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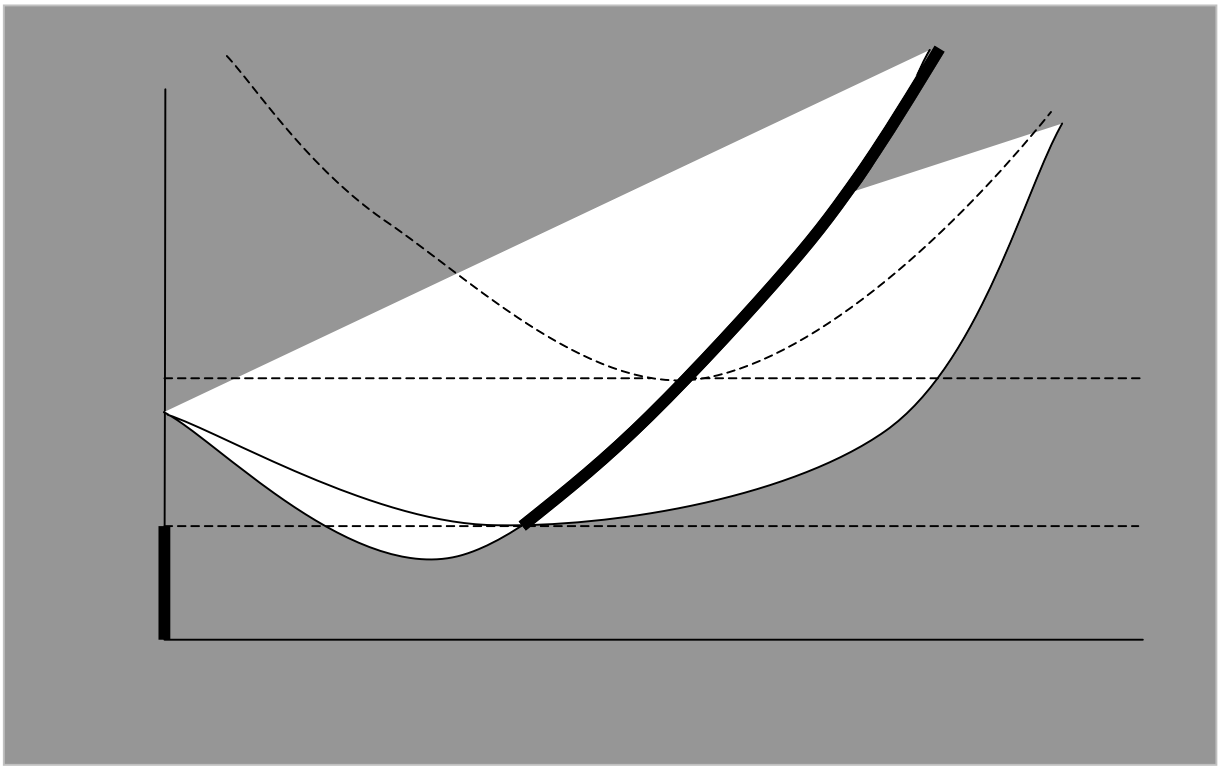
Tomáš Cahlík, Soňa Pokutová, Ctirad Slavík: Human Capital Mobility II



2004

Migration from poorer to richer countries can produce a vicious circle from a gap in real wages through a gap in human capital causing a gap in productivity causing a gap in real wages again. This circle can be linked with another one (based on the effective wage theory) connecting the level of real wages to the prices of non-tradables. Lower wages impact through lower demand on lower prices of non-tradables. Having once lower prices of non-tradables and thus lower wages paid in the non-tradables sector, the real wages in the tradables sector and the general real wages as well are pulled to a lower level. Both circles influence the process of convergence of the Central and East European Countries (CEEC) to the European Union (EU).

In this paper, we show different possibilities for the model specification of this basic mechanism, to cover different links between human capital migration to the real wage (equations 4a, b) and different possibilities for human capital formation in the old EU members (equations 5a-e). We show results of parameters' estimation and some illustrations of model's dynamics. In conclusions, we discuss where problems with parameters' estimation may come from and show where farther changes in model's specification could be done.

Keywords

human capital, mobility, estimation, dynamics

The model

Let us have two economies, the EU and a CEEC country. The development in these economies is modeled by three equations – production function, wage to output relation and human capital accumulation.

Production function

Income per head in time t in both economies is given by:

$$y_t = i_t a_t k_t^{\alpha} h_t^{1-\alpha} ,$$

1)

where $i,\ a,\ k,\ h$ are institutions, world technology, physical capital and human capital – all per capita.

