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Abstract

In this paper we analyze qualitatively and quantitatively the potential effect of the EU accession on the development of several Central and Eastern European (CEE)countries (specifically, the Czech Republic, Hungary, and Poland). To achieve the task we design a small open economy version of the two-sector endogenous growth model of the Uzawa-Lucas style with knowledge diffusion. The model is first calibrated and validated to stylized facts of the economic development during the accession process in the EU periphery countries. We then calibrate the model according to the data on the CEE countries above and simulate their behavior using alternative scenarios in several dimensions. The interplay of various initial conditions and the parameters of the accession generate different accession patterns and also rather different speeds of convergence to the EU average. The model outcomes do not only provide us with these quantitative estimates but also improve our understanding of the economic mechanisms, which underpin those transitions.

Abstrakt

V této práci analyzujeme kvantitativně i kvalitativně potenciální účinek vstupu několika zemí střední a východní Evropy (SVE) (jmenovitě České republiky, Maďarska a Polska) na jejich budoucí vývoj. Pro dosažení tohoto úkolu navrhujeme dvousektorový endogenně růstový model s difúzí znalostí ve stylu Uzawa-Lucas rozšířený na případ malé otevřené ekonomiky. Model je nejprve kalibrován na stylizovaných datech zachycujících ekonomický vývoj ekonomik tzv. EU periférie při jejich vstupu do EU. Poté je model kalibrován na data ekonomik SVE výše a simulováno jejich chování

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pro alternativní scénáře modelových parametrů. Vzájemná interakce různých počátečních podmínek a parametrů přístupu způsobuje odlišná přístupová chování a také různé rychlosti konvergence k EU průměru. Modelové výstupy nám neposkytují jen tyto kvantitativní odhady, ale také zlepšují chápání ekonomických mechanismů zodpovědných za tyto přechodové procesy.

Keywords: Two-Sector Growth Models, Economic Growth and Aggregate Productivity, Macroeconomic Analysis of Economic Development, Human Resources, Human Capital Formation

JEL Classification: O41, O40, O11, O15, J24

1 Introduction

With the process of transition and integration of many Central and East European (CEE) countries entering its final stages before the accession into the EU, the crucial issue becomes whether they indeed succeed in achieving standards of living pertaining in the European Union, and if so, then in what horizon. The success in this process, commonly referred to as the process of cohesion, is deeply interrelated with the attainment of real convergence, i.e. achieving income per capita levels of the most advanced of the EU countries.

In this paper we analyze qualitatively and quantitatively the potential effect of the accession on the development of several Central and Eastern European (CEE) countries (specifically, the Czech Republic, Hungary, and Poland). In order to achieve the task we design an endogenous growth model of an accession economy which captures the key aspects of development in transition economies (TEs) after the accession to EU and the role of human/knowledge capital in this process. Among the 'accession trajectories' we are mainly interested in the income per capita levels and the quantitative assessment of its speed of convergence to the average EU level. Contrary to the overwhelming use of the results of the 'Barro-type' regression analysis for assessing convergence prospects (see e.g. Barbone and Zalduendo, 1996), we build a version of a two-sector endogenous growth model of the Uzawa-Lucas style. Since the TEs are typically small open economies (SOEs) and the aspect of their openness is a critical feature of the process of accession, we need to model a small open economy. For this purpose we use here an open version[1] of Kejak (2003) amended by adjustments costs for investments in physical capital (as in Turnovsky, 1996, and Osang and Turnovsky, 2000) and with an imperfect credit market in the form of an upward-sloping supply of debt (like in Osang and Turnovsky, 2000). The introduction of the second feature into the model is necessary for the existence of balanced growth path (BGP) equilibrium in the open economy with threshold externalities, while the first notion enhances the realism of the calibrated model predictions on the speed of adjustment[2].

Contrary to the neoclassical growth models, which predict convergence, endogenous growth models support the existence of multiple equilibria and divergent behavior of countries[3]. To explain convergence within an endogenous growth framework, the theory has to be amended by the catching-up hypothesis[4]

[1]In the literature there is only a limited number of endogenous growth models of open economies, they are almost exclusively of the AK-type with physical capital only (e.g. Frenkel, Razin, and Sadka, 1991, Turnovsky and Bianconi, 1992 or Turnovsky, 1996). A full analysis of the two-sector endogenous growth open economy model used in this paper can be found in Kejak (2001).

[2]Ortigueira and Santos (1997) use adjustment costs in an endogenous growth model of a closed economy to get the speed of convergence consistent with empirical evidence.

[3]See for example Azariadis and Drazen (1990) or Kejak (2003) who develop an extended Lucas model with these features. Kejak paper differs from Azariadis and Drazen (1990) (i) by the use of a model with infinitely lived households instead of the overlapping generation model, and (ii) by the explicit derivation of the logistic type of externalities (see below).

[4]There is also a recent attempt to include the catching-up hypothesis into the exogenous growth neoclassical framework done by Parente and Prescott (2000). They show that if there are some barriers to the adoption of private knowledge then countries posses different levels of knowledge and there is no convergence among them even in the standard neoclassical setup.

(e.g. Abramovitz 1986, 1994). This concept assumes that countries must possess a so-called social capability - that includes besides others, human capital, infrastructure capacities and institutional settings - to adopt and use the new technologies successfully. It also implies that investment is only a necessary but not a sufficient condition for convergence. Such an amended endogenous growth model with convergence property still preserves the ability of divergent behavior. However, since we study in this paper the behavior of relatively advanced transition countries the concept of complete divergence (driven by the corner equilibria as in the models of footnote 3) is replaced by a weaker concept of temporary divergence which cannot remove the general tendency of catching up but rather makes the transition non-monotonic and protracted.[5]

The use of the broader definition of human capital as knowledge capital and the explicit modelling of the process of knowledge diffusion can be supported by the perception of the process of accession as a progressive opening of the economy in terms of trade and capital flows, on the one hand, and as a massive technological transfer that enables fast technological catch-up with the technological frontier of the advanced countries, on the other. The knowledge diffusion assumes that there is a frontier of "theoretical knowledge" that is given exogenously and its shifts represent large advances in knowledge, as in the case of an industrial revolution. The economy can approach the frontier via the education of people, which facilitates the adoption and implementation of new technologies. Following Kejak (2003), such a diffusion of technology creates threshold or logistic-type externalities in the knowledge capital accumulation process with possibly increasing returns depending on the average level of knowledge[6].

The model is validated through calibration to stylized facts of the economic development in the EU periphery. In general, the experience of the EU peripheral countries[7] fits the predictions of our model reasonably well. The basic message emerges that the experience of the cohesion countries (and that of the transition countries as well) concurs with the endogenous growth theory in that success in the convergence process is not automatically guaranteed by a simple functioning of economic mechanisms, but rather depends upon a careful policy mix and particular economic circumstances. Hence, the examination

[5] Obviously, the accession of the candidate countries will have consequences for the employment situation in these economies. The ongoing integration into the European market will make it necessary for companies to achieve higher productivity levels, if they want to become more competitive in the long run. In particular, agricultural and manufacturing industries will be hit. However, new industries will emerge accompanied by the demand for new qualifications and skills. Structural change is a crucial prerequisite for a successful development. However, unemployment might increase due to mismatch and search processes. Furthermore, higher unemployment rates might lead to wage reductions and to a fall in aggregate demand. Companies will then reduce the degree of capacity utilization aggravating the unemployment problem. Moreover, investment activity could decline and thereby lowering the rate of endogenous technical progress. Solving this problem requires beside others an active labour market policy that supports investment in human capital. Such developments will lower the speed of catching up, because they can be considered as a kind of adjustment costs to a new growth path. Since our model already includes adjustment costs for investment and deals with imperfect capital markets, we do not deal with unemployment and lacks of aggregate demand. Hereby, we follow the traditional approach of endogenous growth theory and leave this to further research. However, we are aware that these processes might lead to a longer stagnation in a worst case scenario.

[6] There is an alternative way to capture the process of knowledge diffusion in an endogenous growth model done by Lucas (1993).

[7] See note 16.

of impacts of policy decisions and the evaluation of the particular economic conditions in the cohesion countries at different stages of their development can assist us in empirical validation of the theoretical model which is designed to capture the stylized facts of economic development that the accession Central and Eastern European (CEE) countries will probably experience in the near future. The theoretical model, in turn, improves our understanding of the challenges the transition countries are yet to confront and thus serve as guidance for policy makers in CEE countries in their quest for policy mixes bringing their countries onto a path of balanced long run growth and convergence.

The careful qualitative analysis of the transitional dynamics of the open economy model allows us to describe and study the effect of initial conditions and parameters on the transitional trajectories. Therefore, after the model is calibrated using the available data on a set of three transition countries: the Czech Republic, Hungary, and Poland, we provide not only a quantitative assessment of the speed of convergence to the EU standards but also discuss the appearance of phenomena such as an accession boom or accession recession[8].

The rest of the paper is organized as follows. In Section 2 we specify the theoretical model of an open economy with imperfect capital mobility, adjustment costs in the accumulation of physical capital and threshold technological externalities in the knowledge sector. The first order conditions and the balanced growth path equilibrium (BGP) are derived in Appendices B and C. The brief analysis of the model using numerical simulations is the content of Section 3. Next, we calibrate the model to stylized facts of the economic development in the EU periphery (Section 4) and extend the calibration to the set of chosen transition countries as well (Section 5). In the rest of the section using alternative scenarios with regard to several dimensions we simulate the behavior of the transition countries with different initial conditions. The interplay of the initial conditions and the parameters of the accession generate different transition patterns and also rather different speeds of convergence to the EU average. Section 6 concludes the paper.

2 Open Economy Model

We consider a two-sector small open economy populated by the continuum of homogenous agents each of whom is endowed with a unit of time, which can be allocated either to the production of good, u, or to the knowledge production, $1-u$. The level of agents' skill/knowledge is h. Thus the effective labor inputs are $l = uh$ and $(1-u)h$ in the goods and knowledge sectors, respectively.

In the goods sector, the economy consists of a large number of identical firms with a constant returns to scale Cobb-Douglas production function $y = F(k,l) = Ak^{\alpha}l^{1-\alpha}, \quad 0 < \alpha < 1$, where k is physical

[8] It is interesting that such phenomena cannot be observed in a closed economy version of the model. The standard Lucas model (see Barro and Sala-i-Martin, 1995) exhibits monotonic 'convergence property': the growth rate of output out of the steady state always exceeds the steady state output growth rate. Albeit the growth rate of the broadly defined output can be either above or below the steady-state value, the Lucas model still cannot exhibit non-monotonic output level behavior.

capital.

As in Kejak (2003) we use the generalized linear Uzawa-Rosen[9] formulation of the production function for human/knowledge capital assuming that the level of productivity in the education sector, B, capturing the effect of knowledge diffusion, depends on the developmental level of a society expressed by the average level of knowledge[10] H

$$\dot{h} = B(H;\phi)(1-u)h \tag{1}$$

with B derived in Appendix A and given by

$$B(H;\phi) = \frac{B_H}{1 + (\frac{B_H}{B_0} - 1)e^{-\phi H}} \tag{2}$$

where B_0 is the initial level of productivity related to a zero level of human capital and ϕ is the diffusion parameter that captures institutional barriers to knowledge adoption. Note that there are constant returns to private inputs for any level of productivity in the production function of the knowledge sector and increasing returns to all inputs at the social level for non-constant levels of productivity (i.e. $\partial B(H;\phi)/\partial H > 0$).

