. The model is estimated using the same method as the baseline regression – the fixed effects estimator.

The model can thus be written in the following form:

$$lni_{i,t} = \rho lni_{t,t-1} + \vartheta z_{i,t} + \zeta_{i,1996-2000} + \zeta_{i,2001-2008} + \zeta_{i,2009-2016} + \psi_t + \varepsilon_{i,t}$$

Where z is a vector of control variables, ϑ is a vector of model parameters associated with them, ζ are time-varying cross-country fixed effects, ψ is the time fixed effect, and ε is an error term.

The estimation results are shown in Table 15.

Surprisingly, foreign potential growth has no impact on investment – the variable is highly insignificant, and the point estimate is small. Among control variables, labor force growth is highly significant – a 1% rise increases investment by 0.1% on impact and 2.3% in the steady state[12], thus investment and labor serve as complements. Services to GDP ratio is even more significant, but quantitatively the effect is very similar – a 1% rise decreases the investment rate by 0.09% on impact and 2.1% in the steady state, which confirms that the transition to a

[12] The steady state impact is equal to $\vartheta/(1-\rho)$.

more service-oriented economy reduces investment to GDP ratio. Corruption also reduces investment, though the effect is somewhat less significant and smaller – a 1% reduction in the control of corruption index reduces investment by less than 0.7% in the steady state. The crowding out effect of government spending is also present (the higher the government spending index, the lower the spending), but quantitatively it is negligible. Finally, population age structure also affects investment – while all point estimates are positive, the large share of the under-25-year-olds is most conducive to rising investment, confirming negative economic effects of low fertility and population ageing.

Table 15. Investment rate regression

	(1) FE
L.ln(i)	0.9570***
	(0.0000)
Foreign potential growth	0.0015
	(0.8424)
ln(n+g+δ)	0.0985***
	(0.0039)
ln government spending	0.0016*
	(0.0956)
ln control of corruption	0.0288*
	(0.0958)
ln services/GDP	-0.0911***
	(0.0000)
ln share of population aged 0-14	0.2157***
	(0.0002)
ln share of population aged 15-24	0.1123***
	(0.0017)
ln share of population aged 25-34	0.0678***
	(0.0093)
ln share of population aged 35-44	0.0341
	(0.1408)
ln share of population aged 45-54	0.0490*
	(0.0761)
ln share of population aged 55-64	0.0645***
	(0.0093)
ln share of population aged 65-74	0.1170***
	(0.0000)
ln share of population aged over 75	0.0475
	(0.1868)
Time-varying cross-country fixed effects	Yes
Time fixed effects	Yes
n	935
N	47
R-squared	0.9954

Robust p-value in parentheses
*** p<0.01, ** p<0.05, * p<0.1

The decomposition of the post-crisis fall in the investment rate into the above-mentioned factors is more complicated than in the case of the TFP regression. The exact expression is difficult to interpret, thus I propose a simplified decomposition, which takes the following form (for derivation and discussion see Appendix 2):

$$lni_{i,2007} - lni_{i,2016} = (1-\rho^9)\frac{1}{\rho}\big(\vartheta(z_{i,2007} - z_{i,2016}) + (\zeta_{i,2001-2008} - \zeta_{i,2009-2016}) + (\psi_{2007} - \psi_{2016})\big) + (1-\rho^9)\big(lni^{SS}_{i,2007} - lni_{i,2007}\big) + transitory\_effects_{i,2007-2016}$$

Where $lni^{SS}_{i,t} = \frac{1}{\rho}(\vartheta z_{i,t} + \zeta_{i,1996-2000} + \zeta_{i,2001-2008} + \zeta_{i,2009-2016} + \psi_t)$ is the steady state value of the investment rate, while $transitory\_effects$ stand for the model residual and steady state movements between 2007 and 2016 that are not accounted for in the simplified decomposition (for details see Appendix 2).

Hence, the movements in investment rate are explained by changes in explanatory variables, time-varying fixed effects, time fixed effects, and the convergence and transitory effects components.

