Istvan Konya

Convergence and Distortions: the Czech Republic, Hungary and Poland between 1996-2009

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(Felzárkózás és torzítások: Csehország, Magyarország, és Lengyelország 1996-2009)

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Contents

Abstract

The paper interprets the growth and convergence experience of three Central-Eastern European economies (the Czech Republic, Hungary, and Poland) through the lens of the stochastic neoclassical growth model. It adapts the methodology of Business Cycle Accounting (Chari, Kehoe and McGrattan 2007) to economies on a transition path. The paper uses the method to uncover distortions (”wedges”) on the labor and capital markets, and then presents various comparisons and counterfactuals based on them. Results show that (i) capital and labor market distortions vary across the three economies, but they are well within the range of advanced economies; (ii) the Polish and Hungarian labor wedges are high, and the Czech labor wedge increases; (iii) the evolution of Hungarian wedges followed a different path than the evolution of Polish and Czech wedges, and (iv) realistic reductions in the capital and labor wedges would lead to significant output gains for Hungary and Poland.

JEL: E13, O11, O47.
Keywords: convergence, distortions, Central-Eastern Europe, business cycle accounting.

Összefoglalás

A tanulmány három közép-európai ország (Csehország, Magyarország és Lengyelország) növekedési és felzárkózási tapasztalatait vizsgálja a neoklasszikus növekedési modell szemszögéből. A módszertan a Chari, Kehoe és McGrattan (2007) által bevezetett gazdaságiciklus-számbevételi eljárás adaptálása növekvő/felzárkózó gazdaságokra. A tanulmány e módszer segítségével azonosítja a munka- és tőkepiaci torzításokot (”ékeket”), majd ezeken alapuló összehasonlító és tényellenes számításokat végez. A főbb eredmények azt mutatják, hogy (i) a tőke- és munkapiaci torzítások különböztek a három országban, de nem térnek el jelentősen a fejlett országokban megfigyelt értékektől, (ii) a lengyel és magyar munkapiaci ékek végig magasak voltak, a cseh pedig növekvő tendenciát mutatott, (iii) a magyarországi ékek eltérő folyamatot követtek, mint a cseh és lengyel ékek, és (iv) a munka és tőkepiaci ékek mérsékelt csökkenése is jelentős kibocsátás növekedéshez vezetne Magyarországon és Lengyelországban.

1 Introduction

Convergence of Central-Eastern Europe (CEE) between 1995-2010 towards Western European GDP levels confirms well to the predictions of neoclassical theory. The economies of the region started with lower capital stocks and productivity, but by 1995 they arguably had institutions similar to their "old"' EU counterparts. Under these circumstances, higher investment rates and faster TFP growth is expected to lead to a narrowing of the GDP lag. Looking at the actual growth experience of the three largest CEE economies - the Czech Republic, Hungary and Poland - shows that convergence did indeed happen. An important question is, however, the extent to which this convergence is higher or lower than we could have expected given the initial conditions in 1995. The main goal of this paper is to evaluate the three CEE economies between 1995-2010 relative to the theoretical benchmark provided by the neoclassical growth model.

The methodology is based on the Business Cycle Accounting (BCA) approach developed by Chari, Kehoe and McGrattan (2007) (CKM). I compare the observed time series of investment, hours, and output to the predictions of the calibrated neoclassical growth model, given initial conditions in 1995. I interpret the difference between data and prediction as distortions, or "wedges"' in the first-order conditions of the model. The wedges are essentially residuals that can be related to the general efficiency of production, and the labor and capital markets. Uncovering these sheds light on the relative size of distortions across the three countries, and also relative to a benchmark, efficient outcome.

A practical difficulty with the application of the BCA methodology is that CEE time series are short and possibly subject to large shocks and structural changes coming from internal (policy) and external sources. Also, since I am interested in the convergence paths, I aim to uncover the levels - and not only the business cycle properties - of the wedges, as opposed to CKM. Therefore I use an empirical strategy that avoids taking a stance on the underlying unobserved stochastic processes driving the wedges, and measure them as directly from the data as possible. In particular, I do not assume - as CKM does - that the wedges follow a VAR process, since I am able to calculate them directly from single equations and without solving explicitly for the policy functions of the reference model.

In order to achieve this, I use auxiliary data to measure expectations in the consumption/investment and borrowing/lending Euler equations. I assume that public forecasts provide a good proxy for these expectations. In particular, I use yearly forecasts prepared by the OECD to capture expected consumption, output and consumer prices. This way I am able to compute the wedges (and the capital wedge in particular) from single equations, and without fully solving the underlying stochastic model.

Given the computed labor and investment wedges, I turn to their interpretation. I show that compared to the same wedges computed for three Western European economies (France, Germany and the UK) and the US, the CEE countries have similar or lower capital wedges, and similar labor wedges. Heterogeneity within the four advanced economies is just as large as within the CEE group. It is interesting to see, however, that Hungary and Poland are the only two countries with high capital *and* labor wedges.

To further understand the role of the wedges in regional differences, I present various simulations with the underlying model. I look at predictions for the CEE economies in the period 2010-2060 in a deterministic framework, with one or more wedges taking on different values than the sample period suggest. First, I allow the Hungarian and Polish capital wedges to approach the lower Czech capital wedge over time. Second, I also allow the labor wedge for these two countries to converge towards the Czech value. Finally, I replace the efficiency wedge processes for Hungary and the Czech Republic with the Polish efficiency wedge process. This way I gradually replace the capital, labor and efficiency wedges with their lowest regional counterparts, and explore the predicted convergence paths for the CEE economies. The exercise reveals that there is significant scope for speeding up convergence relative to the advanced OECD economies for all three countries.

The structure of the paper is as follows. Section 2 presents stylized facts for the CEE countries between 1995-2010, then describes the literature relevant for the exercise. Section 3 details the methodology used to identify the wedges, with particular attention to the measurement of the capital wedge that is a novel contribution of the paper. Section 4 contains the empirical implementation, together with a description of the data sources. Section 5 puts the measured wedges into the context of cross country comparison and counterfactuals. Finally, Section 6 concludes.

2 Context

2.1 GROWTH IN THE CEE REGION

Figure 1 presents yearly time series indicators in the period 1996-2009 for the Czech Republic, Hungary and Poland.[1] The first panel shows that per capita output grew in each country, and the Czech Republic largely maintained its lead over the whole period. Hungary was catching up fast in the first half of the sample, while in the 2000s Poland and the Czech Republic managed faster growth. By the end of the period, due to its exceptional behavior during the world crisis of 2008-2009, Poland caught up with Hungary.

Investment was relatively high and stable in the Czech Republic. In Hungary investment grew fast until 2000, then it leveled off and finally declined. In Poland, investment fluctuated significantly, and declined in the early 2000s. Overall, the level of investment was highest in the Czech Republic, despite the fact that it was the richest economy of the three throughout the sample period. Consumption growth was stable and very similar between Poland and the Czech Republic. In Hungary, however, a large consumption boom occurred between 2000-2005, which later turned into a bust.

Per capita hours are again highest in the Czech Republic, followed by Hungary and Poland. The differences are large: Polish and Hungarian hours lag their Czech counterpart by around 40%. The difference comes mainly from the fact that the Czech employment rate is significantly higher than the Hungarian or Polish levels. Hours, on the other hand, are mostly comparable across the three economies, except for the beginning of the period when Czech hours were higher.

Overall, the figures suggest that there are significant distortions (”wedges”') in the labor and capital markets at least in Hungary and Poland. My goal in this paper is to uncover the quantitative significance of these unobserved determinants of the growth experiences of the three CEE countries.