Human capital accumulation

Basic human capital per capita accumulation equation is given by (see [8], page 117):

$$h_t = h_{t-1} + \mu e^{\phi u} a_{t-1}^{\gamma} \ h_{t-1}^{1-\gamma}$$

2)

where h stands for human capital per capita, a for the world technology frontier (most advanced capital goods up to date), u for the number of years of schooling in the, φ and μ are nonnegative constants. In the first approximation, we will not account for years of schooling explicitly, so (2) can be simplified by using $B = \mu e^{\phi u}$ to:

$$h_t = h_{t-1} + B a_{t-1}^{\gamma} \ h_{t-1}^{1-\gamma}$$

3)

Our extension that links real wage rate gap to human capital migration (formation) in the CEEC countries can take several forms.

$$h_t^{CEEC} = \theta_1 \cdot h_{t-1}^{CEEC} + B_1 \cdot \left(\frac{w_{t-1}^{CEEC}}{w_{t-1}^{EU}} \right)^{\delta_1} \left(a_{t-1}^{CEEC} \right)^{\gamma_1} \left(h_{t-1}^{CEEC} \right)^{1-\gamma_1}, \qquad (4a)$$

where w is the real wage level and δ_1 is expected to be positive. The lower parameter indexes denote country (1 for the CEEC, 2 for the EU). In equation (4a) human capital accumulation is conditional on the wage differential in the CEEC and the EU. If wages in CEEC are lower than in the EU, the growth rate of human capital is sub-standard level. To allow for decreasing human capital in the CEEC observed in the data (note the second summand in equation (4a) cannot be negative if $B_1 > 0$) we include θ_1 and interpret it as depreciation of human capital that can be justified e.g. by forgetting. However, the equation relates the ratio of wages $\left(\frac{w_{t-1}^{CEEC}}{w_{t-1}^{EU}} \right)$ to the human capital formation and not to its mobility, which is the theoretical background of this paper. If wages are higher in the EU, workers in the CEEC will move. If we argue there is human capital mobility, than it should influence directly its level – that is the first summand. Of course the intensity of this effect is to be determined. So there is another equation that can be estimated:

$$h_t^{CEEC} = h_{t-1}^{CEEC} \cdot \left(\frac{w_{t-1}^{CEEC}}{w_{t-1}^{EU}} \right)^{\delta_1} + B_1 \left(a_{t-1}^{CEEC} \right)^{\gamma_1} \left(h_{t-1}^{CEEC} \right)^{1-\gamma_1}. \qquad (4b)$$

We would expect δ_1 to be a positive number (probably smaller than 1), if there is an effect of wage differential on human capital. If there in no effect, than $\delta_1 = 0$ and the equation reduces to the standard one. Moreover, if the wages are equal $\left(\frac{w_{t-1}^{CEEC}}{w_{t-1}^{EU}} \right)^{\delta_1} = 1$ and the equation becomes standard. If wages paid in CEEC are higher than in the EU, it will certainly attract human capital from the EU and the growth rate of skills will be higher than at standard level. This assumption will be tested – whether δ_1 is significantly different from zero or not (we suppose it is positive). Obviously, one could include the depreciation parameter into (4b), which we did in an attempt to get valid estimates (see bellow).

To model the development of human capital per capita in the EU, we have again several choices. Firstly, the human capital that abandons the CEEC country simply enters the EU (the argumentation follows from equation (4b)):

$$h_t^{EU} = h_{t-1}^{EU} + B_2 \cdot \left(a_{t-1}^{EU}\right)^{\gamma_2} \left(h_{t-1}^{EU}\right)^{1-\gamma_2} + h_{t-1}^{CEEC}\left[1-\left(\frac{w_{t-1}^{CEEC}}{w_{t-1}^{EU}}\right)^{\delta_1}\right] \cdot \frac{N^{CEEC}}{N^{EU}}, \qquad (5a)$$

where N stands for population and adjusts for the fact that h is human capital per capita. (Clearly the parameters in this equation are not necessarily equal to those of equation (4b), the only exception being δ_1, which is taken directly from (4b). The EU follows its own path of human capital formation.) However, in reality we observe that qualified workers from the CEEC countries often do unqualified jobs in the EU. So in fact the CEEC countries lose human capital but not all of the migrating human capital "reaches" the EU. If we assume that only a given proportion p of the migrating human capital is in fact used in the EU (5a) changes to:

$$h_t^{EU} = h_{t-1}^{EU} + B_2 \cdot \left(a_{t-1}^{EU}\right)^{\gamma_2} \left(h_{t-1}^{EU}\right)^{1-\gamma_2} + p \cdot h_{t-1}^{CEEC}\left[1-\left(\frac{w_{t-1}^{CEEC}}{w_{t-1}^{EU}}\right)^{\delta_1}\right] \cdot \frac{N^{CEEC}}{N^{EU}} \qquad (5b)$$

and p must be estimated. Alternatively, we will model the development in the EU in the same fashion as in the CEEC countries.

$$h_t^{EU} = h_{t-1}^{EU}\left(\frac{w_{t-1}^{EU}}{w_{t-1}^{CEEC}}\right)^{\delta_2} + B_2 \cdot \left(a_{t-1}^{EU}\right)^{\gamma_2} \left(h_{t-1}^{EU}\right)^{1-\gamma_2} \qquad (5c)$$

Again, note that the parameters are not the same as in (4b). Eventually, the equivalent of (4a) can be used:

$$h_t^{EU} = \theta_2 \cdot h_{t-1}^{EU} + B_2 \cdot \left(\frac{w_{t-1}^{EU}}{w_{t-1}^{CEEC}}\right)^{\delta_1} \left(a_{t-1}^{EU}\right)^{\gamma_2} \left(h_{t-1}^{EU}\right)^{1-\gamma_2}, \qquad (5d)$$

Of course, one can again include the depreciation parameter right into (5c). Finally, if the migrating human capital is not used at all in the more developed EU (recall the Ukrainians with university diplomas who work as construction workers in the Czech Republic) the appropriate equation with the depreciation parameter included is:

$$h_t^{EU} = \theta_2 \cdot h_{t-1}^{EU} + B_2 \cdot \left(a_{t-1}^{EU}\right)^{\gamma_2} \left(h_{t-1}^{EU}\right)^{1-\gamma_2}. \qquad (5e)$$

From these alternatives one will be chosen. As a benchmark, we will discuss what happens if both economies are considered closed, i.e. the human capital accumulation for both the CEEC and the EU economy is given by equation (3).