The contribution of the above factors to the post-crisis potential growth slowdown can be expressed as follows:

$$\theta_1(lni_{i,2007} - lni_{i,2016}) = \theta_1(1-\rho^9)\frac{1}{\rho}\big(\vartheta(z_{i,2007} - z_{i,2016}) + (\zeta_{i,2001-2008} - \zeta_{i,2009-2016}) + (\psi_{2007} - \psi_{2016})\big) + \theta_1(1-\rho^9)\big(lni^{SS}_{i,2007} - lni_{i,2007}\big) + \theta_1 transitory\_effects_{i,2007-2016}$$

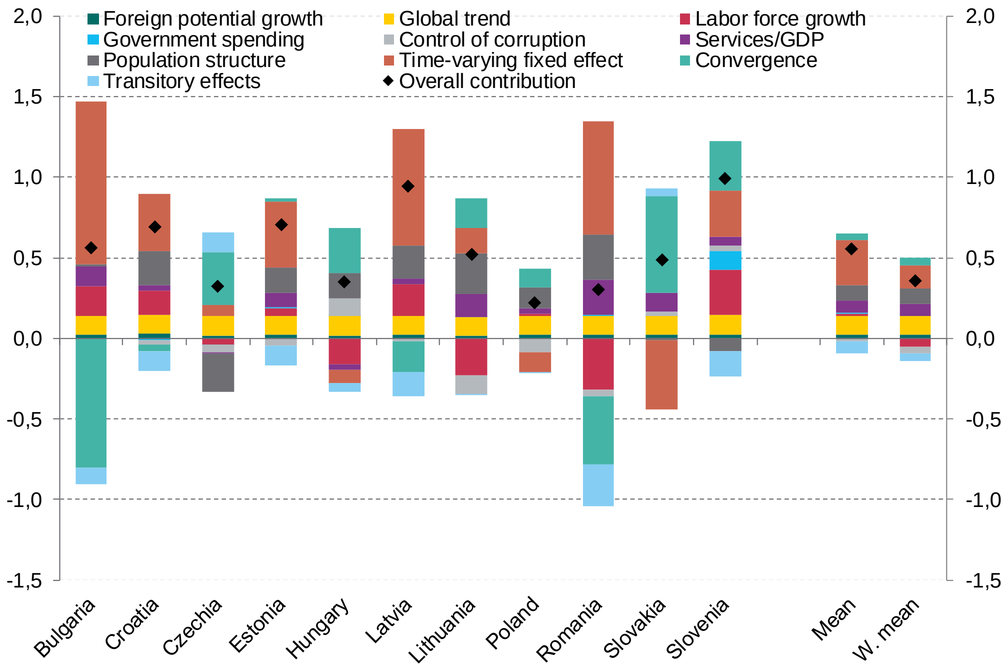
Where θ_1 is the parameter in front of the investment rate estimated in the baseline regression.

The results of the above decomposition are shown in Table 16 and Figure 9.

Foreign potential growth is insignificant in the regression and the point estimate is small, which is reflected in this variable's small contribution to potential growth slowdown. There is, however, a global downward trend in investment rates, probably reflecting phenomena such as falling relative price of capital or higher levels of economic uncertainty following the crisis – this factor contributes 0.12 pp to the potential growth slowdown and is responsible for over 20% of the overall decline in investment rates.

Among control variables, the increasing services to GDP ratio reduced potential growth by 0.07 pp on average, and as much as 0.22 pp in Romania. Population ageing is also confirmed as an important driver of falling investment rates, reducing potential growth by 0.1 pp on average and by 0.28 pp in Romania; there are countries, such as Czechia, where population age structure increased investment. The contributions of labor force growth to potential growth slowdown are sizeable for individual countries, ranging from 0.3 pp in Slovenia to -0.3pp in Romania, but the average contribution in all of CEE is close to zero. At the same time, government spending and corruption have little impact on potential growth slowdown in most of the countries.

Figure 9. Decomposition of investment rate's contribution to potential growth slowdown: 2016 vs 2007 (pp)



Weighted mean utilizes GDP PPP as weights.

The time-varying fixed effect has a large impact on the CEE potential growth slowdown, with contributions ranging from 1pp in Bulgaria to -0.4 pp in Slovenia and explaining 50% of the decline in investment rates on average. Thus, other factors not included in the model – either domestic or external – are the main source of the decline in investment rates[13].

The convergence component has sizeable contributions for some countries – 0.6 pp in Slovakia and -0.8 pp in Bulgaria – but on average explains only a small fraction of the decline in investment rates. Finally, transitory effects are relatively limited in most of the cases, supporting the proposed simplified decomposition as a good enough approximation of the "true" investment rate decomposition.

Summing up, external factors are not a major source of the decline in investment rates, being responsible for 25% of the fall. Factors that may be classified as domestic (labor force growth, government spending, corruption, population age structure, and services to GDP ratio) are only slightly more important as they are responsible for 31% of the decline in investment rates. The time-varying fixed effects are the major driver behind the fall in investment to GDP ratio, but it is not clear whether they reflect domestic factors, or external developments which affect each country in a different manner. Thus, they are classified in neither of the groups.