The installment of physical capital, which can be imported, is costly with quadratic adjustment costs specified in the following standard way

$$\Psi(\iota, k) = \frac{\psi}{2}\frac{\iota^2}{k} \tag{3}$$

with $\psi > 0$.

The agents in our economy can borrow on the imperfect world capital market, where e.g. creditworthiness of the economy influences its cost of borrowing from abroad at the interest rate which depends on the country's debt-capital ratio, $b = \frac{a}{k}$, i.e.

$$r(b) = r^* + vb \tag{4}$$

where a is foreign debt, r^* is the fixed world interest rate and $v > 0$.

In maximizing their life-time utility, the workers seek an optimal life-time consumption, investment and working pattern, $\{c, \iota, u\}$, which they achieve through the appropriate accumulation of financial and

[9] This specification was used in Lucas (1988).

[10] Note that in equilibrium the average level of knowledge capital is equal to the individual knowledge, $H = h$.

human wealth, $k-a$ and h respectively:[11]

$$\max_{\{c_t,\iota_t,u_t\}} \quad \int_0^\infty \quad e^{-\rho t}\left(\frac{c_t^{1-\theta}-1}{1-\theta}\right)dt \quad \text{s.t.} \tag{5}$$

$$\dot{a} \quad = \quad c+\iota(1+\frac{\psi}{2}\frac{\iota}{k})+\delta_k k-y+r\left(\frac{a}{k}\right)a \tag{6}$$

$$\dot{k} \quad = \quad \iota \tag{7}$$

$$\dot{h} \quad = \quad B(H;\phi)(1-u)h \tag{8}$$

$$\lim_{t\to\infty} a_t e^{-\int_0^t r_s ds} \leq 0 \tag{9}$$

$$0\leq \quad u \quad \leq 1 \qquad k_0>0, \qquad h_0>0, \qquad a_0. \tag{10}$$

where the price of the consumption good is normalized to one, ρ is the time preference parameter and θ is the degree of relative risk aversion. Eq. (6) defines the current account deficit, $\dot{a}$, where a is foreign debt, c is consumption, $\iota(1+\frac{\psi}{2}\frac{\iota}{k})$ is the total investment including adjustment costs, $y-\delta_k k$ is net income, and $r(\frac{a}{k})a$ is interest debt payment. The change in capital is equal to the net investment rate ι in Eq. (7). According to (1) the accumulation of human capital is given by (8). Eq. (9) refers to the No-Ponzi-game condition. The first order conditions for the agents optimization problem can be found in Appendix B.

After introducing transformed variables $s\equiv\frac{c}{k}$, $b\equiv\frac{a}{k}$, and $x\equiv\frac{k}{h}$ with the convenient property of zero growth at steady state we obtain the following equations of the dynamic competitive equilibrium[12]:

$$\frac{\dot{x}}{x} \quad = \quad \frac{q-1}{\psi}-B(h;\phi)(1-u) \tag{11}$$

$$\frac{\dot{s}}{s} \quad = \quad \frac{1}{\theta}\left(r(b)-\rho\right)-\frac{q-1}{\psi} \tag{12}$$

$$\frac{\dot{u}}{u} \quad = \quad \frac{B(h;\phi)-r(b)}{\alpha}+\frac{q-1}{\psi}-\left(B(h;\phi)+\frac{\partial B(h;\phi)}{\partial h}\frac{h}{\alpha}\right)(1-u) \tag{13}$$

$$\dot{b} \quad = \quad s+\frac{(q-1)^2}{2\psi}-\frac{F}{k}+r(b)b+\delta_k-\frac{q-1}{\psi}b \tag{14}$$

$$\dot{q} \quad = \quad qr(b)-F_k+\delta_k-\frac{q^2-1}{2\psi}. \tag{15}$$

Due to the presence of the knowledge externality we need also to include Eqs. (1) and (2) to capture the development of human capital and the evolution of productivity B, respectively. It implies that transitional dynamics of the model is not reducible to the development of capital ratios, as it is in the original Lucas model (see Mulligan and Sala-i-Martin, 1993)[13], and policy functions are general functions of all state variables, as well as sectoral allocation. According to (27) in Appendix B the economy asymptotically converges to the BGP when human capital gets sufficiently large.

[11] Whenever possible we suppress time indices to avoid cluttered notation. A dot denotes a time derivative.

[12] The log-linearization of the system around the steady state given in Appendix C reveals that the system is saddlepath-stable with three positive and two negative eigenvalues related to the three quasi-control variables, s, u, q, and the two quasi-state variables, x, b, respectively. See Kejak (2001).

[13] For an extensive analysis of transitional dynamics in the Lucas-Uzawa model and its extended variants see Caballe and Santos (1993), Chamley (1993), Ladron-de-Guevara, et al. (1997), and Kejak (2003).

3 Transitional Behavior of Accession

On a very stylized level, our understanding of the process of accession can be captured by the opening up of the economy to foreign capital markets and by a major improvement in the institutional structure. The latter aspect of the accession is perceived by the accessing country as improved access to the higher knowledge frontier B_H and/or smaller barriers to the knowledge absorption captured by the higher value of diffusion parameter ϕ in Eq. (1) and Eq. (2).

3.1 No Externalities

To isolate the relevance of the opening of the economy, we will begin with the case of no externalities.[14]

3.1.1 Case 1

Let us assume that initially the economy is less abundant in human-knowledge capital than in physical capital, i.e. $(\frac{k}{h})_0 > (\frac{k}{h})^*$ and the debt-capital ratio $b_0 = \frac{a}{k} > 0$ is large. The behavior of the model variables during the transition to BGP is captured in Figure 1. Since physical capital is relatively abundant in the economy, the return to human capital is larger than that to physical capital and investment in human capital is larger than in physical equipment. People spend relatively more time in the knowledge sector (u is very small) than in the production process. The large imbalance between the two types of capital and a very high real interest rate (due to the high debt-capital ratio b and according to Eq. (4)), create a large incentive to use the channel of capital outflow, while at the same time increased consumption contributes little to the de-cumulation of capital. The ensuing capital outflow is manifested through large negative investment. The whole transition can be decomposed in two phases.[15] During the first one the very fast de-cumulation of capital, i.e. an almost immediate outflow of excessive capital contributes to the current account surplus and a large decline in debt a. Since the decline in capital takes place via capital outflow, the stock of debt declines approximately one-to-one with capital during this phase. Thus, the debt-capital ratio stays roughly constant (see the horizontal trajectory in (x, b)-plane). As the physical capital declines and human capital grows, the marginal product of capital and Tobin's q increase, making people increase their working effort u continuously. The development of the returns to capital is consistent with the decline in the real interest rate r paid on the debt, which is the result of lower debt through capital outflow. During the second phase, when k/h is small and close to its steady state value, a small change in k has a much larger effect on the marginal product of capital and so q increases. Also u responds much faster to these changes and the originally very high growth rate in human capital declines. Since the reduction of k during this phase is larger than the one in a, the debt-capital ratio b

[14] A much more detailed analysis of the transitional dynamics of the model is developed in Kejak (2001).

[15] This approach is supported by the the fact that the steady state is a saddlepoint with three positive and two negative eigenvalues (see footnote 12). The stable eigenvalue with the large absolute value is responsible for the fast dynamics whereas the other stable eigenvalue represents the slower dynamics.

falls. Due to the very high growth of productivity, knowledge, and the working time, there is a period of an excessive growth in output along the transition to BGP.

3.1.2 Case 2

Let us now consider the initial conditions such that physical capital is relatively scarce and the economy is a net creditor initially, $(\frac{k}{h})_0 < (\frac{k}{h})^*$, $b_0 > 0$. The behavior of the variables during the transition to BGP is captured in Figure 2. Because of the scarcity of physical capital its relative return is higher, the marginal product of capital and q are high and people have an incentive to save more and invest in physical capital. This can be accomplished in one of the three following ways: (i) by increased work effort, (ii) by lowered consumption or (iii) by increased foreign borrowing. Having a relatively low intertemporal elasticity of substitution people prefer to work more, u is high (close to 1), and they spend only a little time on the accumulation of knowledge. As a result, there is almost no growth in human capital. The level of output is small due to the lack of capital and the low productivity. Negative debt makes the interest rate lower than r^* and increases the incentive to finance the large instalment of new capital via foreign borrowing. Alternatively, since the domestic return is very high, there is an incentive for a large FDI inflow. Therefore, during rapid transition, the current account is characterized by a large deficit and debt is being accumulated at a high rate. The fast capital accumulation decreases returns to physical capital and simultaneously the domestic interest rate rises (as b increases: a grows faster than k). Because of the initially relatively low level of capital the marginal adjustment costs are large and total investment costs are much larger than net investment.

3.2 Externalities and Catch-Up Factor

In this section we will discuss the behavior of the main model variables when externalities in the knowledge sector are present. Let us first start with the economy initially relatively scarce in physical capital, $(k/h)_0 < (k/h)^*$, with initial level of knowledge h_0 such that an externality in the knowledge sector applies, $B(h_0) < B_H$, and the debt is assumed to be initially large, $b > 0$. We can split the transition dynamics of the economy into three phases. During the first phase (similar to case 1 above) the main role is played by relatively high returns to physical capital. Therefore, high investment rates, high working time, high debt, high growth of physical capital and low growth of knowledge are the main features of this phase. However, due to the unlimited access to foreign capital this phase is quite fast (as a matter of fact the phase is not even visible in Figure 3). The driving force of the second phase are the increasing returns in the knowledge sector enabled by the access to the frontier knowledge, which gradually improves productivity of the knowledge sector. As the productivity and returns gradually grow, the composition of physical and human capital changes in favor of human capital. Thus the increase of x slows down and finally reverts in its decline (see the discussion of the low-growth stage and the take-off stage in Kejak (2003)). Tobin's q (capturing the present discounted value of future marginal products of capital) was declining during phase 1 mainly due to the fast decrease in marginal products. However, since the decline in the marginal product of capital slows down and the discount rate r decreases, there is a turning point when q starts to grow again. At this point, investment and capital change the trend and start to increase again. However, returns to knowledge are still increasing (due to the improved access to the frontier) and thus a still higher amount of resources is devoted to knowledge production, u keeps declining and the growth of human capital is faster than that of physical capital. During the first phase of transition there was a decline in output mainly driven by the decrease in working time. Physical output was growing, but the stock of human capital stagnated during this phase. However, the output decline (recession) is only temporary and the economy starts to grow again after it becomes sufficiently productive - during the first phase. The more productive economy also gradually improves its current account and the debt is declining together with the real interest rate.