Wages

We assume mark-up pricing in both economies, the relevant equations[1] are:

[1] Equation (6) is based on [2], chapter 9.

$$w_t^{EU} = y_t^{EU}(1 - m_0^{EU}) \quad \textbf{6)}$$

$$w_t^{CEEC} = y_t^{CEEC}(1 - m_0^{CEEC} - m_1^{CEEC}\frac{y_t^{EU}}{y_t^{CEEC}}) \quad \textbf{7)}$$

The standard equation (6) for the EU is changed by further assumption of different mark-up in the CEEC countries that depends on the ratio of output in the two countries.[2] We will test whether $m_0^{EU} = m_0^{CEEC} + m_1^{CEEC}$. This would namely mean that after the catch-up process is complete, the mark-ups equal in CEEC and EU.

Parameters' description

Institutions *i* and physical capital *k* are normalized to *1* in all periods in both economies, i.e. $i_t^{CEEC} = i_t^{EU} = \left(k_t^{CEEC}\right)^{\alpha} = \left(k_t^{EU}\right)^{\alpha} = 1$. Technology grows with a constant rate in both economies starting on level *1*, so it is equal in both countries in any *t* - $a_t^{CEEC} = a_t^{EU} = e^{g \cdot t}$. We will further assume *g = 0.004717 = 0.4717%*. (This corresponds to a yearly growth rate of technology of *1.9%*, which is a standard assumption). These assumptions are made so that the role of human capital can be analyzed. It is exactly the difference in human capital levels that seems to be the cause of differences in output (one can argue that the differences in physical capital are not large enough, institutions are similar by now and the same technologies are available in EU and CEEC). Moreover, we will assume that α *(share of capital in GDP) = 1/3*. *t* is set to 1 for the first observation.

The levels of human capital will be calculated in the following manner. Applying the above simplifications and using simple algebra equation (1) becomes:

$$y_t = e^{g \cdot t} \cdot h_t^{1-\alpha}, \quad \textbf{8)}$$

$$h_t = \left(\frac{y_t}{e^{0,0047 \cdot t}}\right)^{\frac{1}{1-\alpha}}, \quad \textbf{9)}$$

where we have already substituted for *g* in (9). Equation (9) makes the calculation of human capital per capita levels from available data possible for both the EU and CEEC. Now we have a series of h_t^{CEEC} and h_t^{EU} and the remaining parameters of the human capital

[2] This stands for the real wage gap. Variable mark-up has been recently in the focus of new Keynesian research activities

accumulation equations can be estimated. The real output in the CEEC relatively to the EU can be eventually expressed:

$$\frac{y_t^{CEEC}}{y_t^{EU}} = \left(\frac{h_t^{CEEC}}{h_t^{EU}} \right)^{1-\alpha} . \qquad (10)$$

Data

We use quarterly data in our analysis. The time span of our time series is 1993-01 to 2003-02. Data on real GDP (in PPP and constant 1996$) human capital per employee were calculated using the EIU database. We chose the per employee specification in order to be able to compare the GDP per employee with wages, which are also by construction measured per employee. Before the calculations were done, data on nominal and real GDP were seasonally adjusted using the Census X-11 multiplicative method.[3] Data on real wages (in PPP and constant 1996$ as well) were calculated using Eurostat data. Data on total employment are OECD data available at www.oecd.org. The CEEC country that we analyze is the Czech Republic. European Union is approximated by Germany – we use German data for the EU.

Parameters' estimation

Estimation of the parameters of the human capital accumulation equation for the Czech Republic

We will start with the estimation of equation (4b). Dividing both sides of equation (4b) by h_{t-1}^{CEEC}, substituting for technology and adding disturbances yields:

$$\frac{h_t^{CEEC}}{h_{t-1}^{CEEC}} = \left(\frac{w_{t-1}^{CEEC}}{w_{t-1}^{EU}} \right)^{\delta_1} + B_1 \cdot \left(\frac{e^{0.0047\cdot(t-1)}}{h_{t-1}^{CEEC}} \right)^{\gamma_1} + \varepsilon_t . \qquad (11)$$

Clearly, this equation is nonlinear in parameters and cannot be made linear by any transformation. Therefore, it will be estimated using the Marquardt nonlinear least squares algorithm.[4] Starting values were chosen to correspond to our *apriori* expectations 1, 0.01, 0.33 for δ_1, B_1, and γ_1 respectively. In fact we don't know what the value of B_1 might be, we only know it should be positive and probably not large, therefore it is set to 0.01. The other

[3] After this adjustment was done, we tested for seasonality on the human capital time series. The hypothesis of seasonality was rejected.