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[13] This result can partially stem from the sample end-point bias – 2016 was a trough in the EU funds absorption cycle, and this cyclical movement probably influenced the trend investment to GDP ratio due to HP filter's end-point bias.

Table 16. Decomposition of investment rate's contribution to potential growth slowdown: 2016 vs 2007 (pp)

	Foreign potential growth	Global trend	Labor force growth	Government spending	Control of corruption	Services/GDP	Population structure	Time-varying fixed effect	Convergence	Transitory effects	**Overall contribution**	External
Bulgaria	0.02	0.12	0.18	0.00	0.00	0.12	0.01	1.01	-0.80	-0.10	**0.56**	0.14
Croatia	0.03	0.12	0.15	-0.01	-0.02	0.03	0.21	0.35	-0.04	-0.12	**0.69**	0.15
Czechia	0.02	0.12	-0.04	0.00	-0.05	0.00	-0.24	0.07	0.32	0.12	**0.32**	0.14
Estonia	0.02	0.12	0.05	0.00	-0.04	0.09	0.16	0.40	0.03	-0.12	**0.70**	0.14
Hungary	0.02	0.12	-0.16	0.00	0.11	-0.03	0.16	-0.08	0.28	-0.06	**0.35**	0.14
Latvia	0.02	0.12	0.20	0.00	-0.02	0.04	0.20	0.72	-0.19	-0.15	**0.94**	0.14
Lithuania	0.01	0.12	-0.23	0.00	-0.12	0.14	0.25	0.15	0.19	-0.01	**0.52**	0.13
Poland	0.02	0.12	0.01	0.00	-0.09	0.04	0.13	-0.12	0.12	0.00	**0.22**	0.14
Romania	0.02	0.12	-0.32	0.00	-0.04	0.22	0.28	0.71	-0.42	-0.26	**0.30**	0.14
Slovakia	0.02	0.12	0.00	0.00	0.03	0.11	-0.01	-0.43	0.60	0.04	**0.48**	0.14
Slovenia	0.02	0.12	0.29	0.11	0.03	0.06	-0.08	0.28	0.31	-0.16	**0.99**	0.14
Mean	**0.02**	**0.12**	**0.01**	**0.01**	**-0.02**	**0.07**	**0.10**	**0.28**	**0.04**	**-0.07**	**0.56**	**0.14**
Weighted mean	**0.02**	**0.12**	**-0.05**	**0.00**	**-0.04**	**0.07**	**0.10**	**0.14**	**0.05**	**-0.05**	**0.36**	**0.14**
% of mean	**3.9**	**21.3**	**2.0**	**1.8**	**-3.5**	**13.4**	**17.6**	**50.3**	**6.5**	**-13.4**		**25.2**
% of weighted mean	**6.1**	**32.8**	**-14.5**	**0.7**	**-10.7**	**19.2**	**27.4**	**40.2**	**12.9**	**-14.1**		**38.9**

Weighted mean utilizes GDP PPP as weights

8.3 Recapitulation

So, has the post-crisis potential growth slowdown in CEE economies been caused to a larger extent by domestic or external factors? Let us classify the variables used in all the regressions as either reflecting external or domestic developments and connect the results of all 3 decompositions - from the main growth model, as well as the TFP and investment regressions – to provide the answer.

Global TFP and investment rate trends as well as foreign TFP and foreign potential growth are classified as external factors. Domestic factors include all variables related to population and labor force (labor force growth, human capital, population growth, labor force participation, population age structure, and population density), institutional variables (government effectiveness, government spending, and control of corruption) as well as variables describing the structure of the economy (labor reallocation away from agriculture and the services to GDP ratio)[14].

The exports to GDP ratio is not classified into any group. On the one hand, this variable clearly depends on domestic policies, institutional framework, trade regulations, as well as geographical factors such as territory size, proximity to foreign markets and natural resources. On the other hand, trade policy of CEE countries is largely decided on the European Union level; moreover, external demand and thus exports to GDP ratio depend on economic conditions abroad.

Convergence – both in terms of GDP per worker level and investment rate - is also left out as a separate driver of growth.

Finally, time-varying fixed effects in the investment equation and residuals in all equations are classified as unexplained factors.

The resulting decomposition of potential growth slowdown is shown in Table 17 and Figure 10.