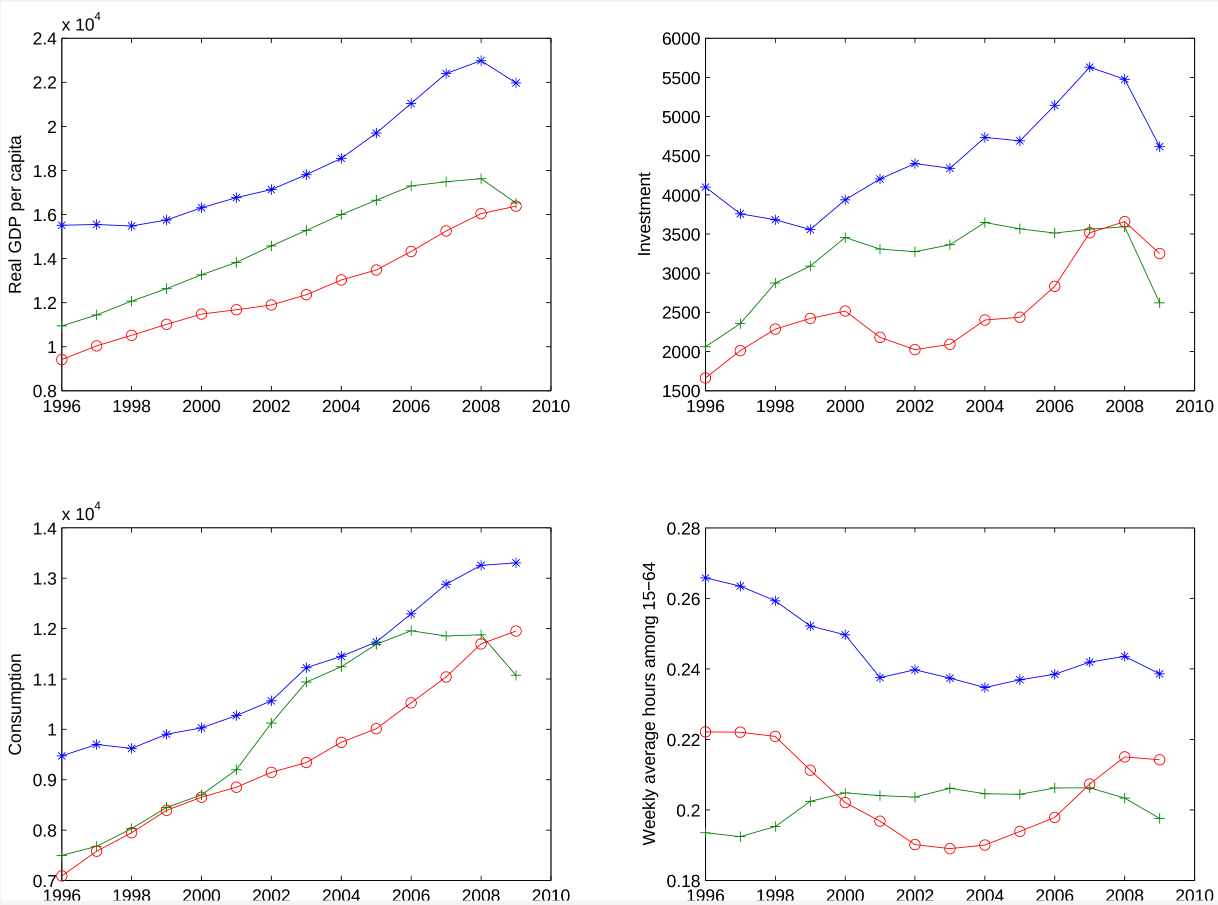
2.2 RELATED LITERATURE

I adopt the methodology of business cycle accounting developed by CKM to the transition economies of the CEE region. My contributions - apart from the different country sample - are (i) the computation of the capital wedge, and (ii) the uncovering of the wedge levels, and not just their business cycle properties. Several other recent articles used BCA. Otsu (2010) provides a small open economy extension, analyzing the Asian crisis of 1997. Cavalcanti (2007) looks at the Portuguese economy, while Kersting (2008) studies Britain in the early 1980s. Relative to Otsu (2010) and Cavalcanti (2007), my approach does not require the full solution of the model, and hence I do not have to make strict assumptions on the stochastic properties of the unobserved wedges.

Another method to find the investment wedge without fully solving the model is used by Kobayashi and Inaba (2006). They assume, however, that agents face a deterministic, perfect foresight environment. This assumption is unlikely to be satisfied in a fast-changing environment such as the CEE region. Therefore, in this paper, I use a stochastic approach, but use auxiliary data that allow the easy computation of the capital wedge. Jones and Sahu (2009) explicitly take into account the changing nature of the Indian economy, and the possible time variation in certain parameters. They also, however, assume perfect foresight.

[1] GDP, consumption and investment data comes from the Penn World Table 7.0, while employment and hours come from the OECD. Data sources are described in more detail in the Appendix.

Figure 1
The CEE region: Czech Republic (*), Hungary (+), Poland (o)



Business cycle accounting, while primarily an empirical exercise, is not free of modeling assumptions. Baurle and Burren (2011) studies whether CKM's assumption, that the unobserved wedge processes are well described by VAR specification, are consistent with rational expectations implied by the underlying model. They find that the VAR assumption is quite restrictive, but can be significantly relaxed if the VAR includes endogenous state variables.

In a recent paper, Curdia and Reis (2010) extend the estimation of DSGE models to correlated shocks. While CKM use a maximum likelihood methodology to estimate the wedges, Curdia and Reis (2010) - in a more detailed DSGE framework - recommend Bayesian inference. This approach could fruitfully combine the advantages of BCA and DSGE techniques.

Christiano and Davis (2006) provide a serious criticism of the BCA approach. The main thrust of their critique is not against the methodology per se, but rather CKM's interpretation of their results. In particular, CKM conclude that the intertemporal wedge did not play an important role in the US experience either under the Great Depression or in the 1982 recession. They reach this conclusion by leaving only one of the estimated wedges in the model simulation, and compare the results of the simulations with the actual data. Christiano and Davis (2006) draw attention to two problems with this procedure. First, the particular way of calculating the intertemporal wedge has a strong impact on the simulated time series. Second, the fact that the wedges are correlated makes the partial impact of an individual distortion hard to identify. Christiano and Davis (2006) thus argue that the conclusions drawn by CKM are not robust.

Based on the criticism of Christiano and Davis (2006) I use BCA first and foremost as a tool to analyze and describe the data. My empirical approach allows me to compute the wedges directly, making the calculation less sensitive to modeling uncertainty. More precisely, the wedges are not sensitive to assumptions regarding the unobserved stochastic processes. The calculation still relies on the functional forms and calibration, but these can be chosen transparently and subjected more easily to robustness checks. While my results are suggestive, the interpretation - and especially the policy conclusions - should be based on structural models that incorporate the stylized facts uncovered here.

To the best of my knowledge the BCA methodology has not been employed in the CEE region yet. Bah and Brada (2009) compute the efficiency wedge (TFP) on the sectoral level, while Burda and Severgnini (2009) draw attention to the problems of TFP measurement in transition economies. They emphasize the problems of estimating the capital stock, and suggest an alternative way of measuring TFP. Since I have a fairly long investment time series, my capital stock estimates should be less problematic. Therefore, the Solow-residuals based on these capital stock measures should also be reasonably reliable. Also, the two alternative measures of Burda and Severgnini (2009) lead to quite different results, so it is not obvious which one should be used instead of the Solow residual.

3 Theoretical Framework

The empirical analysis is based on the one-sector, neoclassical stochastic growth model. The main ingredients are exogenous productivity growth, capital accumulation, and endogenous labor supply. I assume an open economy for accounting purposes, but I treat net exports as exogenous and part of an overall GDP wedge (which also includes government consumption). The main reason for this modeling choice is that endogenizing the current account raises several methodological problems. Given the modeling uncertainty surrounding the current account, I opt for the simpler quasi-closed approach.

3.1 THE BASIC GROWTH MODEL

3.1.1 Households

The representative household draws income from supplying labor, renting capital to firms and earning (paying) interest on deposits (debt). It allocates this income towards consumption, and physical and financial investment. The household's optimization problem is given by

$$\max \mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t N_t \left(\log \frac{C_t}{N_t} + \chi \frac{h_t^{1+\eta}}{1+\eta} \right)$$

$$\begin{aligned} \text{s.t.} \quad C_t + I_t + \left(1+\tau_t^k\right) K_{t+1} + \frac{B_{t+1}}{\left(1+\tau_t^b\right) P_t R_t} &= \left(1-\tau_t^h\right) w_t N_t h_t + \left(1-\delta+r_t^k\right) K_t + \frac{B_t}{P_t} + T_t \\ I_t &= K_{t+1} - (1-\delta) K_t \end{aligned}$$

where N_t is the size of population (the representative household), C_t/N_t is per capita consumption, h_t is the supply of labor hours per person, and K_t is the capital stock. The household can borrow and lend at the gross nominal interest rate R_t, where B_{t+1} indicates bonds carried into period $t+1$ and P_t is the price level. The gross growth rate of population is assumed to be exogenous and constant, $n = N_t/N_{t-1}$. I assume the government finances its expenditures G_t with a lump-sum tax T_t.