[4] The computations were done in EViews, for more information see e.g. EViews Help.

two parameters are expected to be positive too. But we get to the final estimates for a wide range of staring values, as was extensively tested.

Table 1

Included observations: 41 after adjusting endpoints
Convergence achieved after 254 iterations

	Coefficient	Std. Error	t-Statistic	Prob.
δ_1	-0.079359	0.038853	-2.042536	0.0481
B_1	-3.73E-05	0.000804	-0.046362	0.9633
γ_1	-0.548219	1.664756	-0.329309	0.7437

R-squared	0.093098	Mean dependent var	1.004052
Adjusted R-squared	0.045366	S.D. dependent var	0.019870
S.E. of regression	0.019414	Akaike info criterion	-4.975326
Sum squared resid	0.014322	Schwarz criterion	-4.849943
Log likelihood	104.9942	F-statistic	1.950439
Durbin-Watson stat	2.360902	Prob(F-statistic)	0.156188

As the table shows, the results are quite disappointing. First off all, the parameters are not significant (with the exception of δ_1). Secondly, the do not have the expected sign. And finally, the *F-statistics* indicates that the coefficients are not jointly significant, i.e. the hypothesis $B_1 = \delta_1 = \gamma_1 = 0$ cannot be rejected. Adding the depreciation parameter as described above does not improve the results at all, they are therefore not reported. Therefore equation (4a) will be estimated as well. Dividing both sides of equation (4a) by h_{t-1}^{CEEC}, substituting for technology and adding disturbances yields:

$$\frac{h_t^{CEEC}}{h_{t-1}^{CEEC}} = \theta_1 + B_1 \cdot \left(\frac{w_{t-1}^{CEEC}}{w_{t-1}^{EU}} \right)^{\delta_1} \cdot \left(\frac{e^{0.0047 \cdot (t-1)}}{h_{t-1}^{CEEC}} \right)^{\gamma_1} + \varepsilon_t . \qquad \textbf{(12)}$$

This equation was estimated using the same procedure as before (Marquart NLS). Starting values were set to 0.9, 0.01, 1, 0.33. Table 2 summarizes the results. Again, the coefficients are not significant, their signs do not match our expectations, and they are jointly insignificant.

Table 2

Included observations: 41 after adjusting endpoints
Convergence achieved after 95 iterations

	Coefficient	Std. Error	t-Statistic	Prob.
θ_1	-0.111911	86.07444	-0.001300	0.9990
B_1	6.559599	389.8813	0.016825	0.9867
δ_1	-0.088676	6.809024	-0.013023	0.9897
γ_1	0.140981	10.87001	0.012970	0.9897

R-squared	0.160379	Mean dependent var	1.004052
Adjusted R-squared	0.092302	S.D. dependent var	0.019870
S.E. of regression	0.018930	Akaike info criterion	-5.003630
Sum squared resid	0.013259	Schwarz criterion	-4.836452
Log likelihood	106.5744	F-statistic	2.355833
Durbin-Watson stat	2.231425	Prob(F-statistic)	0.087598

Estimation of the parameters of the human capital accumulation equation for Germany

Because we did not obtain "good" estimates of parameters (δ_1 in particular) of the Czech Republic human capital accumulation equation, we cannot use equations (5a) and (5b) to estimate the EU human capital accumulation equation. Therefore, equations (5c), (5d) and (5e) will be used. Transforming (5c) in a similar way as for the Czech Republic yields:

$$\frac{h_t^{EU}}{h_{t-1}^{EU}} = \left(\frac{w_{t-1}^{EU}}{w_{t-1}^{CEEC}} \right)^{\delta_2} + B_2 \cdot \left(\frac{e^{0.0047 \cdot (t-1)}}{h_{t-1}^{EU}} \right)^{\gamma_2} + \varepsilon_t \,. \qquad (13)$$

Table 3 summarizes the estimation results. As we hypothesize that the wage differential should not matter in this case, because the German economy is much greater than the Czech one, the starting values were set – 0, 0.01, 0.33. Just as in the case of the Czech Republic, the coefficients are not significant, their signs do not match our expectations, and they are jointly insignificant.

Table 3

Included observations: 41 after adjusting endpoints
Convergence achieved after 508 iterations

	Coefficient	Std. Error	t-Statistic	Prob.
δ_2	0.021924	0.039546	0.554388	0.5826
B_2	-0.002406	0.087700	-0.027434	0.9783
γ_2	-0.131264	2.716291	-0.048325	0.9617

R-squared	0.030163	Mean dependent var	0.998342
Adjusted R-squared	-0.020881	S.D. dependent var	0.009148
S.E. of regression	0.009243	Akaike info criterion	-6.459462
Sum squared resid	0.003247	Schwarz criterion	-6.334078
Log likelihood	135.4190	F-statistic	0.590931
Durbin-Watson stat	2.350229	Prob(F-statistic)	0.558820

Including the depreciation parameter in the above regression doesn't help either. Therefore a transformed (5d) will be estimated.

$$\frac{h_t^{EU}}{h_{t-1}^{EU}} = \theta_2 + B_2 \cdot \left(\frac{w_{t-1}^{EU}}{w_{t-1}^{CEEC}} \right)^{\delta_1} \left(\frac{e^{0.0047\cdot(t-1)}}{h_{t-1}^{EU}} \right)^{\gamma_2} \quad (14)$$

Table 4 summarizes the results. Again, the coefficients are not significant, their signs do not match our expectations, and they are jointly insignificant.