On average, domestic factors account for 25% of the potential growth slowdown, contributing 0.4 pp. Contributions vary widely across countries, though. The sources of this variation lie in differing trends in labor force growth, labor reallocation away from agriculture and population ageing. Countries that experienced a large dip in the first two variables and fastest population ageing post a very high contribution of domestic factors to the growth slowdown (up to 1.7 pp in Latvia). On the other hand, in countries where labor force growth accelerated following the crisis, domestic factors increased potential growth by as much as 1 pp (Romania and Czechia).

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[14] Most of the variables classified as domestic are to some extent affected also by external factors. However, it seems reasonable to assume that the main source of fluctuations in these variables is of domestic nature.

Table 17. Decomposition of potential growth slowdown – domestic vs external factors: 2016 vs 2007 (pp)

	Convergence in GDP per worker	Convergence in investment rate	Domestic factors	External factors		Unexplained component	**Overall slowdown**
Variables:	-	-	Labor force growth, population growth, labor force participation, human capital, Government Effectiveness, labor reallocation, population density, government spending, corruption, population structure, services/GDP	Global TFP and investment rate trends, foreign TFP and potential growth	Exports/ GDP	Time-varying fixed effect for investment rate, residuals	-
Bulgaria	0.81	-1.64	0.94	0.66	-0.42	1.81	**2.16**
Croatia	0.24	-0.09	1.21	0.58	-0.24	0.46	**2.16**
Czechia	0.49	0.67	-0.92	0.13	-0.32	1.29	**1.33**
Estonia	0.53	0.05	1.10	0.75	-0.24	-0.67	**1.52**
Hungary	0.08	0.58	0.70	0.22	-0.23	-0.79	**0.56**
Latvia	0.77	-0.39	1.74	0.63	-0.42	-0.12	**2.20**
Lithuania	0.93	0.38	0.89	0.53	-0.44	-0.67	**1.62**
Poland	0.86	0.24	0.03	0.26	-0.38	0.01	**1.01**
Romania	1.02	-0.86	-0.99	0.45	-0.28	2.26	**1.60**
Slovakia	0.87	1.23	0.07	0.33	-0.29	-0.49	**1.73**
Slovenia	0.30	0.64	-0.38	0.49	-0.28	1.12	**1.88**
Mean	**0.63**	**0.07**	**0.40**	**0.46**	**-0.32**	**0.38**	**1.62**
Weighted mean	**0.72**	**0.09**	**-0.05**	**0.33**	**-0.33**	**0.55**	**1.32**
% of mean	**38.8**	**4.6**	**24.6**	**28.3**	**-19.9**	**23.6**	
% of weighted mean	**54.7**	**7.2**	**-3.9**	**25.2**	**-25.0**	**41.8**	