Similarly to CKM, I incorporate wedges as equivalent taxes: τ^h is the *labor wedge*, τ^k is the *capital wedge*, and τ^b is the *borrowing wedge*. These wedges distort the labor-leisure choice, the capital investment condition, and the borrowing and lending choice, respectively:

$$\begin{aligned} \chi h_t^{\eta} C_t &= \left(1-\tau_t^h\right) w_t N_t \\ \frac{\left(1+\tau_t^k\right) N_t}{C_t} &= \beta \mathbb{E}_t \left(r_{t+1}^k + 1 - \delta\right) \frac{N_{t+1}}{C_{t+1}} \\ \frac{N_t}{P_t C_t} &= \left(1+\tau_t^b\right) \beta R_t \mathbb{E}_t \frac{N_{t+1}}{P_{t+1} C_{t+1}}. \end{aligned}$$

The first equation is the intratemporal conditions describing labor supply, the second is the intertemporal condition of capital investment, and the third is the intertemporal condition of borrowing and lending.

3.1.2 Firms

The representative firm rents labor and effective capital from competitive factor markets and produces a homogeneous good used both for consumption and investment. Technology is Cobb-Douglas:

$$Y_t = A_t K_t^{\alpha} \left(X_t N_t h_t\right)^{1-\alpha},$$

where A_t is an *efficiency wedge*, X_t is a deterministic labor-augmenting productivity process. I assume that X_t grows at a constant rate:

$$X_t = X_0 \gamma^t.$$

Firms are perfectly competitive on both the goods and factor markets. The first-order conditions of firms are given by the usual equality between factor prices and marginal products:

$$w_t = (1-\alpha) A_t X_t^{1-\alpha} \left(\frac{K_t}{N_t h_t} \right)^{\alpha}$$
$$r_t^k = \alpha A_t X_t^{1-\alpha} \left(\frac{K_t}{N_t h_t} \right)^{\alpha}.$$

3.1.3 Equilibrium conditions

Solving the model first involves the introduction of new variables: $c_t = C_t/(X_t N_t)$, $y_t = Y_t/(X_t N_t)$, $k_t = K_t/(X_t N_t)$, $i_t = I_t/(X_t N_t)$. The first-order conditions of households and firms, and the equilibrium conditions of good and factor markets can be collected as follows:

$$\begin{aligned}
y_t &= A_t k_t^{\alpha} h_t^{1-\alpha} && (1)\\
n\gamma k_{t+1} &= (1-\delta) k_t + i_t && (2)\\
\chi h_t^{1+\eta} &= \left(1-\tau_t^h\right) \frac{1-\alpha}{c_t/y_t} && (3)\\
1+\tau_t^k &= \frac{\beta}{\gamma} \mathbb{E}_t \left(1 - \delta + \frac{\alpha y_{t+1}}{k_{t+1}} \right) \frac{c_t}{c_{t+1}} && (4)\\
1 &= \frac{\beta}{\gamma} \left(1+\tau_t^b\right) R_t \mathbb{E}_t \frac{c_t}{c_{t+1}} \frac{P_t}{P_{t+1}} && (5)\\
y_t &= c_t + i_t + g_t. && (6)
\end{aligned}$$

The variable $g_t \equiv (G_t + \Xi_t)/(X_t N_t)$ is the sum of government consumption and net exports Ξ_t, and is interpreted as the exogenous *GDP wedge*. The main role of g_t is to create a correspondence of the GDP identity between model and data.

Let us rewrite the equilibrium conditions to express some of the wedges in terms of observables. The efficiency, labor and GDP wedge definitions are as follows:

$$\begin{aligned}
A_t &= \frac{y_t}{k_t^{\alpha} h_t^{1-\alpha}} && (7)\\
\frac{1}{1-\tau_t^h} &= \frac{1-\alpha}{\chi h_t^{1+\eta} c_t/y_t} && (8)\\
g_t &= y_t - c_t - i_t. && (9)
\end{aligned}$$

The two intertemporal wedges cannot be solved so simply; I will return to this issue later on.

It is important to emphasize that the wedges are not necessarily the results of market imperfections. The efficiency wedge A_t contains stochastic productivity shocks, and -as we will see - transitory productivity growth stemming from convergence. A_t also reflects changes in the profitability of firms with market power. The latter are absent from the benchmark model economy, but not necessarily in the data. Fluctuations in the capacity utilization of capital are also picked up by the efficiency wedge.

Similarly, the labor wedge can contain distortions and exogenous shocks. Fluctuations in the disutility of work, in addition to taxes levied on labor income both appear in the labor wedge. When labor supply shifts due to demographic or other reasons, the labor wedge changes as well.

3.2 THE INTERTEMPORAL WEDGES

The efficiency, labor and GDP wedges can easily be computed from equations (7), (8) and (6). All three equations are static, and - after calibrating the parameters - contain only observed variables. I will describe the details of this procedurein the next section.

The computation of the intertemporal wedges is more complicated, since eq. (4) and eq. (5) are forward-looking. Expectations, however, depend on the exogenous shocks and processes that ultimately determine the endogenous variables. The wedges are unknown functions of these unobserved stochastic processes. To compute the capital wedge, CKM assumes that (i) there is a one-to-one correspondence between the underlying shocks and the four wedges, and (ii) the wedges themselves follow a first-order vector-autoregressive (VAR) process. With this strong assumption on the stochastic properties of the wedges, standard tools can be used to solve the model. CKM use US data to estimate the VAR parameters, with a full information maximum likelihood method.[2]

The usage of the CKM method is likely to be problematic in the CEE region. The short time series makes maximum likelihood unreliable and potentially impossible to use. Moreover, in transition economies structural breaks are likely, coming both from large changes in these economies, and also from large changes in the regulatory environment and government policy. Partly for this reason, my goal is to measure not only the business cycle properties of the wedges, but also their absolute levels. This further complicates the *ex-ante* choice of exogenous processes consistent with model and data.

For these reasons I use a different empirical method than CKM. Although the expectations in the intertemporal conditions are not directly observable, I assume that public forecasts are a good proxy for them. There are various such forecasts for the CEE countries. For international comparability within the region and also with advanced economies, and for the length of the available time series, I use yearly forecasts from the OECD Economic Outlook between 1996-2009. The Appendix provides further details.

From (4) and (5) it is easy to see that the borrowing wedge in itself does not influence the determination of GDP, consumption, investment and employment. The reason is that the capital wedge already incorporates all distortions, including the borrowing wedge, that influence the capital investment decision of households.

Nevertheless we can decompose the capital wedge using the borrowing wedge to gain further insight into the determinants of the intertemporal decisions. To do this, I employ a log-linear approximation of the intertemporal equations[3]:

$$\tau_t^k = \log\left(\frac{\beta}{\gamma}\right) + \mathbb{E}_t \log\left(1-\delta+\frac{\alpha y_{t+1}}{k_{t+1}}\right) + \mathbb{E}_t\left(\log\frac{c_t}{c_{t+1}}\right) \tag{10}$$

$$0 = \log\left(\frac{\beta}{\gamma}\right) + \tau_t^b + \mathbb{E}_t\left(\log\frac{c_t}{c_{t+1}}\right) + \mathbb{E}_t\rho_{t+1}, \tag{11}$$

where $\rho_{t+1} \equiv R_t/\pi_{t+1}$ is the ex-post real interest rate, and π_t is inflation.

When we combine (10) and (11), expected consumption growth drops out, and we get the following condition:

$$\tau_t^k + \tau_t^b = \mathbb{E}_t \log\left(1-\delta+\frac{\alpha y_{t+1}}{k_{t+1}}\right) - \mathbb{E}_t\rho_{t+1}. \tag{12}$$

Let us define $\tau_t^i = \tau_t^b + \tau_t^k$ as the *investment wedge*.

The capital wedge can be thought of as the combination of the investment and borrowing wedges. The investment wedge measures the discrepancy between the arbitrage conditions of capital investment and the riskless bond, while the borrowing wedge is the error in the arbitrage equation between consumption and borrowing/lending. This way we can identify whether inefficiencies on the capital market originate from consumption or investment lending. When presenting the empirical findings I thus show this decomposition as well.

[2] CKM do not consider a borrowing wedge. This amounts to the assumption that the borrowing wedge is the function of the same underlying shocks as the other wedges, i.e. it is spanned by them.

[3] Since the wedges are likely to be close to zero, I utilize the approximation $x \cong \log(1+x)$, where $x = \tau^k, \tau^b$.

4 Empirical Implementation

This section describes the practical implementation of the method described above, and presents the results of the empirical exercise. I start by describing the data, then turn to the calculation of the individual wedges, including empirical problems and their treatment.