Table 4

Included observations: 41 after adjusting endpoints
Convergence achieved after 133 iterations

	Coefficient	Std. Error	t-Statistic	Prob.
θ_2	0.776633	72.68693	0.010685	0.9915
B_2	0.222882	73.25138	0.003043	0.9976
δ_2	0.095914	31.21240	0.003073	0.9976
γ_2	0.004529	1.307090	0.003465	0.9973
R-squared	0.029983	Mean dependent var		0.998342
Adjusted R-squared	-0.048667	S.D. dependent var		0.009148
S.E. of regression	0.009368	Akaike info criterion		-6.410495
Sum squared resid	0.003247	Schwarz criterion		-6.243317
Log likelihood	135.4151	F-statistic		0.381218
Durbin-Watson stat	2.351211	Prob(F-statistic)		0.767103

Finally, we will estimate equation (5e) in the following form:

$$\frac{h_t^{EU}}{h_{t-1}^{EU}} = \theta_2 + B_2 \cdot \left(\frac{e^{0.0047\cdot(t-1)}}{h_{t-1}^{EU}} \right)^{\gamma_2} . \quad (15)$$

Table 5 indicates that not even this specification helps obtain significant estimates of the parameters concerned.

Table 5

Included observations: 41 after adjusting endpoints
Convergence achieved after 66 iterations

	Coefficient	Std. Error	t-Statistic	Prob.
θ_2	0.804729	64.84579	0.012410	0.9902
B_2	0.049482	39.20547	0.001262	0.9990
γ_2	-0.098083	32.89547	-0.002982	0.9976
R-squared	0.022652	Mean dependent var		0.998342
Adjusted R-squared	-0.028788	S.D. dependent var		0.009148
S.E. of regression	0.009279	Akaike info criterion		-6.451746
Sum squared resid	0.003272	Schwarz criterion		-6.326363
Log likelihood	135.2608	F-statistic		0.440356
Durbin-Watson stat	2.363627	Prob(F-statistic)		0.647050

Mark up estimation

As for equation (6), the parameter m_0^{EU} can be estimated, the regression equation being:

$$w_t^{EU} = (1 - m_0^{EU}) \cdot y_t^{EU} + \varepsilon_t \tag{16}$$

Using the Breusch-Godfrey LM test for autocorrelation in residuals in the simple model (16) indicates an AR(1) process in residuals. We will account for this fact by transforming the equation and applying a Marquardt nonlinear least squares algorithm to the transformed equation.

$$w_t^{EU} = \rho \cdot w_{t-1}^{EU} + (1 - m_0^{EU}) \cdot y_t^{EU} - \rho \cdot y_{t-1}^{EU} + u_t , \tag{17}$$

where ρ is the autocorrelation parameter and u_t is white noise. This procedure is advantageous over the standard ones (Cochrane – Ortcut, Prais – Winsten transformations) because both parameters can be estimated simultaneously. Table 6 summarizes the estimation results. The estimated mark-up over the gross wages in the EU is roughly 64%.

Table 6

Included observations: 41 after adjusting endpoints
Convergence achieved after 5 iterations

Variable	Coefficient	Std. Error	t-Statistic	Prob.
$1 - m_0^{EU}$	0.360462	0.002472	145.8171	0.0000
ρ	0.826395	0.119014	6.943669	0.0000

R-squared	0.979591	Mean dependent var	4534.883
Adjusted R-squared	0.979068	S.D. dependent var	234.6131
S.E. of regression	33.94385	Akaike info criterion	9.934843
Sum squared resid	44935.22	Schwarz criterion	10.01843
Log likelihood	-201.6643	F-statistic	1871.920
Durbin-Watson stat	1.981517	Prob(F-statistic)	0.000000
Inverted AR Roots	.83		

Equation (7) can be rewritten:

$$\frac{w_t^{CEEC}}{y_t^{CEEC}} = (1 - m_0^{CEEC}) + (-m_1^{CEEC}) \cdot \frac{y_t^{EU}}{y_t^{CEEC}} + \varepsilon_t \tag{18}$$

The regression results are summarized in Table 7. We control for AR(1) again.