Weighted mean utilizes GDP PPP as weights

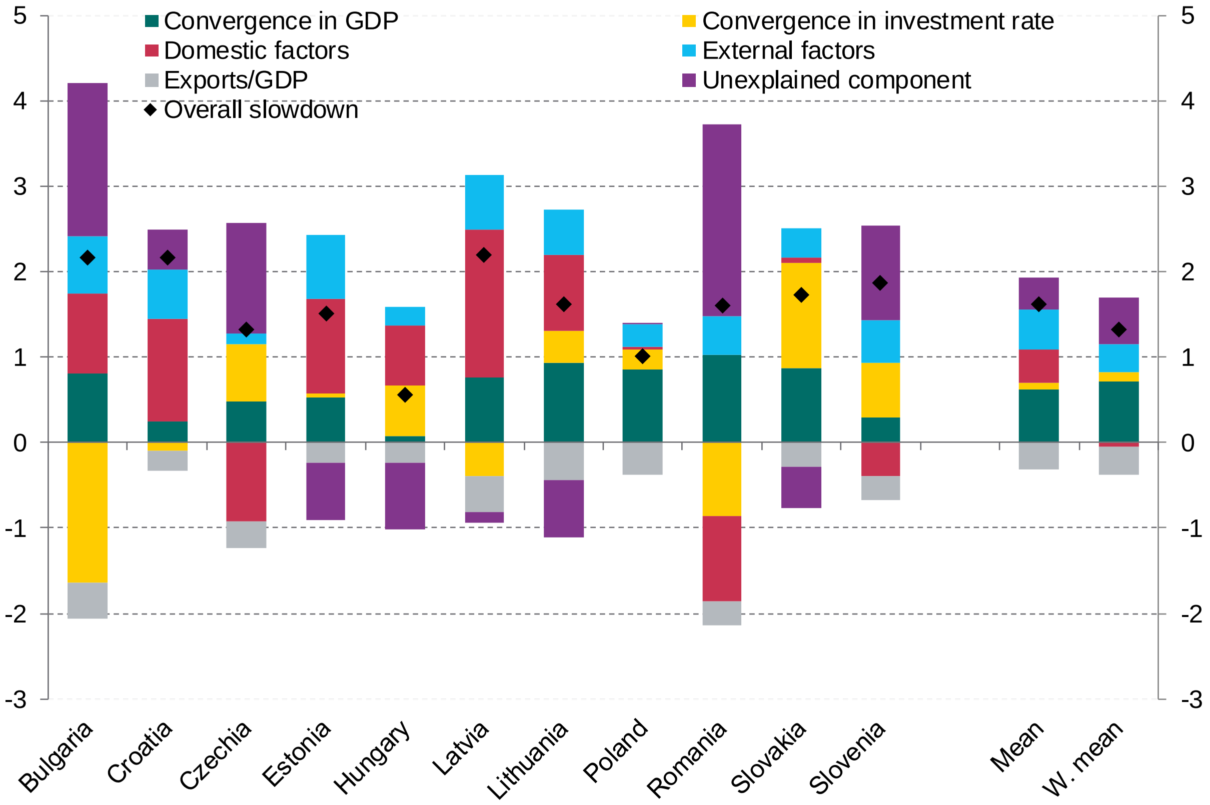
External factors are responsible for 28% to the decline in potential growth, contributing 0.46 pp. Understandably, the contributions differ less across countries, though they still range from 0.1 pp in Czechia to 0.7 pp in Bulgaria. The variation stems from the foreign TFP component, reflecting differences in the structure of trading partners and their developments in TFP.

Convergence in terms of GDP emerges as a major driver of potential growth slowdown, accounting for 39% or 0.63 pp of it on average. As mentioned earlier, contributions vary from 0.1 pp in Hungary to 1 pp in Romania. Convergence in terms of the investment rate has little impact on average, but the variation across countries is large, ranging from 1.2 pp in Slovakia to -1.6 pp in Bulgaria.

Exports to GDP ratio increased in all the countries, and thus it raised potential growth by 0.2-0.4 pp. Unexplained factors account for 24% of the slowdown, contributing 0.38 pp. Residuals in both the growth and TFP regressions are sizeable and vary significantly across countries, and so do the time-varying fixed effects from the investment regression.

All in all, convergence in terms of GDP per worker is the main source of the post-crisis potential growth slowdown in CEE, consistently subtracting from potential growth in all the countries. External factors also play a role and have a consistent effect across the countries. Domestic factors contribute significantly to the slowdown as well, though the variation across countries is large. Variation across countries is equally high for convergence in terms of investment rates. Finally, there remains a relatively large unexplained part of the slowdown.

Figure 10. Decomposition of potential growth slowdown – domestic vs external factors: 2016 vs 2007 (pp)



Weighted mean utilizes GDP PPP as weights.

9. Caveats and Conclusions

This paper shows that convergence has been responsible for about 40% of the potential growth slowdown in the CEE countries following the financial crisis. The other important drivers of the growth slowdown have been lower investment activity and lower TFP growth; thus, in this respect the paper confirms the results obtained by the growth accounting literature (Podpiera et al., 2017). Further analysis shows that the decline in investment rates can be attributed i.a. to common global trend, population ageing and increasing services to GDP ratio, while TFP is highly correlated with investment rates. Decomposing the sources of growth into domestic and external factors, it is found that each of them contributed about 25-30% to the potential growth slowdown.

Two comments should be made about the estimate of convergence's contribution to the potential growth slowdown. Firstly, since the fixed effects model is used, the coefficient on the lagged dependent variable is biased downwards, which biases the contribution of convergence upwards. If the actual speed of convergence is 2% - as stated by Barro and Sala-i-Martin (1992) – instead of 3.1%, the contribution of convergence to the slowdown should decline by about 1/3. On the other hand, part of convergence in the TFP level is probably captured by the counterintuitive decline in the time-varying cross-country fixed effect, which biases the role of convergence in explaining potential growth slowdown downwards. Moreover, the speed of convergence increases even further when additional variables (government effectiveness and exports to GDP ratio) are included in the regression.