4 Periphery Countries Accession to EU and Model Calibration

The discussion of the theoretical model in the preceding sections illuminated the factors and decisions that promote either growth and convergence on the one hand, or a relative stagnation and temporary divergence on the other. The exposition also highlighted a plethora of phases and possibilities through which the development of a model economy may take place. The investigation of feasible trajectories of transition countries based on this concept, then, requires a validation by calibrating to stylized facts of their economic development. Although we cannot find in the economic history examples of transitions from centrally planned to market economies, we do have several examples of the integration process into the European Union. One of them, which can provide enough guidance about the likely development paths of the CEE countries and thus help us in calibrating the theoretical model is the recent experience of a subset of EU countries, commonly referred to as peripheral[16]. This intuition is supported by several facts.

First, many of the EU candidate CEE countries have already undergone most of the reforms necessary for accession to the EU. The special features of the transformation process become relatively less important and the economic development is shaped more and more by standard market mechanisms. Second, peripheral countries upon their accession into the EU shared many characteristics (identified in the literature as important for growth) that are similar to the conditions prevailing among the candidate CEE countries. In particular, their income per capita levels were about the same, they were (and still are) relatively small and open economies and their infrastructure was underdeveloped compared to the core of the EU. Third, the economic development of peripheral countries required a massive reallocation

[16] We use the term 'EU periphery' for countries and regions of the EU, which received 'Objective 1' status within the CSF program in 1989. The term 'periphery' comes from the observation that these regions, originally with 75% or less of the EU average GDP per capita, lie on the western and southern seaboards of the EU. Because of the paucity of data, we nonetheless restrict this meaning to analyzing the actual development of four countries only: Greece, Ireland, Portugal and Spain.

of resources on the wake of progressive trade liberalization, rapid technological change, influx of foreign capital (especially in the form of foreign direct investment) and high speed of both physical and human capital accumulation.

These similarities show that the recent economic experience of the EU periphery can indeed become a useful tool for studying the process of convergence of the most advanced among the transition countries. This fact has already been recognized by other studies on transition economies (see for instance, Barry et al., 2000, Kejak and Vavra, 1999). The calibration of our model is provided in Appendix E and F.

4.1 EU Peripheral Countries: Stylized Facts

In a companion paper (Kejak, Vavra, and Seiter, 2001a) we examine the post-war development of the cohesion countries, namely Greece, Ireland, Portugal and Spain, hoping to identify the factors responsible for the observed patterns of growth and convergence since the early 1960s. We found that until recently the group as a whole failed to keep up with the predictions of neoclassical growth theory with regard to convergence to the EU average income per capita standards. Most recently only Ireland drifted away from the group and surpassed the EU average.

The pattern of convergence in the EU periphery has not been monotonic, though. Peripheral countries displayed higher than EU average growth rates and partly converged in the period of 1960-1975. Yet, they remained among the poorest economies in Western Europe. This feature prevailed in the decade 1975-1985, when they hardly maintained their relative income per capita standards. It was only in the late 1980s when the process of convergence resumed and the peripheral countries, led by Ireland, began to approach the EU average income levels. It was also then, when the relative homogeneity of the group broke and differences between the forerunners (Ireland and Spain) and a laggard (Greece) became more apparent.

We reviewed most of the basic channels identified by theory as important for long-run growth in order to see whether they are capable of explaining the observed phenomena in the process of peripheral convergence. We found, however, that taken separately, these factors cannot account for most of the observed patterns. In particular, rates of capital accumulation have always been higher and the size of government smaller in the periphery than in the core, yet the countries failed to converge. Enrolment ratios have been rising steadily throughout this period as well as the exposure of the countries to international trade flows. Neither did the combination of the individual growth factors in standard growth regressions prove very helpful. We find that together they predict reasonably well within the group variations in growth rates until the end of the 1980s, but are not capable of explaining the stagnation of 1975-1985. Likewise, they failed to predict differences in individual records over the recent decade, perhaps partly because the measures we have used were no longer adequate.

We vaguely attribute the relative success of these countries since the mid-1980s to the progress of accession and integration within the EU, even though the cohesion countries generally entered the Communities in different periods (notably Ireland being a member since 1973). It is believed that the theoretical framework introduced in this paper and pioneered by Kejak (1993, 2003) enabled us to identify the channels through which the progress of integration could have impacted positively on the recent convergence record in the EU periphery and that it also has the potential of explaining the stagnation of the pre- and early accession periods. If so, the implications for the current transition countries together with relevant policy lessons would immediately follow.

In the quest for the period of technological take-off in the EU periphery we are especially concerned with the periods immediately preceding and following the accession of these countries. We already argued in terms of the model language that the process of accession can manifest itself using two basic channels. On the one hand, as progressive opening of the economy in terms of trade and capital flows, and on the other, as a massive technological transfer that enables fast technological catch-up with the technological frontier of the advanced countries. Hence, it is precisely the developments in the periods around the accession that can be used to validate our theoretical approach.

Taking each channel in turn, we documented in the companion paper (Kejak et al., 2001a) that each of the peripheral countries did see their share of exports substantially rise around the time of their entry into the Community. Apart from Greece, all of the countries managed to preserve and increase the shares since then, with Ireland almost doubling its initial value. Higher trade openness went along with improved access to international financial markets. Higher capital mobility envisaged by the process of integration should have enabled better opportunities for intertemporal substitution of consumption as well as for financing the local physical capital build-up. As a consequence of higher local marginal returns to capital, foreign savings would be attracted.

In line with economic theory, current account deficits rose rapidly, financed by various sorts of capital inflows. Buch (1999) reports that following entry, the structure of capital inflows shifted away from bank loans and investment towards FDI and portfolio investment. In terms of the model language this can be interpreted as a fall in the risk premium on capital investments in the periphery, which is the model variable controlling the degree of openness. With the exception of Greece, all the peripheral countries increased their share of FDI[17] inflows in GDP since accession. Of interest is also the case of Ireland which

[17] Our accent on FDI, which we share with others (see for instance Barry and Bradley, 1997), is motivated by a widespread finding that the FDI are carriers of technological transfers and knowledge spillovers (see for instance Barry and Bradley, 1997 or Coe and Helpman, 1995). Hence, we take the shares of FDI in GDP as proxies for the progress of technological transfer and catch-up. In sum, both opening to capital market flows and technological transfer began taking place in the EU periphery only in the 1980s, but the process has been very gradual. The speed of the capital account liberalization was hindered by fears of possible financial crises and capital flights that would result from a sudden rise in risk premia imposed on investment in these countries. As a consequence, the process of opening and capital mobility liberalization has been very gradual, often antedating the actual entry into the Community. This accords with the findings of Buch (1999) who cannot find a statistically significant effect of the EU entry on the degree of capital mobility for a subset of peripheral countries. She too puts the blame on the staggered nature of the process and announcement effects, especially in the case of Spain and Portugal. On the other hand, technological transfer through FDI operated only gradually after the integration process reached a certain irreversible momentum owing to large installation costs. As the cases of Spain and Portugal demonstrate, the inflows of FDI began to rise well before their actual entries into the EU.

did not begin to see substantial FDI inflows until the late 1980s, well after its entry into the Community in 1973. This can be partly attributed to protectionist and isolationist economic policies of previous periods, whose legacy survived until some reforms of the 1980s. Hence, we may loosely interpret the mid 1980s as the period when integration came into being, at least in the sense of trade openness and capital liberalization. In the model language, this would also be the moment since when the peripheral countries would have begun to exploit their technological potential.

4.2 EU Peripheral countries: calibration to stylized facts

The purpose of this subsection is to position the economic development of several EU peripheral countries, namely Greece, Ireland, Portugal and Spain, within the highly abstract nature of the theoretical model and to derive model parameters consistent with their individual experiences. In this vein, the experience of the EU periphery will serve as a natural benchmark from which we can quantitatively assess hypothetical trajectories of development for the transition countries of interest: Czech Republic, Hungary, and Poland.

Appendices E and F provide details on the calibration of the main model variables, i.e. mainly human and physical capital stocks. The outcome of the calibration process in terms of the transformed model variables, the consumption-capital and physical-human capital ratios, s and x, respectively, appears in Table 3. Evolution of k and h is also depicted graphically in Figures 4 - 6. In general, the observed patterns conform very well to the theoretical predictions of the model. First, the initial period between 1960 to 1975 was characterized by a high rate of physical capital accumulation alongside with only moderate improvements in knowledge. The trajectory of k versus h is therefore very steep in this period for all peripheral countries. This reflects a relatively low BGP rate of growth through the low productivity in the knowledge sector. The fact that the countries did experience fast growth and convergence during this period is due to transitional dynamics along the lines of conventional neoclassical growth models. As a check, we also observe that the German trajectory in this period is much steeper. This corresponds to the intuitive relative positioning of these countries as a technological leader (Germany) and laggards (the periphery). The development across the peripheral countries was also quite uniform, as they maintained their initial relative standing.

Second, we begin to see interesting differences in the 1975-85 period, when the $k - h$ trajectory for the group as a whole began to bend towards that of Germany. This may suggest that the potential of take-off began to be realized already in this phase, at least in some countries. The behavior of the group was influenced by the developments in Portugal and Spain, where the trend from the previous period was broken. We already noted elsewhere that it was in these two countries where the announcement effects of likely accession materialized in high FDI inflows prior to accession. Because we interpret FDI as carriers of technological change, these developments are entirely consistent with the model predictions. Interestingly, trajectories of Greece and Ireland continued to be very steep in this period, pointing to low productivity in the knowledge sector without the catch-up potential.

Third, in the period 1985-2000, bluntly identified as the period of the catch-up, we observe that the slope of trajectories of all countries, inclusive of Ireland and Greece, has approached that of Germany (in the 1985-1990 period). The fact that the EU periphery in this period did begin to converge is therefore not surprising in the light of the model prediction. The failure of Greece (whose trajectory has interestingly the lowest slope since 1980) to converge is pathological and is most likely attributable to social and institutional obstacles that have prevented it so far from capturing the benefits of higher technological potential. Similarly, we have no means of explaining the sudden rise in the slope of the Irish trajectory in the most recent period. We suppose, that it may be linked to accounting and measuring problems. Because this recent experience of Ireland has also shifted the slope of the group average, we do not comment on it, until more country specific research is done.

Taking stock, the experience of the EU peripheral countries in the 1975-1995 fits the model predictions reasonably well. This allows us to use the model in explaining both the seeming puzzle of the relative stagnation in the EU periphery in 1975-1985 and the convergence in the recent period, which could not be accounted for using conventional growth factors and techniques (Kejak et al., 2001a). It appears that the stagnation of the 1975-85 period was a consequence of low technological potential as the forces of transitional dynamics through physical capital accumulation of the previous period petered out and technological potential could not be realized because of various (mostly institutional) obstacles. Only increased openness and inflows of FDI, enabled by the EU membership, paved the way for the diffusion of knowledge from the technologically more advanced countries.

5 Accessing Transition Countries

5.1 Transition countries: calibration to stylized facts

Mapping the hitherto experience of transition countries into the "model language" is complicated primarily by the lack of reliable time series. This is especially painful in the case of measuring physical capital, for a bad guess on the initial value would have seriously biased the results. Because our last schooling attainment data were from the mid 1990s, we decided to calibrate the initial conditions for transition economies in 1995.