Table 7

Included observations: 41 after adjusting endpoints
Convergence achieved after 6 iterations

	Coefficient	Std. Error	t-Statistic	Prob.
$1 - m_0^{CEEC}$	0.056614	0.047276	1.197539	0.2385
$-m_1^{CEEC}$	0.193108	0.020613	9.368227	0.0000
ρ	0.938849	0.031516	29.79004	0.0000
R-squared	0.865818	Mean dependent var		0.379944
Adjusted R-squared	0.858756	S.D. dependent var		0.016265
S.E. of regression	0.006113	Akaike info criterion		-7.286520
Sum squared resid	0.001420	Schwarz criterion		-7.161137
Log likelihood	152.3737	F-statistic		122.5991
Durbin-Watson stat	2.737031	Prob(F-statistic)		0.000000
Inverted AR Roots	.94			

Further on, we tested whether the "equilibrium" ($y_t^{EU} = y_t^{CEEC}$) mark-ups in CEEC and EU differ significantly or not, i.e. whether $m_0^{EU} = m_0^{CEEC} + m_1^{CEEC}$. This was done in a rather non-rigorous way by substituting for $\theta = m_0^{EU} - (m_0^{CEEC} + m_1^{CEEC}) \Leftrightarrow m_0^{CEEC} = 0.64 - m_1^{CEEC} - \theta$ (0.64 the estimated mark-up for Germany from the previous regression) and testing H_0: $\theta = 0$ using a regular *t-statistics* from this auxiliary regression. The estimated regression equation is:

$$\frac{w_t^{CEEC}}{y_t^{CEEC}} - 0.36 = \theta + m_1^{CEEC} \cdot \left(1 - \frac{y_t^{EU}}{y_t^{CEEC}}\right) + \varepsilon_t \quad (19)$$

The estimated θ is *-0.11* with a *p-value = 0.0024* against a two-sided alternative. The null hypothesis is therefore rejected. So the mark-ups seem to be different in equilibrium. More importantly, the equilibrium mark-up in the Czech Republic is greater than in Germany. A problematic issue is that the coefficient $\beta_0 = (1 - m_0^{CEEC})$ is insignificant, as can be seen in the above table.

Estimating a simple model for the Czech Republic, i.e. equation:

$$w_t^{CEEC} = (1 - m^{CEEC}) \cdot y_t^{CEEC} + \varepsilon_t \quad (20)$$

gives the following results (see Table 8). Interestingly, the mark-up estimated from this equation is roughly 62%, which is less then in the case of Germany and opposite to the equilibrium markup as estimated from the previous regression.

Table 8

Included observations: 41 after adjusting endpoints
Convergence achieved after 4 iterations

Variable	Coefficient	Std. Error	t-Statistic	Prob.

$1-m^{CEEC}$	0.382503	0.007678	49.81921	0.0000
ρ	0.808860	0.096599	8.373354	0.0000

R-squared	0.955111	Mean dependent var	2517.933
Adjusted R-squared	0.953960	S.D. dependent var	298.8703
S.E. of regression	64.12856	Akaike info criterion	11.20721
Sum squared resid	160386.4	Schwarz criterion	11.29080
Log likelihood	-227.7477	F-statistic	829.8053
Durbin-Watson stat	1.958174	Prob(F-statistic)	0.000000
Inverted AR Roots	.81		

At this stage we conclude that our regression results for the human capital accumulation equations are at the very least surprising if not unrealistic. This may be caused by several factors. We will mention two of them here, the first is the fact that we only cover a very short period of time while this model is a long period one in its spirit. The second drawback of our analysis is the short length of the time-series used as such. This is the reason why we will use different parameter values in the model dynamics' simulations.

Model's dynamics – some illustrations

The purpose of this section is to show that different parameter specifications lead to entirely different model dynamics. In the simulations we used the following standard parameter values:

Table 9

Basic parameters		EU	CEEC
- growth of A	g	0,02	0,02
- share of capital on Y	α	0,33	0,33
Mark-up			
- related to domestic output	m0	0,2	0,1
- related to foreign output	m1		0,1
Parameters of HC growth			
- importance of knowledge	ϕ		0,10
- years of schooling	u		10
- importance of A	γ		0,34

- importance of wage diff.	δ		0,33
- importance of past HC	1-γ-δ		0,33
- importance of the total	μ		0-0,01

The first step is to see the behaviour of the model under standard textbook conditions, i.e. conditions in which human capital accumulation is defined as in equation (2):

$$h_t = h_{t-1} + \mu e^{\phi u} a_{t-1}^{\gamma} \, h_{t-1}^{1-\gamma}$$

Here, the only leading factors are intensity of the whole effect (μ), effect of quality of education (φu), available technology (a) as share of human capital in previous period (HC accumulation). We have two countries with different conditions but there is no interaction between them. European economy grows at the constant pace (only by the growth of technology, which is $a_t^{CEEC} = a_t^{EU} = e^{g \cdot t}$).

In CEEC the growth is fuelled also by growth in human capital and so this is the main difference among countries. We assume that all factors of the human capital growth are positive so the accumulation must be positive as well.[5] If we assume quality of education (years of schooling) to be a constant, then the leading factor of the model is the intensity factor of the human capital accumulation (μ) and intensity of technology accumulation (γ). What is a reasonable value of this factor? It must be positive so:

- for μ=0, the human capital in CEEC remains constant just like in the case of EU. CEEC economy grows at the same speed as EU and the only factor that matters is the HC initial level. If HC in CEEC is lower than 1, it will cause faster growth in EU than CEEC and increasing gap in output (Figure 1, 2). Only existence of different initial level of human capital and no linkage between economies can result in different growth paths.