My results have several other caveats. Firstly, the growth model is quite simplistic - despite the inclusion of time-varying cross-country fixed effects, it still does not control well for cross-country differences in TFP growth. Even in the augmented version, additional variables fail to decrease the role of time-varying cross-country fixed effects in explaining the potential growth slowdown, suggesting that their ability to explain developments in TFP is limited.

Moreover, the decomposition between domestic and external drivers of growth remains quite crude. The main model does not distinguish well between domestic and global components of TFP growth, while the TFP regression run to decompose changes in domestic TFP suffers from a small sample size. At the same time, the investment regression is built in quite an ad-hoc manner, and still finds that a large part of the decline in investment to GDP ratios is explained by time-varying fixed effects which have no clear economic interpretations.

It should be noted that the regression methods might not constitute the best approach to investigating the external environment's impact on potential growth. An interesting alternative is proposed by Hagemejer and Mućk (2019) who decompose GDP into domestically absorbed and exported components using a novel growth accounting approach. Their approach does not account for convergence, however.

Econometric methods used in this paper are also far from being perfect. In particular, I have failed to correct for the fixed effects bias on the lagged dependent variable. Moreover, despite attempts to use instrumental variables techniques, I have found explanatory variables to be exogenous. It remains unclear, however, whether this is indeed due to weak endogeneity of these variables or due to problems with weak instruments and imprecise estimates.

Going forward, it would be interesting to delve deeper into determinants of TFP and introduce more variables that robustly influence GDP directly into the model equation. The investment rate equation could also be improved to better distinguish between domestic and external factors of growth - the data could be corrected for declining relative price of capital, one could still look for better proxies of the external environment's influence on investment and better control variables. From econometric perspective, looking for better instruments for proximate causes of growth continues to be worthwhile.

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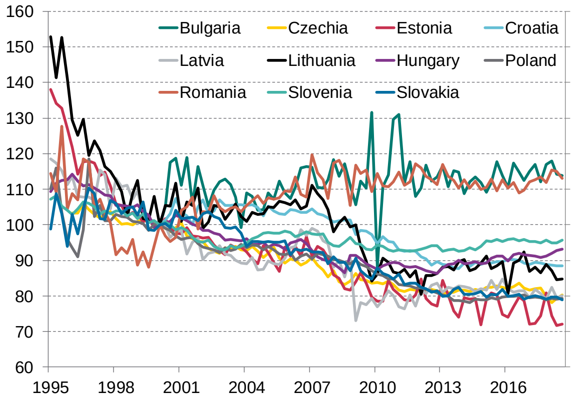
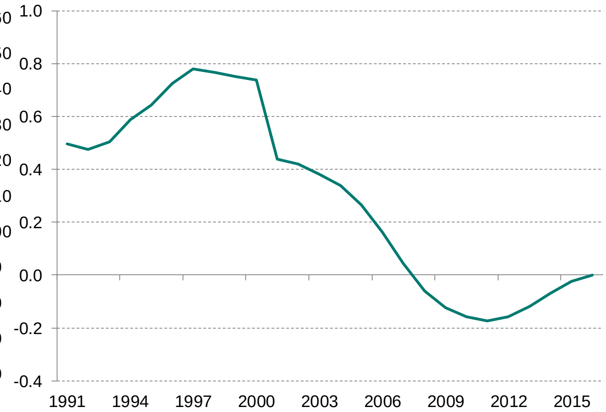
Appendix

Figure A.1 Price of capital goods relative to the price of consumption goods (index, 2000Q1 = 100)



Source: Own calculations based on Eurostat data.

Figure A.2 Global TFP growth – baseline specification (%)



The level of global TFP growth has no interpretation – only differences between given points in time should be analysed.

1. Derivation of the MRW Model

The human capital-augmented Solow model of Mankiw, Romer and Weil (1992) is comprised of the following equations:

$$Y_t = K_t^{\alpha} H_t^{\beta} (A_t L_t)^{1-\alpha-\beta}$$

$$A_t = A_0 e^{g^A t}$$

$$L_t = L_0 e^{nt}$$

$$\dot{k}_t = i y_t - (n + g^A + \delta) k_t$$

$$\dot{h}_t = i_h y_t - (n + g^A + \delta) h_t$$

$$y_t = k_t^{\alpha} h_t^{\beta}$$

Where Y_t is GDP, K_t – physical capital stock, H_t – human capital stock, A_t – TFP, L_t – labor force, $k_t = {}^{K_t}/_{A_t L_t}$, $h_t = {}^{H_t}/_{A_t L_t}$ and $y_t = {}^{Y_t}/_{A_t L_t}$ are model variables in per effective labor terms, i – investment in physical capital to GDP ratio; i_h - investment in human capital to GDP ratio, n – labor force growth; g^A – steady state TFP growth; δ – depreciation rate.