For the value of the physical capital, we employed the stylized fact for developed economies: $\left(\frac{K}{N}\right)_{1995} = 2.5\left(\frac{Y}{N}\right)_{1995}$, which also corresponds to the situation in the EU periphery (Hall and Jones, 1998). Measures of the stock of knowledge were derived with the same procedure as above, using the notional level of knowledge stock in the year 1990 for which we also had the attainment data.

With regard to the model channels of integration, i.e. access to foreign savings and technological transfer, here we find, too, that the process of integration was taking place along two lines: capital inflows (as a proxy for openness or low risk premium) and increase in the share made by FDI (as a proxy for the progress of technological catch-up), which is well documented[18]. The similarity of these developments in several transition countries with those of the EU peripheral in the 1980s allows us to treat them as in the phase of technological take-off. We believe this is certainly the case for the Czech Republic, Hungary and Poland which we analyze in the next section. For this reason we base our calibration of the knowledge capital stock on the parameters obtained from the EU periphery countries in the period 1985-2000. Our results on this calibration for the three CEE countries are summarized in Table 4.

5.2 Transition countries: Accession trajectories

In this section we parameterize several scenarios in order to analyze the effects of accession on the structure of the CEE economies and simulate their transition process to assess the speed of their convergence to the EU average. As already mentioned above, the accession may have a large impact on the social and institutional infrastructure (see Kejak, Seiter, and Vavra, 2001b) some of which we capture here:

- by the level of accessible frontier knowledge, B_H, with the direct effect on the long-run growth rate of the accession country;
- by the speed of knowledge diffusion ϕ, a catch-up factor;
- by the parameters of capital accumulation process, ψ and δ.

Using alternative scenarios with respect to these three dimensions we simulate the development of CEE countries under different initial conditions. As we shall see, the interplay of initial conditions and parameters of accession generate different transition patterns and also rather different speeds of convergence to the EU average.

As already explained, we analyze only a subset of transition countries, namely the Czech Republic, Poland and Hungary. We believe that this particular choice displays enough diversity that is characteristic of the group of transition countries as a whole. This diversity translates into the behavior of the model economy through initial values of the relevant variables. Especially, the relative initial position of the stocks of human and physical capital is important with respect to their BGP trajectories. Figure 7

[18] It is a matter of repetition to note that in terms of market based trade flows most transition countries have completed their journey from an almost autarchy to substantial openness (measured by the ratio of trade flows to GDP) in just a decade. In line with this, the majority of the CEE countries began their transition paths as net creditors, but in line with the theory they soon began importing capital to finance their consumption and capital accumulation. This was reflected in the size of their current account deficits, widely experienced throughout the decade. While in the mid-1990s, the majority of the countries in question, with the exception of Hungary and Poland, still kept positive net investment balances, none of them were able to do so at the end of the decade. These financing needs exercised pressures on the liberalization of their capital accounts, all along with the fears that a sudden capital flight or financial crises may threaten the stability of their currencies. To alleviate these fears most countries took a gradual and cautious approach towards the current account liberalization and throughout the 1990s maintained some sort of capital controls, especially with regard to short term capital. Nevertheless, comparison to peripheral countries in the 1980s undertaken by Buch (1999) suggests that the extent of capital mobility achieved by CEE countries in the mid 1990s was probably about the same. FDI inflows accompanied the progress in opening, especially in the case of Hungary and the Czech Republic they were sufficient to finance the current account deficits.

depicts initial conditions for the three countries in the k-h plane and positions them with respect to the BGP trajectories corresponding to a 4% growth rate. We observe that, while both Poland and Hungary are scarce in physical capital (relative to the BGP trajectory), the Czech Republic appears to be capital abundant in this respect. We also note that the initial position of Poland seemed to be very close to a hypothetical BGP trajectory of 4% growth.

We illustrate the mechanics of the transition processes from these initial conditions in a number of alternative simulations, each one designed to capture the effects of a specific isolated channel. The individual factors of interest are those that lay at the forefront of the discussion in the theoretical sections of the paper, namely the steady state-growth rate, the speed of the diffusion process, the rates of depreciation and the installation cost of capital. The simulation results are summarized in terms of the number of years necessary to achieve the current income per capita level of the EU 15 (see Tables 5). The tables are accompanied by a set of Figures 8 to 10 depicting the trajectory of output of the three countries before the current level of the EU average is reached. In the first set of alternative simulations (Table 5A and Figure 8) we explore the implications of different BGP growth rates, leaving all other factors constant. It is instructive to split the transition process into three phases. The first phase is entirely driven by the effects of the immediate opening of the economy in terms of capital flows. It is therefore very fast: the more accessible foreign capital markets become, the faster it is. Its main feature is the elimination of basic physical capital imbalances with respect to the properties of the final BGP. Hence, this phase is only important for the transition process of economies that are relatively far from their BGPs, such as Hungary and the Czech Republic, and will play only a minor role in a country such as Poland, if we assume 4% BGP growth rate[19].

The initial conditions of these countries also differ in that while the Czech Republic is positioned above all of its hypothetical BGPs, and thus exhibits relative excess of physical capital, the other two economies are found below in the case of the lowest BGP, being relatively scarce in capital. However, the relative initial distance from BGP depends on the assumed growth rate. In the case of a 3% growth rate, the Czech economy is very close to the respective BGP and so the first phase (characterized by rapid, almost instantaneous, decumulation of the capital stock) will not take place. Instead, the second phase will step in with a much slower decumulation of capital when the existing stock is being consumed or exported. As a consequence, the initial level of debt falls, putting a downward pressure on the prevailing interest rates. The fall in interest rates, in turn, combines with the fall in the capital stock in higher marginal returns to capital and Tobin's q. Increasing marginal returns to capital shifts the consumers' decision away from education to work, since investing and producing becomes relatively more attractive again. Overall, the luxury of having the excess of physical capital at the moment of accession allows people to allocate immediately a lot of time to adopting knowledge with all the benefits of fast growing

[19] It should be noted, though, that this characterization depends on the chosen parameters that determine the BGP. For instance, the initial position with respect to the BGP will be different for different BGP growth rates.

productivity. Thus, the effects of moderately rising u and the faster fall in the capital stock roughly cancel out each other in their impact on output. In effect, the country is likely to exhibit a stagnation of growth rates during this period. We can well observe this in Figures 5 for the case of 3% BGP growth rate. The depth of stagnation or decline will, however, be dampened by higher returns to knowledge adoption. Poland and Hungary, on the other hand, can exhibit initially very high returns to their low levels of capital stock for the cases of low BGPs. Hence, during the first phase these countries will experience a massive capital inflow, which will fast reduce these returns. More importantly, though, this period will be characterized by a desire to work hard and long, the value of u reaching its upper limit of one. This is a direct consequence of excessive capital returns: it pays off to work and invest at the expense of further education. As a result, the economy is growing extensively in this phase: the growth being entirely driven by capital accumulation at constant u. The second phase is more gradual than the first one, and takes over at the beginning of the technological catch-up process. This process manifests itself by reallocation of resources from production to knowledge accumulation. The reallocation is motivated by the improved productivity of the knowledge sector. This improvement is made possible through the new technological frontier, which becomes more and more apparent as all the three countries move along their BGPs. As a consequence, people work less (u falls), causing a unanimous slowdown in the economic performance. The third and final phase comes into play when the true potential of the new technological frontier is fully reaped and realized. The allocation of resources between work and education will remain steady and so will the rates of physical and human capital accumulation.

In sum, the experience of the three countries along their transition paths will differ in several important respects. First, the countries with lower initial levels of capital stock (Hungary and Poland) may experience an initial period of extensive growth, which will push their level of output higher relative to the capital abundant country (the Czech Republic) suffering from stagnation. These differences are born out at low BGP of 3%. The slowdown of sectoral reallocation then hits all three countries in a comparable way. Second, as the numbers in Table 5A reveal, the actual length of the convergence periods will depend on the initial distance from the respective BGP. In this case, the Czech economy benefits from its relative closeness to its BGP. This effect even dominates the negative effect of relative stagnation noted above. Third, the numbers of Table 5A conceal the fact that the extent and length of the reallocation slowdown vary according to the steady state growth rates and may not even be present at all. This is because higher growth rates along the BGP are tantamount to higher levels of the technological frontier. For this reason, the bold format employed in the tables highlights the cases of temporary slowdown.

In Table 5A we can see how long it will take Poland, the Czech Republic and Hungary to reach the current level of income per capita of EU 15 under three different scenarios with different BGPs: 3%, 4% and 5%. The results reflect our discussion above. The lowest BGP of 3% leads to protracted transition hurting mainly the most developed Czech Republic. Hungary and Poland start their accession with a boom followed by a brief reallocation recession before converging to the BGP. Importantly, the initial boom in Hungary makes its catching-up process with EU even faster than the one of the Czech Republic. For the higher growth rates the speeds of convergence are monotonically increasing with the BGP growth rates and the initial values of income. The transitions can be characterized by an accession boom followed by a smooth transition to BGP with only one exception of the accession recession in the case of Hungary with 3% growth rate.

Table 5B captures the effect of improved social infrastructure by removing barriers of knowledge adoption and thus speeding up the catch-up process (the higher ϕ means faster diffusion process). Unambiguously, lower costs to knowledge adoption are linked with a faster catching up process. The transition process is protracted due to accession recession when the adoption costs are high, but it is most painful for the Czech Republic and the least for Hungary.

In Table 5C we have analyzed the role played by a lower depreciation rate of physical capital in the catch-up process. The combination of the lower depreciation rate and a lower growth rate results in all the countries being initially below their BGPs. According to our discussion above there is the three-phase process with an initial accession boom (driven by capital inflow), followed by a recession. The country hit most by this development is the Czech Republic with the smallest boom phase contrary to Hungary's largest one. Interestingly, the Czech Republic is initially very closely situated to its 3% BGP. As such, it enjoys the best parameter setup with a slight initial accession boom followed by a negligible slowdown on its way to the BGP. Contrary to this, Hungary and Poland, initially below their BGPs, will experience the accession recession preceded with none or a negligible accession boom. The results of the last simulation scenarios highlight the role of the costs to physical capital adjustment on the process of accession and are provided in Table 5D. In principle, higher adjustment costs harm the transition process by making the adjustment in physical capital more resource-demanding. However, at the same time they bring about relatively higher investment in knowledge. Thus, the total effect is ambiguous. The interplay of these mechanisms and initial conditions make the effect of higher adjustment costs beneficial to the speed of transition for Hungary and Poland. However, in the case of the Czech Republic both higher and lower adjustment costs speed up the catching up process.

6 Conclusions

The contribution of the paper comes in two parts. First, we built an endogenous growth model of a small open economy with human/knowledge capital of the Lucas style and with S-shaped knowledge externalities. Second, we employ the model to capture the key aspects of development in TEs and to analyze the effect of accession to the EU in terms of their growth prospects. Extensions by adjustment costs to physical capital and an imperfect credit market via an upward-sloping debt supply enabled us to analyze transitional dynamics as well as sectoral adjustments. The model was validated through calibration to stylized facts of economic development in the EU periphery. We find that the experience of the EU peripheral countries fits model predictions reasonably well.