Figure 1: Output in EU and AC

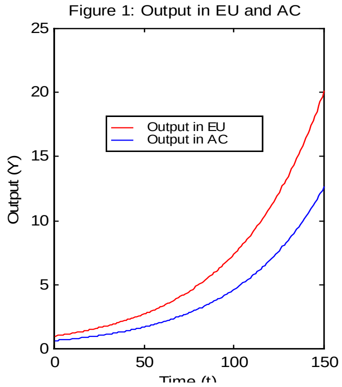
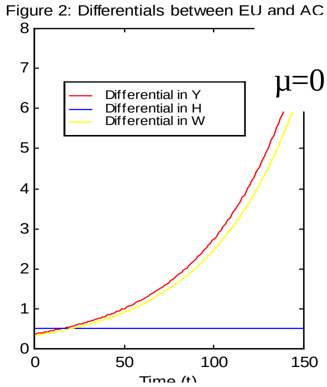


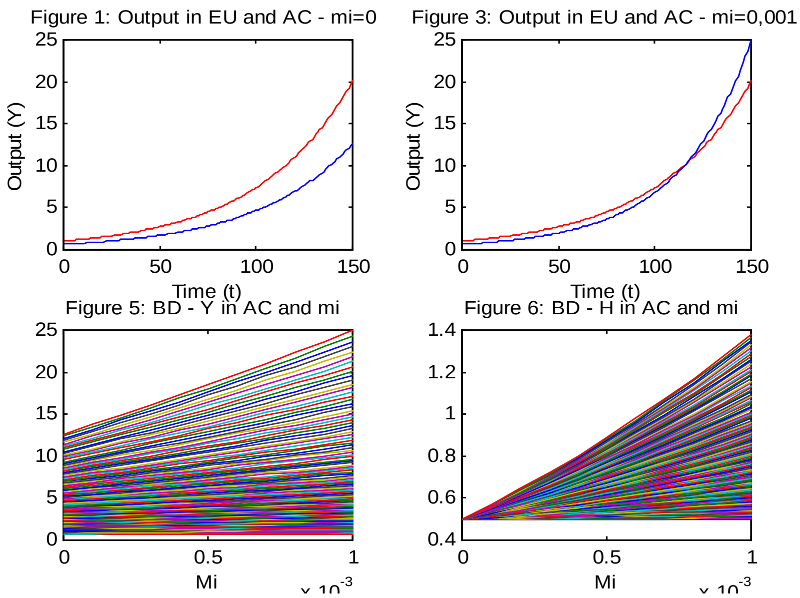
Figure 2: Differentials between EU and AC



Model for μ=0

[5] We leave away the possibility of decreasing of human capital.

- A positive μ can increase enormously the growth in CEEC – in fact, its value equal to 0,001 can generate faster growth in CEEC in 120 periods (Figures 1, 3, 5, 6).



The magnitude of this effect can be lower if we change gamma. This parameter reflects the importance of technology in human capital formation. And so it is clear that this model expects two sources of human capital accumulation: technology and past knowledge. We suggest that elasticity of both sources sums up to one. If we let gamma vary in the model, it has only limited effect – it shortens time to reach break point. So, as the first approximation, we use gamma = 0,5. It this first step, our result is, that human capital accumulation can be the only source of convergence.

In ***the second step***, we look at what happens after our extensions to the textbook specification

1) <u>human capital accumulation</u> is blocked by wage differential but there is no depreciation of human capital, i.e. we use an adjusted equation (4a):

$$h_t - h_{t-1} = \mu \left(\frac{w_{t-1}^{CEEC}}{w_{t-1}^{EU}} \right)^{\delta} e^{\phi u} a_{t-1}^{\gamma} h_{t-1}^{1-\gamma} \qquad (21)$$

2) Now we have to face the problem of another parameter entering our equation – delta. The wage differential is as the other source of HC accumulation (time varying). Thus it would seem logical to assume that parameters sum up to one:

$$h_t - h_{t-1} = \mu e^{\phi u} \left(\frac{w_{t-1}^{CEEC}}{w_{t-1}^{EU}} \right)^{\delta} a_{t-1}^{\gamma} h_{t-1}^{1-\gamma-\delta} = B \left(\frac{w_{t-1}^{CEEC}}{w_{t-1}^{EU}} \right)^{\delta} a_{t-1}^{\gamma} h_{t-1}^{1-\gamma-\delta} \qquad (22)$$

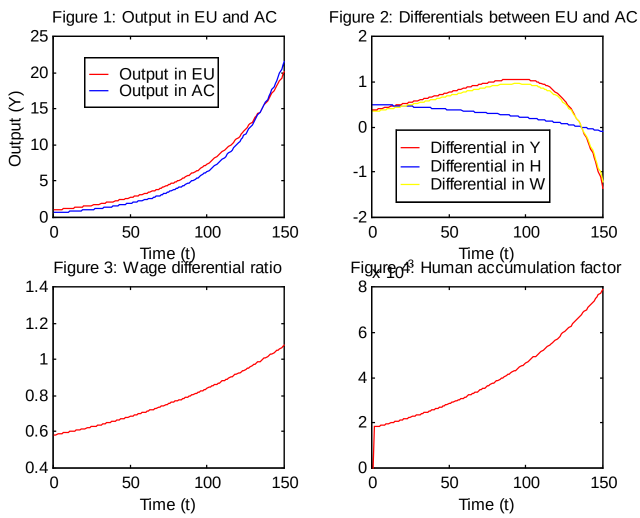
It has also a practical advantage – we have a possibility to test this restriction and we have a limit to its value.