The steady state values of physical and human capital per effective labor can be obtained from their laws of motion:

$$k^{SS} = \left(\frac{i^{1-\beta} i_h^{\beta}}{n + g^A + \delta} \right)^{1/_{1-\alpha-\beta}}$$

$$h^{SS} = \left(\frac{i^{\alpha} i_h^{1-\alpha}}{n + g^A + \delta}\right)^{1/_{1-\alpha-\beta}}$$

Thus, the steady state value of GDP per effective labor is the following:

$$y^{SS} = i^{\alpha/_{1-\alpha-\beta}} i_h^{\beta/_{1-\alpha-\beta}} (n + g^A + \delta)^{-\alpha-\beta/_{1-\alpha-\beta}}$$

Which can be easily translated into steady state GDP per worker, specified in logarithms:

$$ln\left(\frac{Y}{L}\right)_t^{SS} = \frac{\alpha}{1-\alpha-\beta} ln\, i + \frac{\beta}{1-\alpha-\beta} ln i_h + \frac{\alpha+\beta}{1-\alpha-\beta} ln(n + g^A + \delta) + lnA_0 + g^A t$$

This model can already be estimated under the assumption that all economies are in their respective steady states. To account for convergence, we need the out- of-steady-state version of the model, however.

Approximating the growth rate of y around the steady state, one obtains the following expression:

$$\hat{y}_t \approx (\, n + g^A + \delta)(1 - \alpha - \beta)(lny^* - lny_t)$$

Where $(\, n + g^A + \delta)(1 - \alpha - \beta)$ is the speed of convergence, which I denote as λ.

Hence, one can write that output at time t is a combination of initial output and steady state output:

$$lny_t = e^{-\lambda t} lny_0 + (1 - e^{-\lambda t}) lny^*$$

Substituting with steady state determinants, one gets what follows:

$$lny_t = e^{-\lambda t} lny_0 + (1 - e^{-\lambda t}) \frac{\alpha}{1-\alpha-\beta} ln\, i + (1 - e^{-\lambda t}) \frac{\beta}{1-\alpha-\beta} ln i_h + (1 - e^{-\lambda t}) \frac{\alpha+\beta}{1-\alpha-\beta} ln(n + g^A + \delta)$$

And in terms of per capita output:

$$ln\left(\frac{Y}{L}\right)_t = e^{-\lambda t} ln\left(\frac{Y}{L}\right)_0 + (1 - e^{-\lambda t}) \frac{\alpha}{1-\alpha-\beta} ln\, i + (1 - e^{-\lambda t}) \frac{\beta}{1-\alpha-\beta} ln i_h + (1 - e^{-\lambda t}) \frac{\alpha+\beta}{1-\alpha-\beta} ln(n + g^A + \delta) + (1 - e^{-\lambda t}) lnA_0 + g^A t$$

2. Derivation of the Investment Decomposition

The decomposition of the post-crisis fall in the investment rate is more complicated than in the case of the TFP regression. Due to the presence of its 1st lag in the regression, investment rate is persistent and depends on its past levels. Note that the converging process like this can be expressed in the following way:

$$lni_{i,t} \approx lni_{i,t-1} + \frac{(1-\rho)}{\rho}\left(lni_{i,t}^{SS} - lni_{i,t}\right) + \varepsilon_{i,t}$$

$$\frac{1}{\rho} lni_{i,t} \approx lni_{i,t-1} + \frac{(1-\rho)}{\rho} lni_{i,t}^{SS} + \varepsilon_{i,t}$$

$$lni_{i,t} \approx \rho lni_{i,t-1} + (1-\rho) lni_{i,t}^{SS} + \rho\varepsilon_{i,t}$$

Where the steady state value is $lni_{i,t}^{SS} = \frac{1}{\rho}(\vartheta z_{i,t} + \zeta_{i,1996-2000} + \zeta_{i,2001-2008} + \zeta_{i,2009-2016} + \psi_t)$. Substituting recursively up to the initial period in the sample (1996), the investment rate in 2016 might be expressed in the following way:

$$lni_{i,2016} \approx \rho^{20} lni_{i,1996} + (1-\rho)\sum_{j=0}^{19} \rho^j lni_{i,2016-j}^{SS} + \sum_{j=0}^{19} \rho^{j+1}\, \varepsilon_{i,2016-j}$$