Using alternative scenarios we simulate behavior of model economies for different initial conditions of three transition countries: the Czech Republic, Poland and Hungary. The scenarios are designed to explore the effects of individual factors on the speed of their transition process to the BGPs. These factors include the steady state growth rate, the speed of the diffusion process, rates of depreciation and installation cost of capital. The interplay of initial conditions and parameters generate different accession patterns and also rather different speeds of convergence to the EU average.

According to the first set of scenarios meant to capture the implications of different assumptions about BGP growth rates the individual experiences along the transition path may differ in several important respects. Firstly, the countries with lower initial levels of capital stock (such as Hungary and Poland) may experience an initial period of extensive growth, which would push their level of output higher relative to the capital abundant country (the Czech Republic) suffering from stagnation. The slowdown of sectoral reallocation then hits all the three countries in a comparable way. Second, the actual length of the convergence periods will depend on the initial distance from the respective BGP. We show that countries may profit from the relative closeness to their BGP. This effect can even dominate the negative effect of relative stagnation. Third, the extent and length of the reallocation slowdown vary according to the stedy state growth rates and may not even be present at all. This is because higher growth rates along the BGP are tantamount to higher levels of the technological frontier. The second set of scenarios with improved social infrastructure showed unambiguously that lower costs to knowledge adoption are associated with a faster catching up process. The transition process is protracted due to the accession recession when the adoption costs are high, but it is most painful for the Czech Republic and the least for Hungary. The combination of the lower depreciation rate and a lower growth rate results in all the countries being initially below their BGPs. An initial accession boom (driven by capital inflow) will be followed by recession. The country hit most will be the one closest to its BGP. The last scenarios concern the role of the costs of physical capital adjustment in the process of accession. They show that higher adjustment costs hurt the transition process by making the adjustment in physical capital more resource-demanding. However, they also bring about relatively higher investment in knowledge. Thus the total effect is ambiguous. The interplay of these mechanisms and initial conditions make the effect of higher adjustment costs beneficial to the speed of transition for Hungary and Poland. However, in the case of the Czech Republic both higher and lower adjustment costs speed up the catching up process.

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A Threshold Externalities

There are two ways technological innovation can occur in the model: (i) large discontinuous advances which coincide with important eras like industrial revolutions and (ii) more cumulative and continuous progress during which the society learns how to use this potential. Much like Zilibotti (1995), we consider the former as being exogenous in the sense that economic activity has no effect on the occurrence of revolutionary advances. The second type of innovation depends on the gap between the present level of technology and the frontier productivity level given by the first type of innovation (see Nelson and Phelps, 1966).

Accordingly, technical progress is driven by investment in human capital[20] such that:

$$\frac{\dot{B}_t}{B_t} = \phi \frac{B_H - B_t}{B_H} \dot{H}_t \tag{16}$$

where B_H means the frontier productivity, $B_H \geq B_t$, $\phi > 0$ is the parameter of the speed of diffusion and H is the average level of human capital in the economy[21]. Consistently with Parente and Prescott (2000), the diffusion parameter is a measure of the barriers to knowledge adoption. We can see that the farther from the frontier an economy is and higher the diffusion parameter, the faster the growth of productivity for a given level of investment is. After solving Eq. (16) we obtain the following logistic solution

$$B(H; \phi) = \frac{B_H}{1 + (\frac{B_H}{B_0} - 1)e^{-\phi H}} \tag{17}$$

where B_0 is the initial level of productivity related to a zero level of human capital. We can easily see from (2) that the productivity monotonically increases with the level of human capital, $\partial B / \partial H \geq 0$, and there is an upper bound of productivity given by B_H (i.e. if H goes to infinity, productivity converges to B_H).

B First Order Conditions

The agents know the technology for creating new knowledge in the education sector, they, however, take the average level of accumulated knowledge, H, as given. We find the following necessary conditions for

[20]The existence of human capital makes our model different from the standard learning-by-doing models (Arrow, 1962; Romer, 1986) and from the model in Zilibotti (1995) where technical progress is a by-product of the investment in physical capital.

[21]Benhabib and Spiegel (1994) have provided empirical evidence confirming the existence of human capital externalities and the positive dependency of per capita income growth depends positively on average levels of human capital.

the dynamic optimization problem given by Equations (5)-(10)

$$\lambda = c^{-\theta} e^{-\rho t} \tag{18}$$

$$\lambda A(1-\alpha)(\frac{x}{u})^{\alpha} = \mu B(H;\phi) \tag{19}$$

$$q = 1 + \psi \frac{\iota}{k} \tag{20}$$

$$\dot{q} = qr(b) - \frac{y}{\alpha k} + \delta_k - \frac{q^2 - 1}{2\psi} \tag{21}$$

$$\dot{\lambda}/\lambda = -r\left(\frac{a}{k}\right) \tag{22}$$

$$\dot{\mu}/\mu = -B(H) \tag{23}$$

$$\lim_{t\to\infty} \quad k_t q_t \lambda_t = 0 \tag{24}$$

$$\lim_{t\to\infty} \quad b_t \lambda_t = 0 \tag{25}$$

$$\lim_{t\to\infty} \quad h_t \mu_t = 0 \tag{26}$$

$$\lim_{H\to\infty} \quad B(H) = B_H \tag{27}$$

where $H = h$ in equilibrium. Eq. (18) gives the condition that the maximizing agent is indifferent between consuming another unit of the good or saving it in the form of physical capital because the return from consumption (marginal utility) is the same as the return on investment in physical capital (shadow value λ). Eq. (19) states that the marginal return to study must be equal to the marginal return to work if working time u is smaller than 1. Eq. (20) specifies the static relation between Tobin q and the investment rate. Eq. (21) claims that the net return on domestic capital equates to the marginal cost borrowing. The last two Eqs., (22) and (23), describe the development of the shadow prices of capitals. The growth rate of the shadow value of knowledge capital is given by $-B(H)$. The TVC conditions given by (24)-(26) are straightforward.

C Balanced Growth Path

Using the first order conditions given by Eqs. (18)-(27) and accumulation equations (6)-(8) we can obtain the specification of the balanced growth path:

$$g^* = \frac{(B_H - \rho)}{\theta} \quad (28)$$

$$b^* = \frac{B_H - r^*}{v} \quad (29)$$

$$q^* = 1 + \psi g^* \quad (30)$$

$$u^* = 1 - \frac{1}{\theta}\left(1 - \frac{\rho}{B_H}\right) \quad (31)$$

$$q^* B_H = F_k^* - \delta_k + \frac{(q^* - 1)^2}{2\psi} \quad (32)$$

$$x^* = \left(\frac{\alpha A}{F_k^*}\right)^{\frac{1}{1-\alpha}} u^* \quad (33)$$

$$s^* = (g^* - B_H)b^* - \frac{q^{*2} - 1}{2\psi} + \frac{F_k^*}{\alpha} - \delta_k. \quad (34)$$

According to Eq. (28), consumption, physical and human capital and debt grow with a positive balanced growth rate $g^* > 0$ only if productivity in the education sector is sufficiently high and/or people are not too impatient. Combined with Eq. (31), we can see that a positive growth rate is possible only if some fraction of the endowed time is spent on education $u^* < 1$[22]. For an economy with a high degree of relative risk aversion (i.e. low intertemporal elasticity of substitution σ) where people prefer to smooth the consumption path, the resulting balanced growth rate will be lower while a thriftier and more patient society will enjoy higher growth rates. Eq. (32) shows the relation between the marginal product of capital F_k^*, Tobin q^*, given by (30) and the return to human capital B_H. It extends the standard result that in the presence of no capital adjustment costs net returns from both capitals are identical at the steady state (i.e. $F_k^* - \delta_k = B_H$). The relation between the capitals ratio x^* and the marginal product of capital is in (33). The last Eq. (34) captures the expression for the consumption-capital ratio s^*, it depends positively on debt b^* when preferences are logarithmic.

D Model calibration

The aggregate production function introduced earlier has the following general form:[23]:

$$Y = AK^\alpha (huN)^{1-\alpha}. \quad (35)$$

The effective labour input, huN, derives from the decision of all representative households to allocate the total time of their members to work, uN, augmented by their average level of knowledge capital,

[22]The situation when people spend all their time in schools and do not work seems to imply maximum growth in human capital. This is not feasible, however, on the BGP because the output F is zero and physical capital is, therefore, consumed and steadily declines rather than growing at the rate $g^* > 0$. This implies that $u^* > 0$.

[23]We use this formulation, because we feel, that once the average knowledge capital is correctly accounted for, there should be only little or no place for additional factors of labour input augmentation.

h. In this interpretation, N would stand for the total hours available in the economy. Because we lack reliable data on working hours for all the countries in question, we rather interpret N to be the total size of population, assuming away variations in average working hours. Instead of assuming that each person splits its time between work and knowledge accumulation, we simply suppose that each representative household decides on how many of its members spend their time working (fraction of u), while others are occupied with knowledge accumulation or leisure. This interpretation then implies that we measure labor input using the number of workers, L, such that $L = uN$. The normalized versions of this production function in terms of the total population and total workers can therefore be written as:

$$\frac{Y}{L} \equiv \frac{Y}{uN} = A\left(\frac{K}{uN}\right)^{\alpha} h^{1-\alpha}. \tag{36}$$

Because the theoretical model has been cast in the former representation, we also adopt GDP per capita in 1995 prices as our measure of economic performance and formulate all intensive variables with respect to total population. We choose the year 1960 as our starting period and normalize the starting level of GDP per capita so that EU15 equals 100. Collecting the stylized facts for the peripheral countries that could be matched across the model properties meant especially the computation of variables featuring in the normalized system variables of $s = c/k$ and $x = k/h$. While the evolution of consumption per capita, c, was trivial to obtain, it was more difficult to construct the physical and knowledge capital intensities, k and h. Thanks to our interpretation of the labor input, a measure of u can simply be computed from the available time series as a fraction of working population, $\frac{L}{N}$.

E Calibration of knowledge capital

As for the knowledge, accumulated by the non-working population, we assume that it is costlessly transmitted within households, so h refers to the average level of knowledge capital per worker. Like many other researchers, we lack direct measures of knowledge capital that would be relevant for our model framework. Many of them employ (variously amended) concepts of educational attainment (e.g. Hall and Jones, 1998, Temple, 2001) or enrolment ratios as the closest available measures. We too intend to use the easily available information on educational attainment in the construction of the stock of knowledge capital. Unlike the standard practice though, we don't think the educational attainment is directly applicable as a proxy for knowledge capital (as we use it), essentially because the two are related but distinct concepts.