4.1 DATA

Data comes from the Penn World Table 7.0 (PWT), from the OECD statistical library[4], and from the Eurostat[5]. The PWT contains constant price GDP per capita measured in international dollars (purchasing power parity), consumption and investment shares, and total population. The advantage of using variables measured in international prices is that (i) we can directly compare them across countries, and (ii) we control for the differences in relative prices. Nevertheless, problems using PWT data are well documented, see for example Deaton and Heston (2010). Since countries in my sample are all upper middle income and advanced OECD economies, and most of them are in Europe, data problems are likely to be less of an issue than for more general PWT comparisons.

Employment data comes from the OECD. Since the model works with labor hours, I compute the same measure from the data. I take the employment rate in the 15-64 age category, multiple it by average weekly hours, then divide by the weekly time endowment (assumed to be $7 \cdot 16$). The resulting value falls from 0 and 1.

Yearly average nominal interest rate is from the Eurostat, and it corresponds to the annualized value of the three month money market rate. Expected inflation, GDP and consumption are from the December issues of the OECD Economic Outlook. I use one year ahead forecasts, so for example $\mathbb{E}_{2000}Y_{2001}$ is the December 2000 issue forecast for the year 2001.

Although the OECD also prepares a forecast in June, I use the December projections for two reasons. First, in December data for the preceding year is nowcasted with a higher precision, which is closer to the informational assumptions of the model. Second, the first issue that contained detailed data for the CEE region is from December 1996. Using the December forecasts thus enables me to start my sample in 1996.

4.2 CALIBRATION

Most of the model parameters are easy to calibrate. I set the discount factor to $\beta = 0.96$, which yield a steady state annual interest rate of 4%. The growth rate of populations n is given by an exponential trend fitted on the population time series.

The share of capital is set at $\alpha = 0.33$, which contains the division of mixed income between capital and labor income (Gollin 2002). This value is assumed to be common across countries, following Caselli (2005). The depreciation rate is set to $\delta = 0.06$, which is consistent with values in other papers (Caselli 2005).

The inverse of the Frisch elasticity of labor supply is set to $\eta = 2$. This parameter is difficult to calibrate, and micro and macro estimates differ widely. I use a value that is consistent with macro literature, but which is not too high. Luckily this parameter only influences the labor wedge, and even there the main conclusions are unaffected by the precise value

[4] stats.oecd.org

[5] http://epp.eurostat.ec.europa.eu/portal/page/portal/eurostat/home/

chosen. The other labor market parameter, χ, can be computed from the steady state as

$$\chi = \frac{1-\alpha}{\bar{h}^{1+\eta}\bar{C}/\bar{Y}}.$$

Long-run labor supply is chosen to correspond to the US value.[6] More precisely, I set the employment rate, average hours, and the consumption share to their sample average for the United States. This yields $\bar{h} = 0.2575$ and $\chi = 52$.

To calibrate the long-run productivity growth parameter γ, I assume that it is common for all countries, and I take its value from CKM, $\gamma = 1.016$. Since this is the growth factor of labor augmenting productivity, the corresponding TFP growth rate is 1%. Note that productivity growth over and above the common trend is captured by the efficiency wedge.

4.3 THE EFFICIENCY WEDGE

I compute the efficiency wedge from the Solow-residual, using (7). Since the equation is static, I can use the original variables instead of the transformed ones. The Solow residual then is a combination of the efficiency wedge A_t and labor augmenting productivity growth X_t. To get the efficiency wedge, I first remove trend growth from the Solow residual:

$$A_t = \frac{SR_t}{\gamma^{(1-\alpha)t}}.$$

Next, I normalize this measure by the sample average of the US value. The efficiency wedge is thus given as a fraction of the assumed world knowledge frontier (the US level).

4.3.1 Capital stock

Lacking reliable aggregate capital stock data I use the Perpetual Inventory Method (PIM). Substituting for capacity utilization, the capital accumulation equation is written as

$$K_{t+1} = (1-\delta)K_t + I_t.$$

The method requires an initial capital stock, which is not directly available. Fortunately, the PWT contains a relatively long investment time series for most of the countries analyzed. Thus I assume, following Caselli (2005), that the initial capital stock grew at its steady state growth rate, $n \cdot \gamma$. This gives the following initial estimate:

$$K_0 = \frac{I_0}{n \cdot \gamma - 1 + \delta}.$$

Given that my sample period for the computation of the wedges starts in 1996, the capital stocks for this period should not be sensitive to the initial conditions.[7]

The capital-output ratios for the CEE countries are shown on Figure 2. The capital-output ratio was between 2 and 3 throughout the sample period, with no obvious trend in either country. This indicates that convergence of the CEE countries was driven mostly by TFP growth. Although the capital stocks expanded, they do not seem to have been far below than what was implied by the level of productivity.

4.3.2 Results

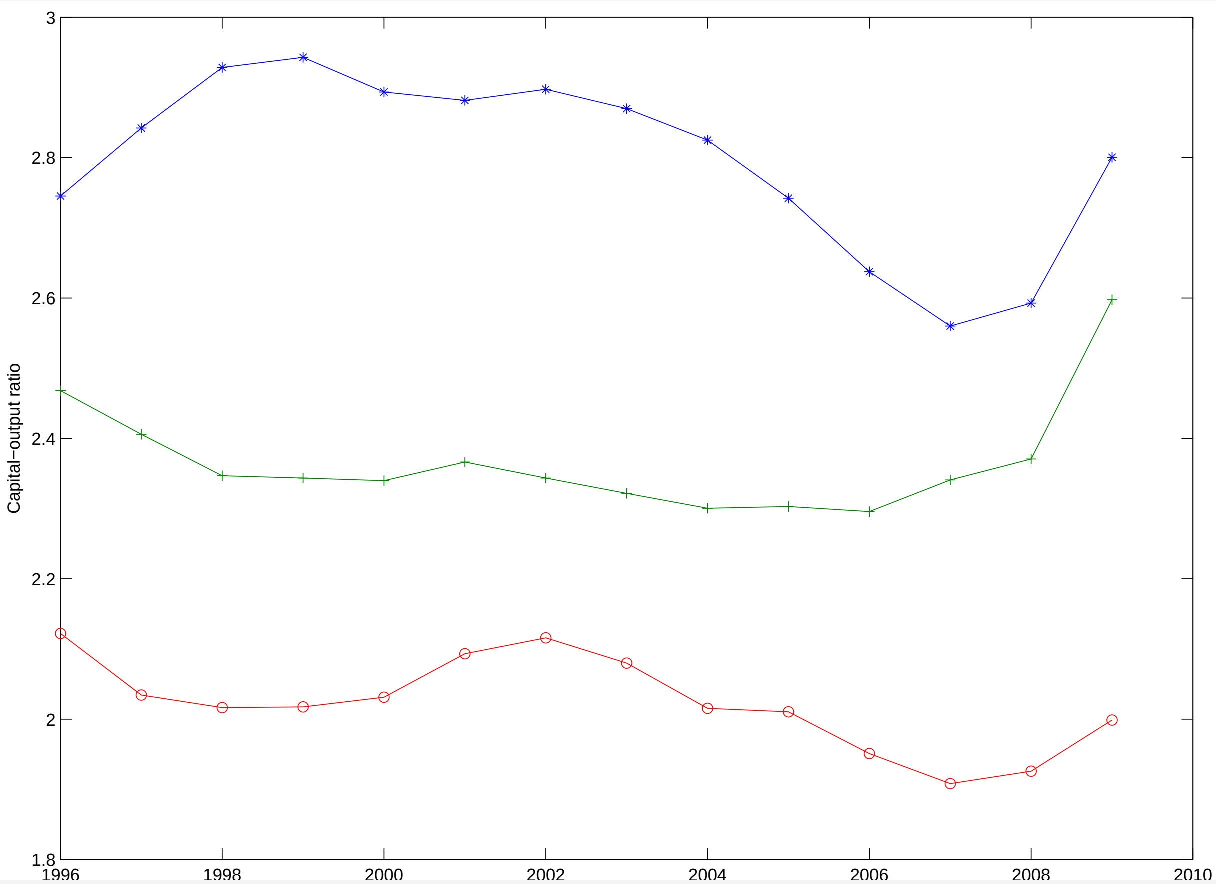
Figure 3 presents the efficiency wedge for the three countries, using the procedure described above.[8] At the beginning of the period Hungarian productivity was highest, and along with Polish TFP it expanded quickly. Polish TFP growth kept up,

[6] The steady state labor input serves only as a benchmark against which the labor wedge is evaluated. Changing it would simply represent a rescaling of the wedge, without any effect on its shape and dynamics.

[7] The investment series go back to 1970 for Poland and Hungary and Germany, and to 1950 for France the UK and the US. For the Czech Republic investment data starts from 1990. Fortunately, the EU-KLEMS project (O'Mahony, M. and M. Timmer, 2009) has capital stock estimates for the Czech Republic, and those values are consistent with the steady state assumption.