Given the convergence speed of $(1-\rho)$ = 4.3%, the investment rate in 2016 is in over 40% explained by the investment rate in 1996. It also depends on the whole path of steady state investment rates over the course of 20 years, which makes interpretation of the results more difficult. Explaining the post-crisis fall in the investment rate by subtracting this from the expression for the investment rate in 2007 does not help matters:

$$\begin{aligned} &lni_{i,2007} - lni_{i,2016} \\ &\qquad \approx (\rho^{11} - \rho^{20}) lni_{i,1996} + (1-\rho)\sum_{k=0}^{10} \rho^k lni_{i,2007-k}^{SS} - (1-\rho)\sum_{j=0}^{19} \rho^j lni_{i,2016-j}^{SS} \\ &\qquad + \sum_{k=0}^{10} \rho^{k+1}\, \varepsilon_{i,2007-k} - \sum_{j=0}^{19} \rho^{j+1}\, \varepsilon_{i,2016-j} \end{aligned}$$

Still, the decline in investment rate depends on the initial rate and the steady state path over the full course of 20 years.

Due to the difficulty in interpreting such an expression, I propose a simplified decomposition. Let us assume that the steady state jumped in 2008 and remained at the same level until 2016. Let us also forget about the stochastic error term for a moment. Under these assumptions, using 2007 as a base year, investment rate in 2016 is simply:

$$\begin{aligned} lni_{i,2016} &= lni_{i,2007} + (1-\rho)\sum_{j=0}^{8} \rho^j \left(lni_{i,2016}^{SS} - lni_{i,2007}\right) \\ &= lni_{i,2007} + (1-\rho^9)\left(lni_{i,2016}^{SS} - lni_{i,2007}\right) \end{aligned}$$

We can divide $lni_{i,2016}^{SS} - lni_{i,2007}$ into 2 parts - the steady state movement between 2016 and 2007 and the deviation from the steady state in 2007:

$$lni_{i,2016}^{SS} - lni_{i,2007} = \left(lni_{i,2016}^{SS} - lni_{i,2007}^{SS}\right) + \left(lni_{i,2007}^{SS} - lni_{i,2007}\right)$$

The change in investment rate between 2016 and 2007 thus becomes a sum of steady state movement component and the convergence component:

$$lni_{i,2016} - lni_{i,2007} = (1-\rho^9)\left(lni_{i,2016}^{SS} - lni_{i,2007}^{SS}\right) + (1-\rho^9)\left(lni_{i,2007}^{SS} - lni_{i,2007}\right)$$

In reality, the steady state moves every year – depending on the path and average value of the steady state between 2007 and 2016, investment rate will end up higher or lower than predicted by the above expression. Moreover, there is a part of the movement in the investment rate unexplained by the model – the model residual, which will also affect the path and the final value of the investment rate. These components are grouped together and referred to as "transitory effects":

$$\begin{aligned} lni_{i,2016} - lni_{i,2007} &= (1-\rho^9)\left(lni_{i,2016}^{SS} - lni_{i,2007}^{SS}\right) + (1-\rho^9)\left(lni_{i,2007}^{SS} - lni_{i,2007}\right) \\ &+ transitory\_effects_{i,2007-2016} \end{aligned}$$

Finally, recall that the difference in steady state values between 2007 and 2016 can be denoted as follows:

$$lni_{i,2007}^{SS} - lni_{i,2016}^{SS} = \frac{1}{\rho}\left(\vartheta(z_{i,2007} - z_{i,2016}) + \zeta_{i,2001-2008} - \zeta_{i,2009-2016} + \psi_{2007} - \psi_{2016}\right)$$

Thus, the full decomposition of the post-crisis decline in the investment rate is described by the following expression:

$$\begin{aligned} lni_{i,2007} - lni_{i,2016} &= (1-\rho^9)\frac{1}{\rho}\left(\vartheta(z_{i,2007} - z_{i,2016}) + (\zeta_{i,2001-2008} - \zeta_{i,2009-2016}) + (\psi_{2007} \right. \\ &\left. - \psi_{2016})\right) + (1-\rho^9)\left(lni_{i,2007}^{SS} - lni_{i,2007}\right) + transitory\_effects_{i,2007-2016} \end{aligned}$$

The movements in investment rate are explained by changes in explanatory variables, time-varying fixed effects, time fixed effects, and the convergence and transitory effects components.