As already highlighted in the introductory parts, our concept of knowledge is directly related to the concept of human capital of Lucas (1988) and Uzawa (1965). These concepts can jointly be understood as pools of ideas and inventions increasing productivity. On the other hand, education improves the ability to adopt and implement new technologies and ideas, both of domestic and foreign origins. Temple (2001) in his extensive survey of literature on growth effects of education speaks about 'skills acquired through education.' The distinctive feature of these two concepts lies in the fact that while a simple allocation of time to production of ideas and inventions improves productivity (by expanding the available pool of knowledge), better education has no such direct consequences. This distinction is crucial for any empirical work on level or growth accounting, because unless a direct measure of knowledge (or human) capital is available, one cannot employ measures of education attainment directly in place of production factors.

This is also the reason why we think most research studies failed to find significant impacts of human capital (or knowledge) accumulation on growth performance of countries when they use educational attainment as a factor of production (see for instance, Temple, 2001, Hall and Jones, 1998). In their influential empirical contribution, Benhabib and Spiegel (1994), inspired by the earlier work of Nelson and Phelps (1966), recognize this by arguing that "the role of human capital is indeed one of facilitating adoption of technology from abroad and creation of appropriate domestic technologies rather than entering on its own as factors of production."

In their empirical treatment, though, 'human capital' is simply a measure of school attainment, so the concepts of education and human capital become equivalent. We consider it a gross simplification that leads to the (in our view false) conclusion that it is the stock of human capital which affects the growth of per capita income. This is certainly not the case of productivity enhancing stock of knowledge (or disembodied human capital) that we have in mind here. Nevertheless the conclusions of Benhabib and Spiegel become directly relevant for ours, once we strictly interpret their concept of 'human capital' as educational attainment, which it effectively is.

To sum up, we interpret education in line with Benhabib and Spiegel as the capacity to absorb new ideas and creatively build upon the existing (productivity improving) knowledge stock in generating new ones. As a consequence, it is the level of education (measured, for instance, by average attainment) that matters for flows of productivity improving inventions, and hence for the growth of knowledge stock. This also means that we cannot use measures of school attainment instead of knowledge capital as a factor of production. The construction of a measure of knowledge capital from the available data on school attainment is described in more detail in Kejak and Vavra (2002). It suffices for our present purposes to register the accumulating equation which is consistent with the effect of education on growth of knowledge capital:

$$\log h_t = \log h_s + \gamma \int_s^t \log E_\tau d\tau. \tag{37}$$

This functional specification forms the basis of our measure of knowledge capital. We proxy the level of skills acquired through education, E, by data on the average school attainment in the population aged 25 and more which come from Barro and Lee (2000) and go back to 1960. Because of the five year paucity of the attainment data we approximate the integral in (37) for any year T for which the data are available as:

$$h_t = h_{t-\Delta t} e^{\gamma \frac{\log E_{t-\Delta t} + \log E_t}{2} \Delta t}, \quad (38)$$

where $\Delta t = 5$. Note that this specification is entirely consistent with the 'ad hoc' specification used by Benhabib and Spiegel in testing whether the level of education (which they refer to as 'human capital') impacts on growth. They use the average of the log of attainment to proxy the percentage change in the human capital as the factor of production.

The last piece of our exercise requires calibration of the scale parameter γ. It follows from the discussion in the main text that γ should be high during the productivity take-off, and lower before (or after). We adopt the growth rate of income per capita as a proxy discriminating between these cases. Because we are mostly interested in explaining the productivity performance of the EU peripheral countries in two different stages of their development, we conveniently allow only for two values of γ: before (and inclusive of) 1985 and after. We substitute the productivity growth rate for the rate of knowledge accumulation in (28) and compute γ for every year of data on educational attainment. We then average the gammas in the period of 1986-2000 (representing the take-off) and before[24].

F Calibration of capital stock

As regards the data for the value of capital per worker, $\frac{K}{L}$, we used the perpetual inventory formula starting with a notional value in 1960. To derive this notional value, $\left(\frac{K}{L}\right)_{1960}$, we took the average growth rate of investment per worker over the 1960s, g, and assumed the rate of depreciation, δ, of 7%[25]. Then, we determined $\left(\frac{K}{L}\right)_{1960}$ as $\frac{(I/L)_{1960}}{(g+\delta)}$. Using this approach, the potential bias in the notional value would rapidly fall and arguably will have disappeared by the onset of the 1980s, which is our period of interest. To check for this bias, we also experimented with the notional value set according to stylized fact for developed economies: $\left(\frac{K}{L}\right)_{1960} = 2.5\left(\frac{Y}{L}\right)_{1960}$.

[24]The construction of knowledge capital stock using (38) is additionally complicated by the possibility of transitional dynamics out of BGP that make h behave differently from (28). Because we assume the effect of this distortion is greater the further we go back in history (the possibility that the country is far from its BGP increases), we account for it by averaging γ only in the 1975-1985 period, instead of 1960-1985. We then use this γ_{75-85} in constructing the human capital index for the whole 1960-1985 period and γ_{86-00} for the 1986-2000 period with the help of (38). Our estimates of the evolution of knowledge stock in the four peripheral countries since 1960 are summarised in Table 1.

[25]We, however, experimented with other rates of depreciation, ranging from 2-20%, without significant alteration to our results.