[8] In the following I use productivity, TFP and the efficiency wedge interchangeably. Note that trend productivity growth is the same in all countries, so the efficiency wedge capture extra productivity growth in addition to distortions and possibly demand effects.

Figure 2
Capital stocks: CZ (*), HU (+), PL (o)



but Hungarian slowed down by the second half of the sample. In the Czech Republic, on the other hand, initial sluggish productivity growth quickened significantly by the second half of the period, at least until the world crisis in 2008-2009.

The efficiency levels were nevertheless quite similar in the three countries, despite very different productivity and investment levels seen in Section 2.1. While the Czech Republic has significantly higher capital stock and employment, it does not produce correspondingly more than Hungary and Poland. In fact, by the end of the period the three countries had basically the same levels of productivity, due to some extent to the remarkable robustness of the Polish economy in 2008-2009.

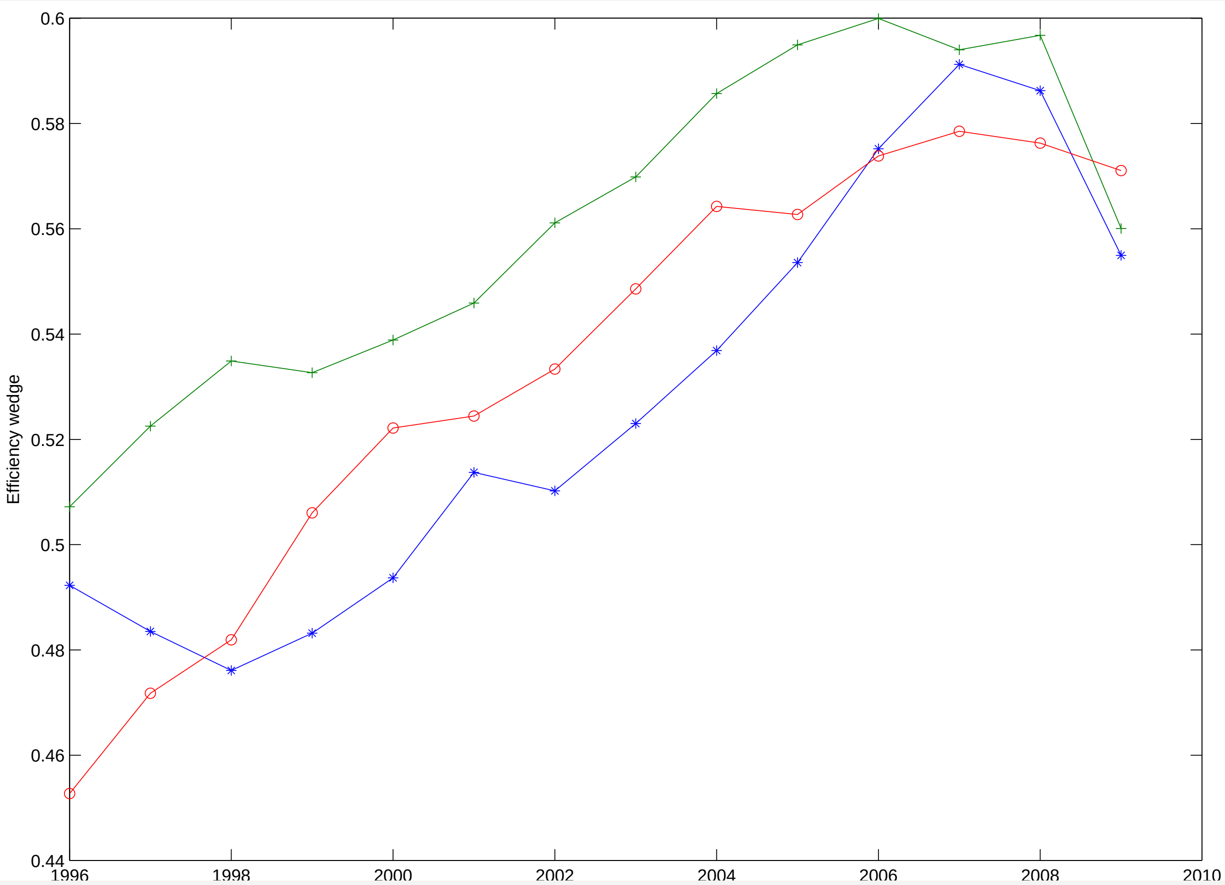
4.4 THE LABOR WEDGE

Computing the labor wedge is simple, using eq. (8). Figure 4 shows the logarithm of the labor wedge for the three countries.

The labor wedge is the mirror image of TFP: it is lowest for the Czech Republic, and very large for Poland and Hungary. The Hungarian wedge was high throughout the period, while in Poland the initial and final levels were lowest. Note that even in the Czech Republic, the labor wedge increased significantly by the second half of the sample period.

The dynamics of the Hungarian labor wedge is different from that of Poland and the Czech Republic. This is probably due to the unique nature of the Hungarian business cycle, which peaked in the mid 2000s. Poland and the Czech Republic, on the other hand, appear to have a quite synchronized business cycle, apart from the crisis of 2008-2009.

Figure 3
The efficiency wedge: CZ (*), HU (+), PL (o)



4.5 THE INTERTEMPORAL WEDGES

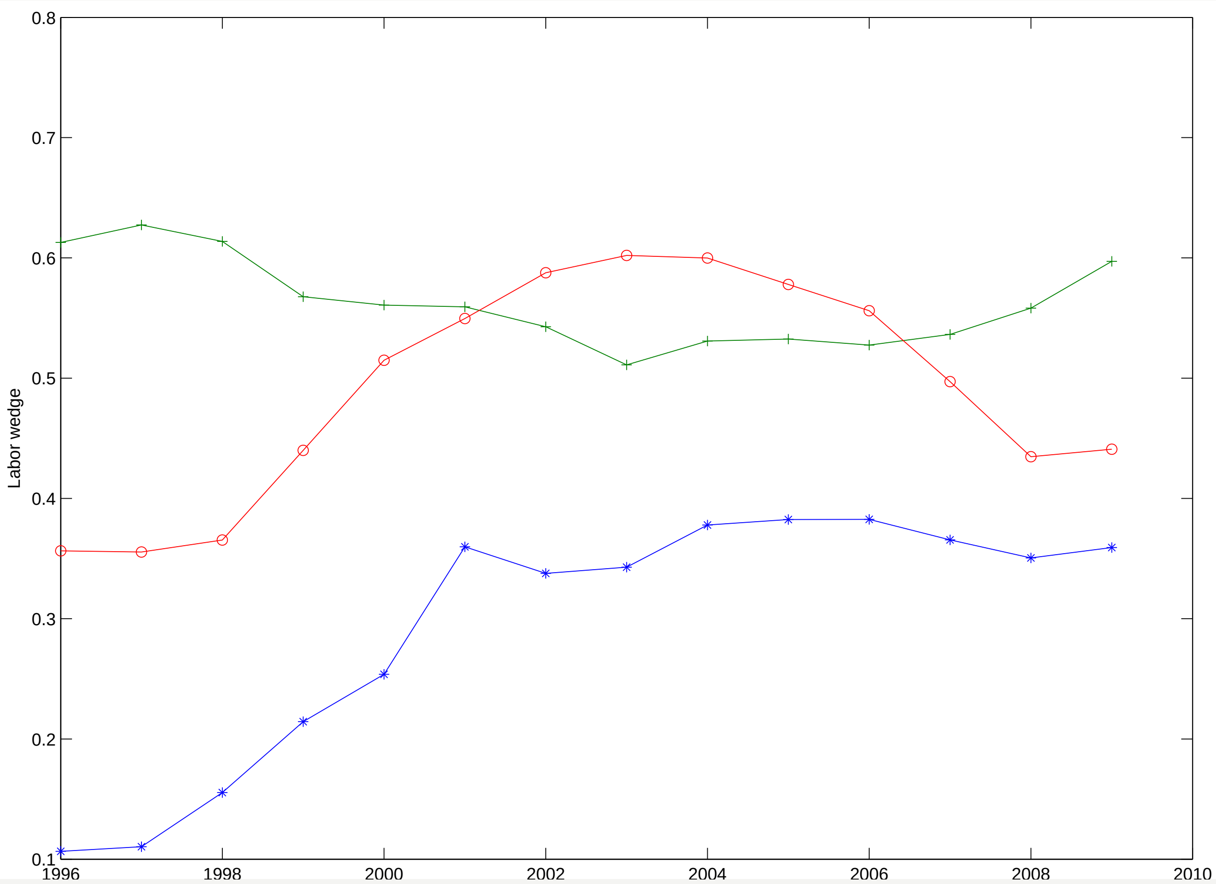
Figure 5 plots the intertemporal wedges in the three economies, using equations (10), (11) and (12). Recall that the capital wedge is the combination of the investment and borrowing wedges.