3) <u>wages</u> are related to foreign output as well – in the form of mark-up, i.e.

$$w^{EU} = (1-m0)y^{EU}$$

$$w^{AC} = (1-m0)y^{AC} - m1y^{EU}$$

As for the value of the mark-up in both countries, we assumed that is the same – 20%. There can be reasons why in CEEC countries there can be lower mark-up (less costly work), but there is important problem. As you can see from the following graph, the ratio of wages (in EU and CEEC) eventually falls below 1 in our model.



Model for mi=0,0 01 gamm

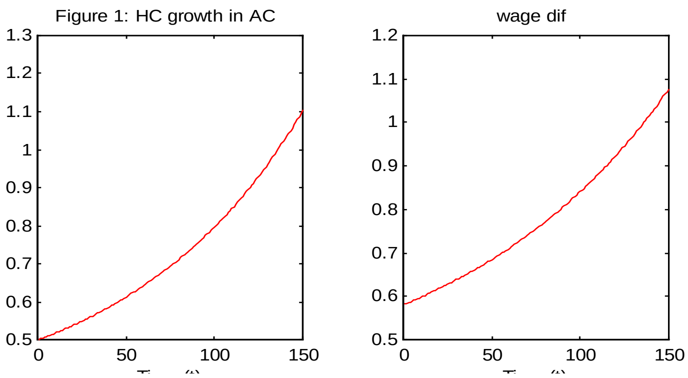
It means that the growth of wages in CEEC is faster than in EU. Let´s analyse it in more detail:

$$\frac{w_t^{AC}}{w_t^{EU}} = \frac{\left(1-m0^{AC}\right)y_t^{AC} - m1^{AC}y_t^{EU}}{\left(1-m0^{EU}\right)y_t^{EU}} = \frac{\left(1-m0^{AC}\right)y_t^{AC}}{\left(1-m0^{EU}\right)y_t^{EU}} - \frac{m1^{AC}}{\left(1-m0^{EU}\right)} = \frac{\left(1-m0^{AC}\right)\left(h_t^{AC}\right)^{1-\alpha}}{\left(1-m0^{EU}\right)} - \frac{m1^{AC}}{\left(1-m0^{EU}\right)}$$

So the difference of wages is again the function of human capital in AC. If it grows, it is helped also by the growth of wages. Substituting it back to our equation of HC accumulation:

$$h_t - h_{t-1} = \mu e^{\phi u}\left(\frac{w_{t-1}^{CEEC}}{w_{t-1}^{EU}}\right)^{\delta} a_{t-1}^{\gamma} h_{t-1}^{1-\gamma-\delta} = B\left(C\left(h_{t-1}\right)^{1-\alpha} - D\right)^{\delta} a_{t-1}^{\gamma} h_{t-1}^{1-\gamma-\delta} = Be^{\gamma g(t-1)}\left(C\left(h_{t-1}\right)^{1-\alpha} - D\right)^{\delta} h_{t-1}^{1-\gamma-\delta}$$

where C and D are substitutes for relative mark-ups. This process is difficult to evaluate but it is clear that some positive initial value will generate positive human capital growth in all following periods. The development of human capital and wage differential now looks as shown in the figures bellow.



At the end of the day, the variable of an economist's interest is the output gap. As we can see different models, or more precisely different parameter values, lead to opposite output gap developments – for some models the output gap between the EU and the acceding countries is widening, for other models the acceding countries are catching up the EU and eventually reach the EU output per capita.

Conclusions

Different model specifications allow for a variety of totally different developments of the relevant variables as shown above. We have tried to use econometric methods to discriminate between these alternative specifications and choose the appropriate model. However, the results of our regression estimations are a bit disappointing. We obtained significant and more or less reasonable estimates for the mark-up equation. However, it is the human capital accumulation equation that drives the dynamics of the model. Estimated parameters of this equation were mostly insignificant and frequently had opposite signs than expected. Moreover in all 5 estimated human capital accumulation equations parameters are jointly insignificant at the 5% significance level.

The most important point now is to clarify where the departures from the expected results come from. Standard explanations are short time series and problems with non linearity. We used quarterly data for our estimates – we did not have any choice because of the short time period.

The basic problem that we cannot overcome in any meaningful way is that the phenomenon of migration is probably detectable only in yearly data and there is no way to get such data in a time relevant for our research. There is probably no way how to verify our model with the help of econometric analysis – but no model has been ever rejected just on the basis of unsuccessful econometric verification.

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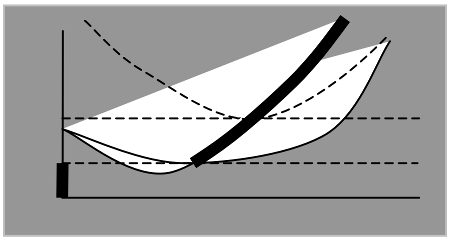

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Univerzita Karlova v Praze, Fakulta sociálních věd,
Institut ekonomických studií [UK FSV – IES] Praha 1, Opletalova 26.
E-mail : ies@mbox.fsv.cuni.cz *http://ies.fsv.cuni.cz*