Figure 1 Transition dynamics without externality – Case A

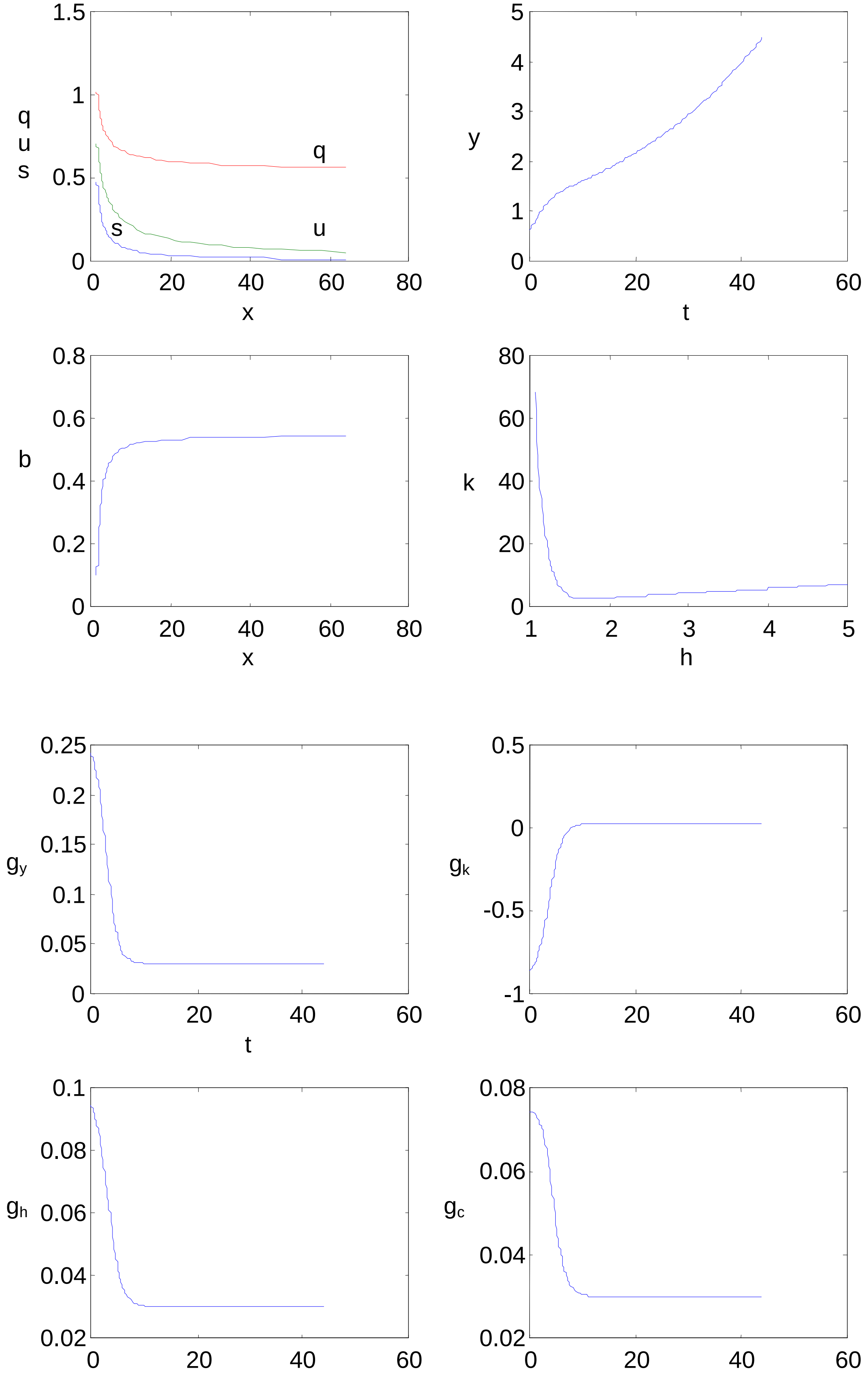


Figure 2 Transition dynamics without externalities - Case B

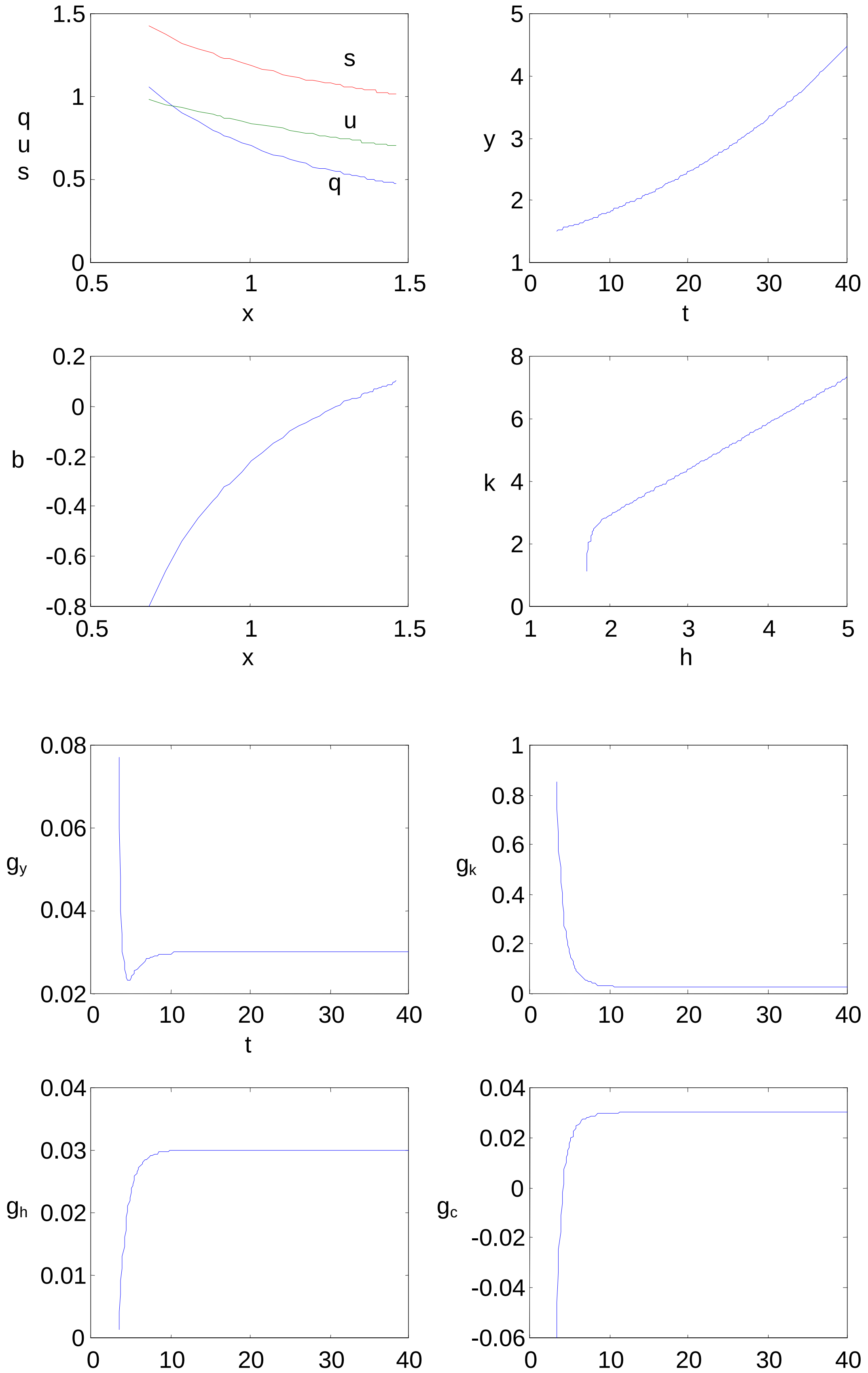


Figure 3 Transition dynamics with externalities

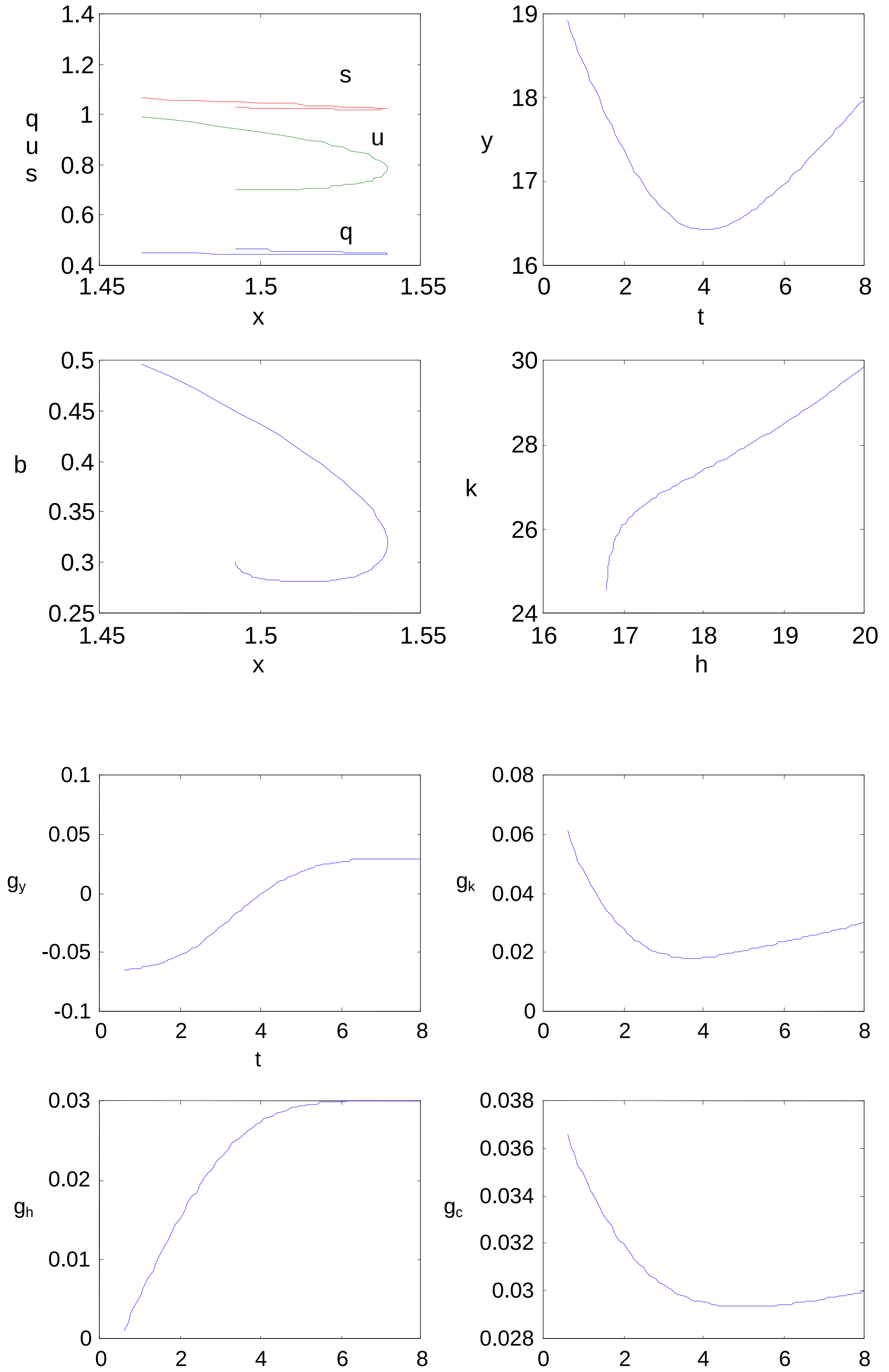


Figure 4 **Relative evolution of k and h in the EU periphery**

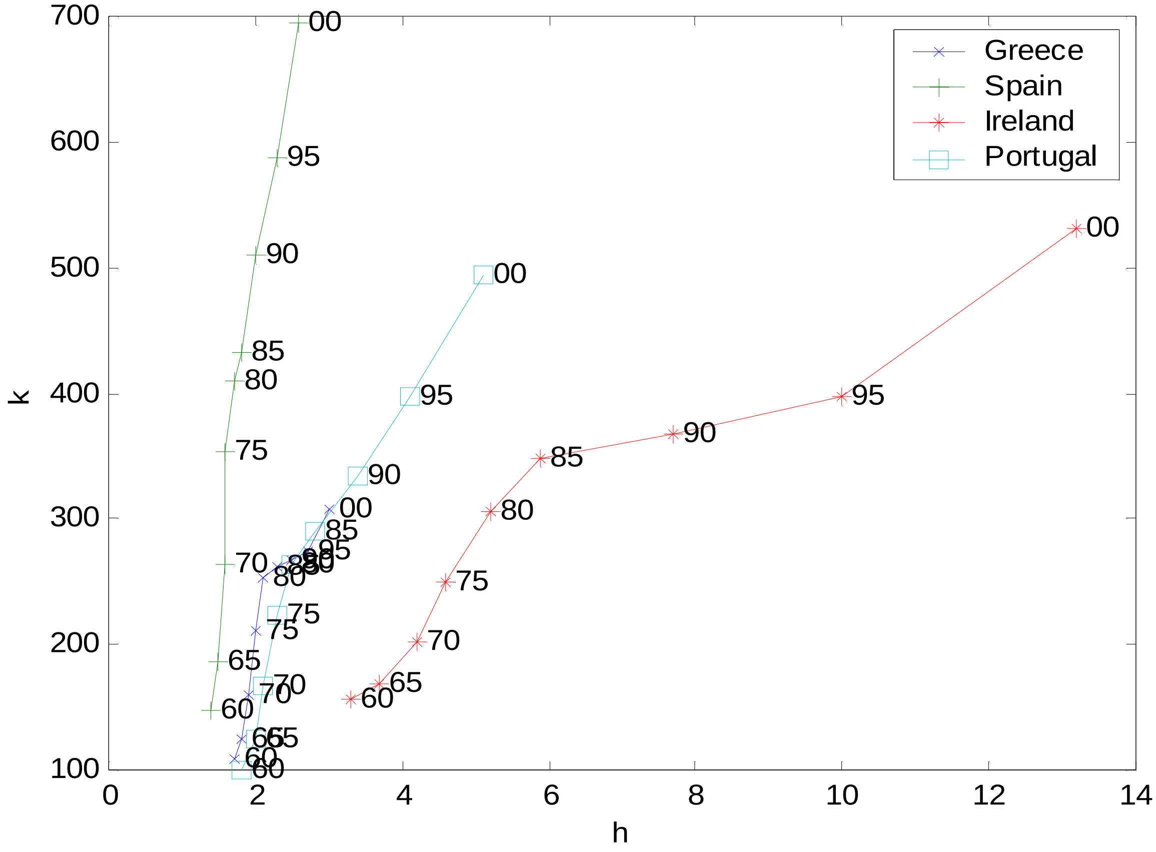