The investment wedge - the distortion in the arbitrage condition between capital and bonds - is quite similar across the countries. Although with a lot of volatility, we can see a distinct increase over the sample period. This indicates that relative to the risk-free rate, capital investment in the CEE economies became less efficient over time. This reflects the fact that - probably due to the EU accession in 2004 - the risk-free rate was falling steadily (not shown), at least until 2008. Investment, however, did not respond enough to the decline in its opportunity cost.

The borrowing wedge, between consumption and saving/lending, shows a less obvious pattern and differs considerably across countries. It was high and increasing in the Czech Republic, low but increasing in Poland, and high but decreasing in Hungary. The divergence between the Czech Republic and Poland on the one hand, and Hungary on the other, is especially stark in the period 2001-2007. Apparently consumption in the Hungarian economy took advantage of the lowering of credit constraints captured by the declining interest rate, much more so than consumption in the other two countries.

The last panel shows the net effect of the capital market distortions. The consumption-investment decision was basically undistorted in the Czech Republic, while the capital wedge was high throughout in Poland. Hungary started with a low wedge level, but became similar to Poland by the end of the sample. The decompositions revealed, however, that the low Czech wedge is the result of high wedges for borrowing both for capital investment and for consumption. In Poland, on the

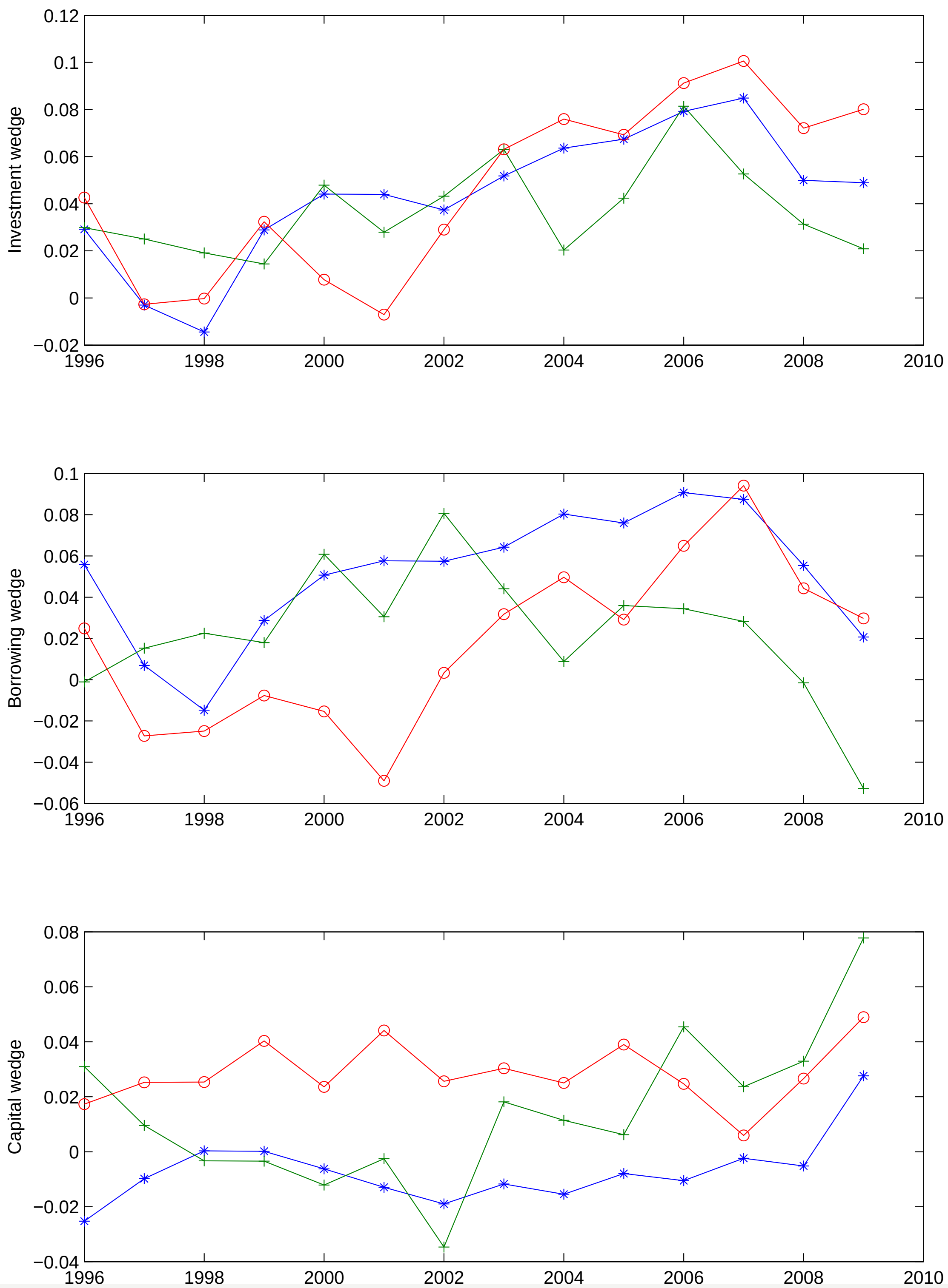
Figure 4
The labor wedge: CZ (*), HU (+), PL (o)



other hand, the stability of the capital wedge is a result of increases in both the investment and borrowing wedges. Finally, in Hungary the increase in the capital wedge reflects a rise in the investment wedge, and a fall in the borrowing wedge.

Overall, we can conclude that the capital markets faced significant distortions in the CEE regions, which influenced consumption and investment to varying degrees. As in the case of the labor market, we see similar developments in Poland and in the Czech Republic, while Hungary went down a different path.

Figure 5
Intertemporal wedges: CZ (*), HU (+), PL (o)



5 Interpretation

In this section I examine two issues that help interpreting the wedges. First, I investigate the labor and intertemporal wedges further by comparing the CEE economies to advanced European countries and the US. These countries seem a natural control group. Next, I run counterfactuals where I reduce various wedges subsequently, and infer the potential increase in GDP due to the reduction of a wedge. Of course the policy implications of this exercise should be taken cautiously, since the wedges are not necessarily independent of each other. Thus any policy step could influence other wedges, even if targeted at a particular market.

5.1 WEDGES IN GERMANY, FRANCE, THE UK, AND THE US

I repeat the wedge computation for three large Western European economies and the US to get a perspective on the size of the CEE wedges. In particular, the magnitude of the investment wedge must be evaluated relative to countries with presumably efficient capital markets. Germany, France and the UK are natural benchmarks for the CEE countries, and are also different enough from each other that we can draw robust conclusions by looking at all three instead of just one of them. I also include the United States as a country on the technological frontier, and as a further reference point for the Western European economies. I use the same calibration as for the CEE countries, with only the population growth rates being country specific.

Figure 6 plots the labor and intertemporal wedges for France, Germany, the UK, and the US. The labor wedge is low in the UK and in the US, and high in Germany and France. The German and French levels are higher than the labor wedges in the CEE countries, with the partial exception of Hungary. This is mainly a consequence of their very low hours per worker.

The investment wedges are surprisingly different across the WE countries. While their dynamics are similar, the UK levels are about 5% higher than the German ones (with France and the US in between). Also note that these wedges are comparable to CEE levels, indeed the latter are significantly lower at the beginning of the sample.

The same is largely true of the borrowing wedge, although CEE levels became higher by the end of the period. Among the four advanced countries, the borrowing wedges are quite similar, probably reflecting similar developments in their real interest rates. Note, however, the large swings in the US value after 2000.

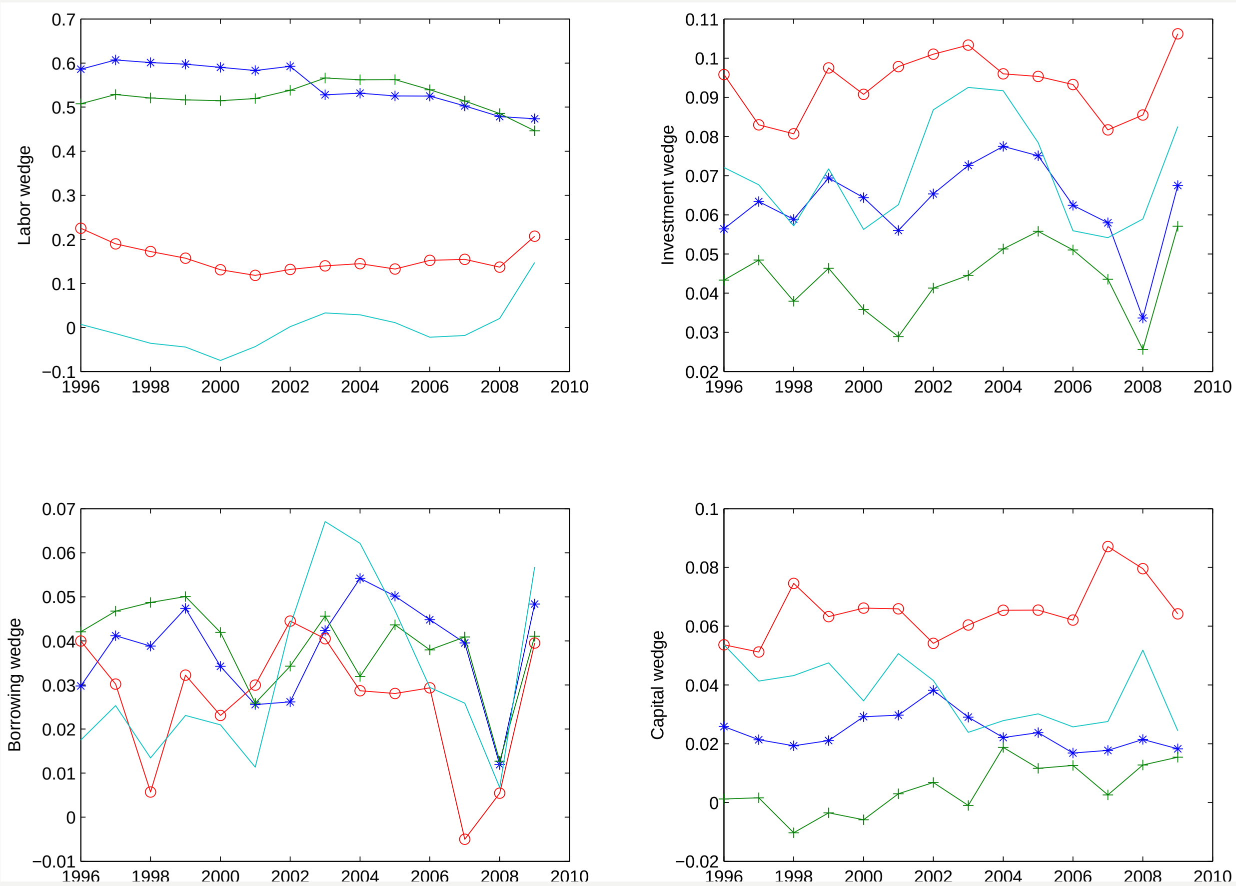
The capital wedge is lowest in Germany, and highest in the UK. Again, the CEE values are well within the range of the advanced economies. Thus we can conclude that while CEE capital market distortions are present, they do not seem to be higher than the distortions in rich countries. The partial exception is Germany, but even there, the capital wedge is low largely because the investment and borrowing wedges offset each other.

5.2 COUNTERFACTUALS

The model used to compute the wedges can also be used for counterfactual analysis and projections. By eliminating one or more wedges, we can produce hypothetical scenarios. In this section I examine the consequences of reducing the labor, capital and efficiency wedges on the future growth experience of the CEE economies.

To compute the wedges, I used auxiliary data that allowed me to avoid assumptions on the unobserved stochastic properties of the wedges. This is no longer possible: for the simulations, we have to make assumptions on the information set of decision makers. In what follows, I use the following setup.

Figure 6
Wedges in France (*), Germany (+), the UK (o) and the US (-)



1. The simulations are deterministic. I look at the consequences of known reductions of the wedges on future GDP growth. The simulations start with 2009 initial conditions for all state variables, including the wedges.

2. The wedges are modelled as independent AR(1) processes:

$$z_t = \rho z_{t-1} + (1-\rho)\bar{z}, \tag{13}$$

   where $z = \log\left(A/A^{US}\right), \tau^h, \tau^k, g$. The parameters are computed by fitting AR(1) regressions on the calculated wedges between 1996-2009. In the regressions I assume that $\bar{A} = A^{US}$, $\bar{g}$ equals the sample average of government consumption, and steady state net exports are zero. Lacking external data on the steady state of the labor and capital wedges, for these two I estimate (13) with constant terms, and set the steady state values to $\bar{z}/(1-\rho)$. Table 1 presents the estimated autoregressive parameters and steady state levels for the three wedges.

3. I examine the effects of reducing the wedges sequentially. First, I simulate the model by keeping the long-run value of the wedges country specific, as described in the previous paragraph as the baseline case. Second, I set the steady state capital wedge to its regional minimum, the value of the Czech Republic for all countries. Third, keeping the capital wedge at the Czech level, I lower the steady state labor wedge to its regional minimum, also the value of the Czech Republic. Finally, keeping the labor and capital wedge steady states at the Czech level, I set the convergence parameter of the efficiency wedge process to its regional maximum, which is the Polish value. Note that I assume a gradual convergence of the wedges, and keep the AR(1) parameters and initial conditions country-specific.

Since there is a large number of potentially interesting variables and cases, I only report the evolution of GDP per capita. For easier comparisons, I present two figures: one where I show the simulations by country, and another where I plot paths

Table 1
Fitted wedge processes

	Czech Republic		Hungary		Poland	
	Steady st.	AR	Steady st.	AR	Steady st.	AR
Efficiency wedge	1	0.9765	1	0.9751	1	0.9646
Labor wedge	0.3962	0.821	0.555	0.7611	0.5311	0.8188
Capital wedge	0	0.5524	0.018	0.5819	0.0293	−0.126
GDP wedge	0.1366	0.9097	0.1111	0.9905	0.0855	0.6095

by the simulation exercise. Both are interesting: the first compares the effects of the various wedge reductions for the same country, while the second gives us the effect of a given wedge reduction for all countries.

Figure 7 shows the simulations by country. The stars represent the baseline, pluses correspond to the reduction of the capital wedge, circles indicate the additional reduction in the labor wedge, and diamonds stand for the further improvement in the efficiency wedge. Since it is the reference country for the labor and capital wedges, the Czech Republic would benefit only from faster productivity growth, and significantly so. Hungary, having high labor and sizable capital wedges, and also slower productivity growth than Poland, would gain from the reduction of all distortions. The gains are quite evenly distributed across the wedges. Poland would benefit mostly from a reduction of its high capital wedge, and somewhat less from a decline in its labor wedge.

Figure 8 plots the same simulations by wedge type. If all wedges followed their country specific processes (the baseline), the Czech Republic would essentially keep its lead. Poland would experience convergence for some time due to temporarily faster productivity growth, but later it would fall back due to its high capital wedge. Reducing that wedge to the Czech level, however, would cause Poland to overtake the Czech Republic (top right panel). Reducing the capital and labor wedges would lead to fast Hungarian convergence to the Czech level, and would accentuate the Polish productivity advantage (lower left panel). Finally, reducing all three distortions to the lowest common level would lead to an elimination of regional differences in about 10 years.

Overall, gains from reducing distortions are significant for all countries. In case of Hungary, improving all three distortions would lead to a 34% higher GDP per capita in 20 years, relative to the baseline scenario. Note that the simulations are based not on the total elimination of the wedges, only on their gradual reduction to the regional minimum. Thus we can conclude that there are significant gains from realistic reductions in distortions in the CEE economies, especially in Hungary and Poland.

As a word of caution, it must be kept in mind that the wedges are likely to be correlated. For example, the fast productivity growth in Poland might have been a consequence of its low employment rate (high labor wedge). The example of the advanced economies from the previous section also shows that it is unlikely for a single country to have low wedges in both the capital and labor markets. Still, the exercise in this section highlights that there are significant gains from relatively modest reductions in distortions in the CEE economies.

Figure 7
Simulations by country: baseline (*), $\bar{\tau}^k$ (+), $\bar{\tau}^k$, $\bar{\tau}^h$ (o), all (◇)

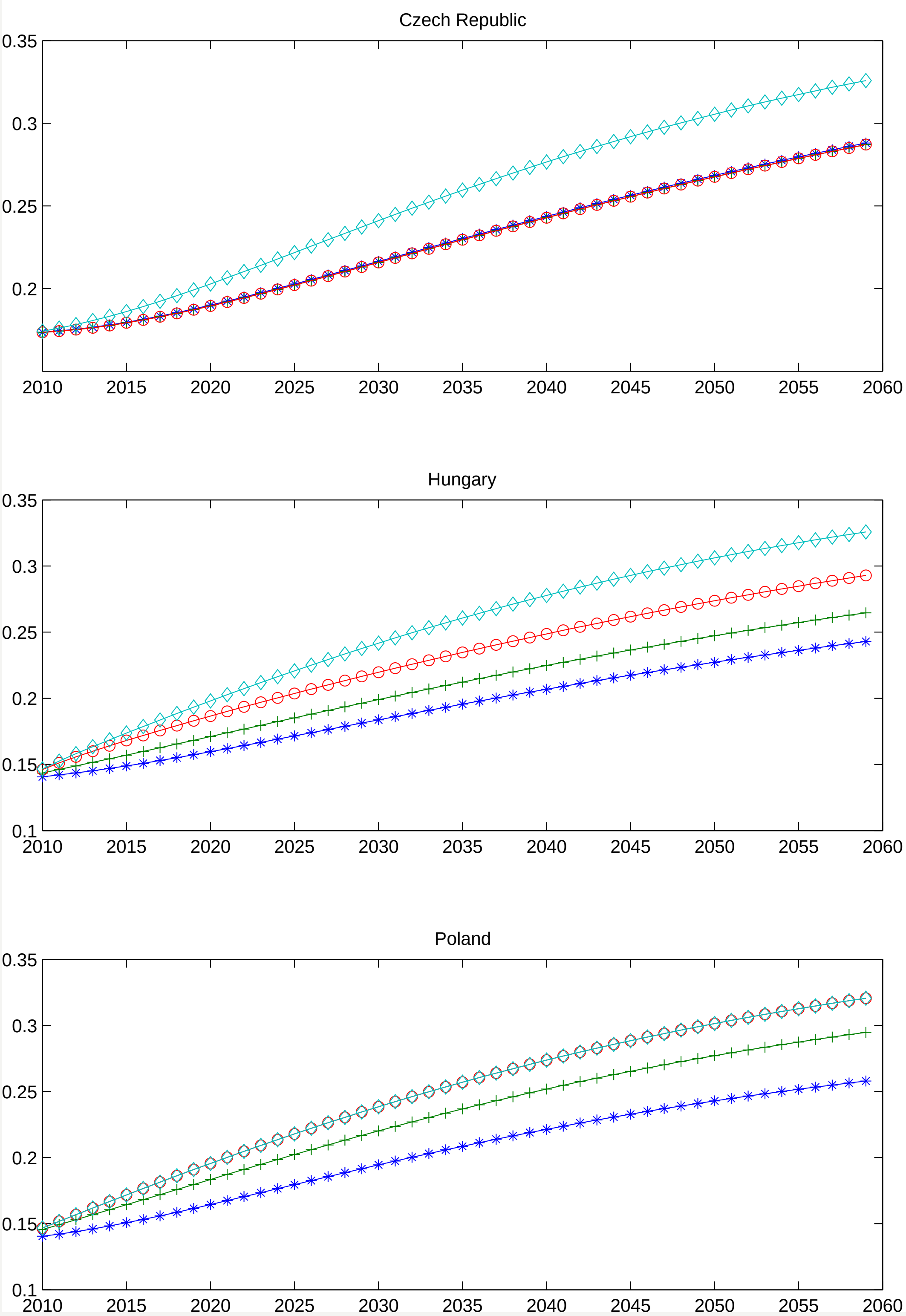
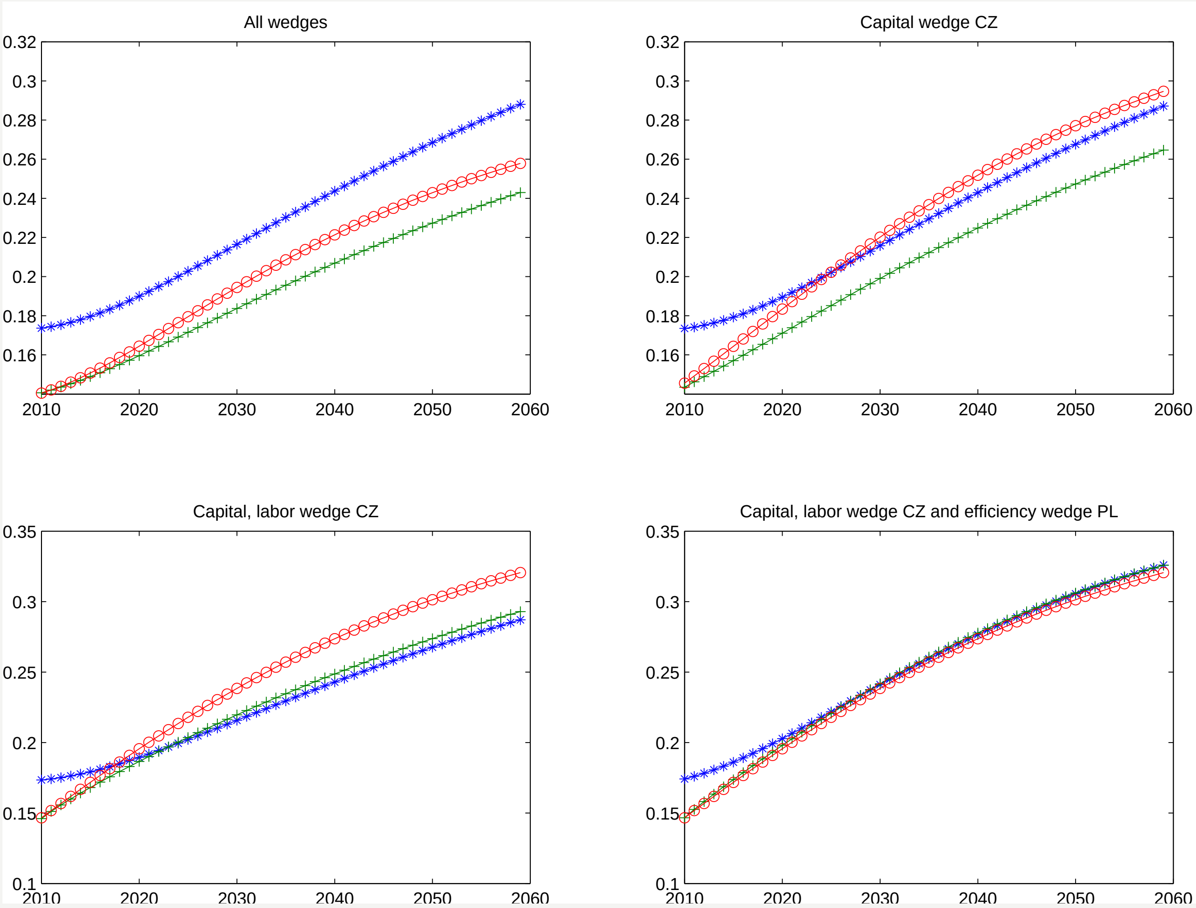


Figure 8
Simulations by wedges: CZ (*), HU (+), PL (o)



6 Conclusion

This paper has computed and analyzed distortions in three Central-Eastern European economies. It found that there are sizeable wedges in the capital market in all three countries, and the labor wedge in Hungary and Poland are also significant. The paper showed that the CEE labor and capital markets are not particularly inefficient relative to Western Europe, but significant efficiency gains are nevertheless possible, especially for Poland and Hungary.

The purpose of the paper was to explore the capital, labor and overall distortions in the CEE economies that hindered their convergence. This was mainly an empirical exercise, and not an in depth analysis of what led to the identified wedges. Detailed policy recommendations on how to reduce the measured wedges need to be based on a more structural approach. This would be an important extension, but it is beyond the scope of the current paper. Nevertheless, the paper is a first step in this direction, on which one can base a more targeted investigation.

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Appendix A Data

Table 2
Data sources

Variable	Description	Source
GDP	Real GDP in international dollars $RGDPL * POP$	PWT 7.0
Consumption	Real consumption in international dollars $RGDPL * POP * KC$	PWT 7.0
Investment	Real investment in international dollars $RGDPL * POP * KI$	PWT 7.0
Employment	Employement rate, population aged 15-64	OECD
Hours	Weekly average hours, 15-64, employees	OECD
Interest rate	Annualized three month money market rate, yearly average	Eurostat
Inflation	Household consumption deflator	Eurostat
Forecasts for GDP, C, π	One year ahead projections for real GDP, real consumption, and consumption deflator	OECD Economic Outlook December 1996-2009

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