Figure 5 **Evolution of k and h in the EU periphery and Germany**

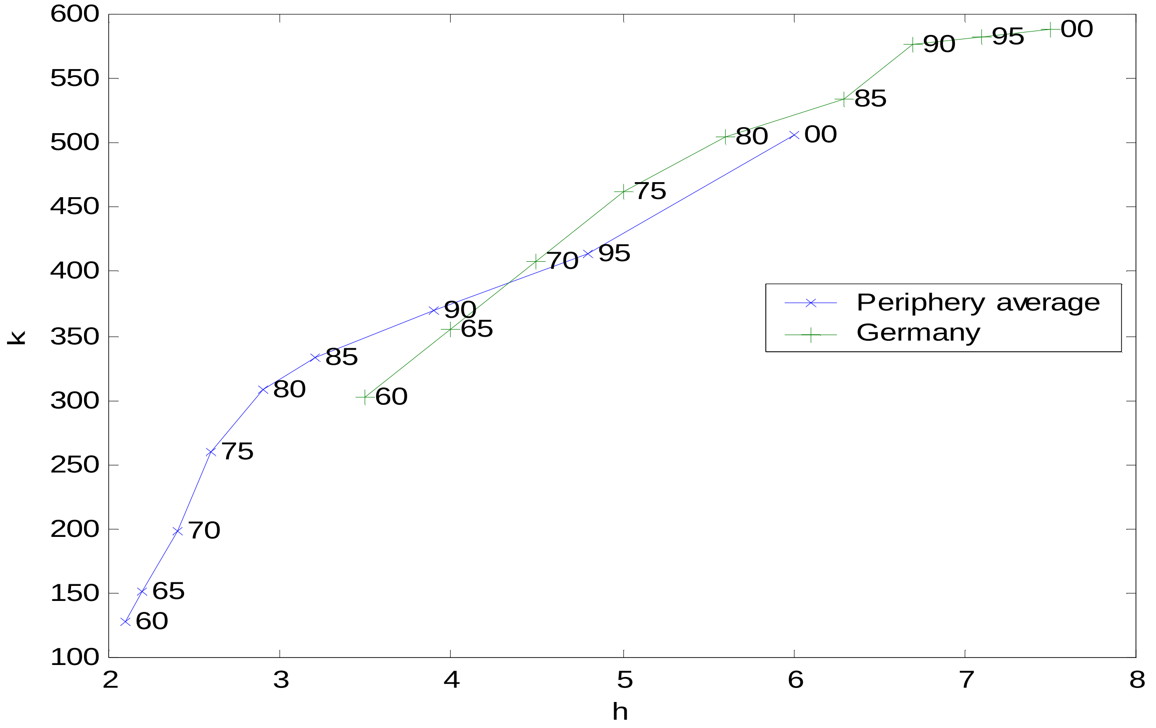


Figure 6 Evolution of k and h in the EU periphery

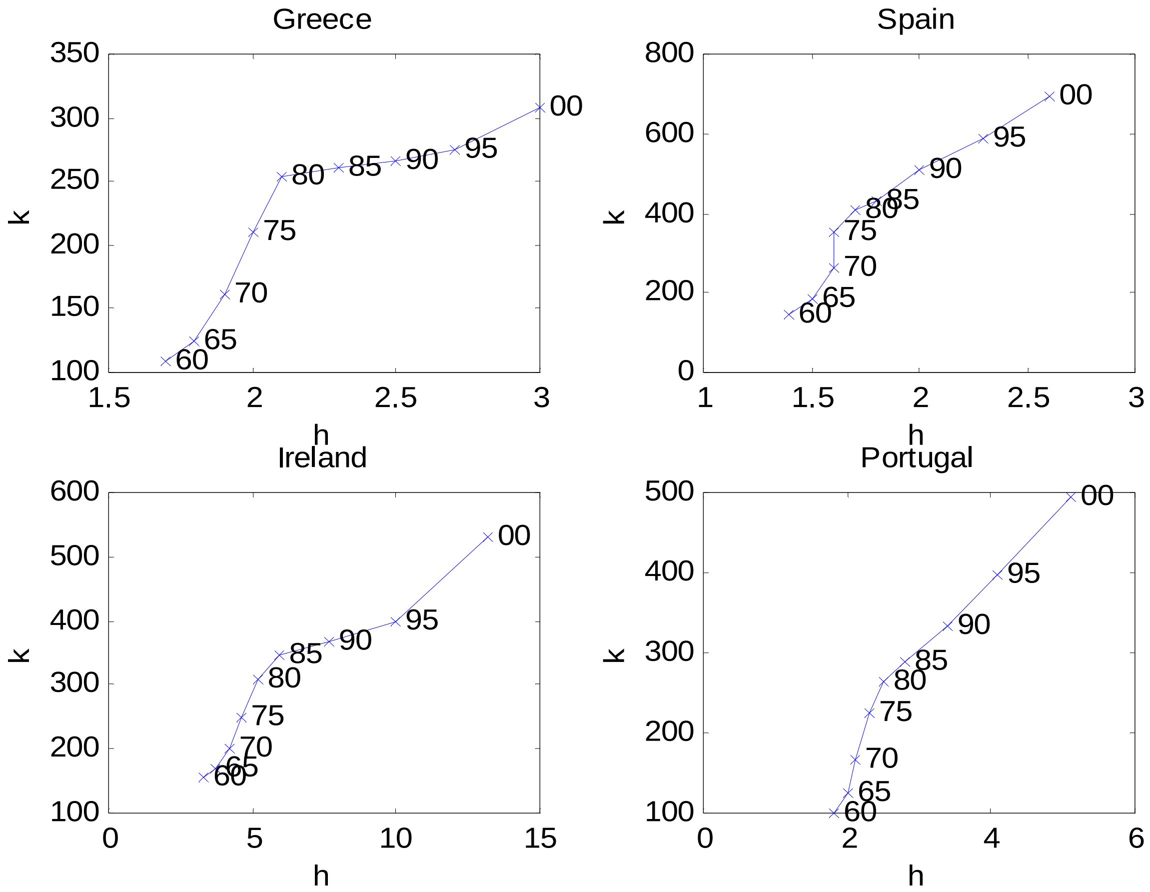


Figure 7 Initial conditions in selected transition countries

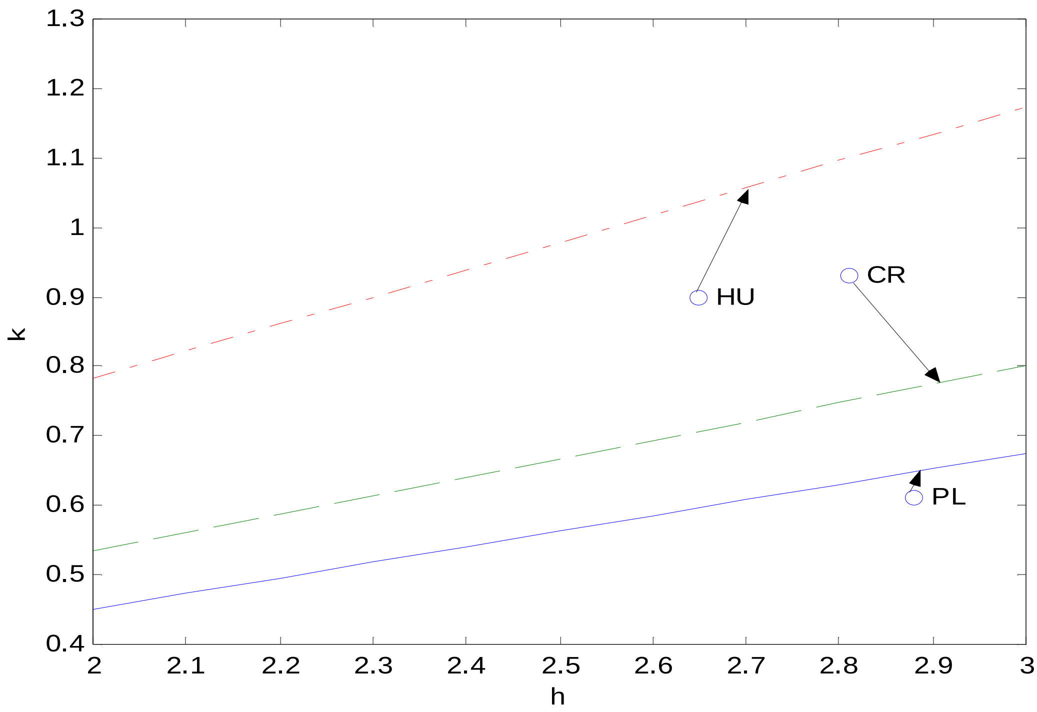
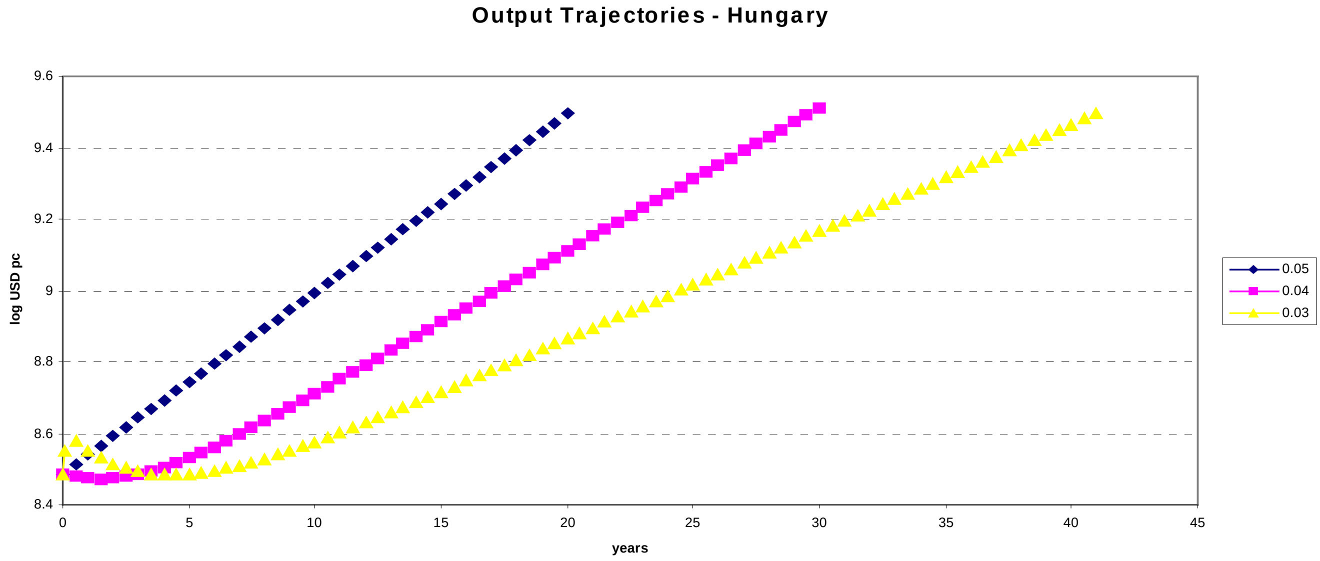
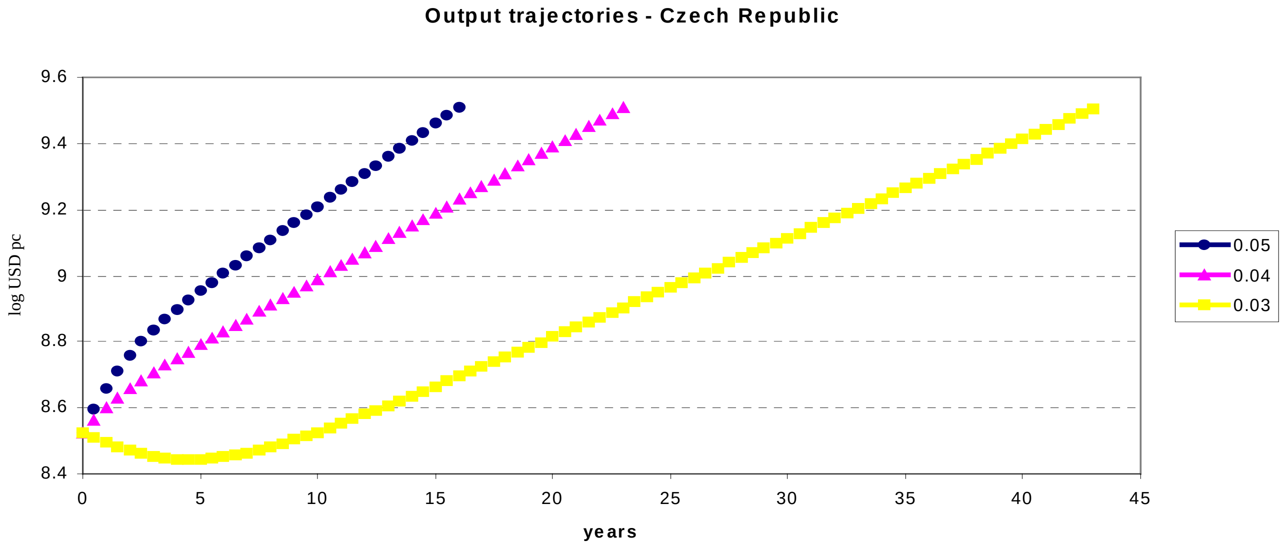


Figure 8 Output trajectories for different BGP growth rates





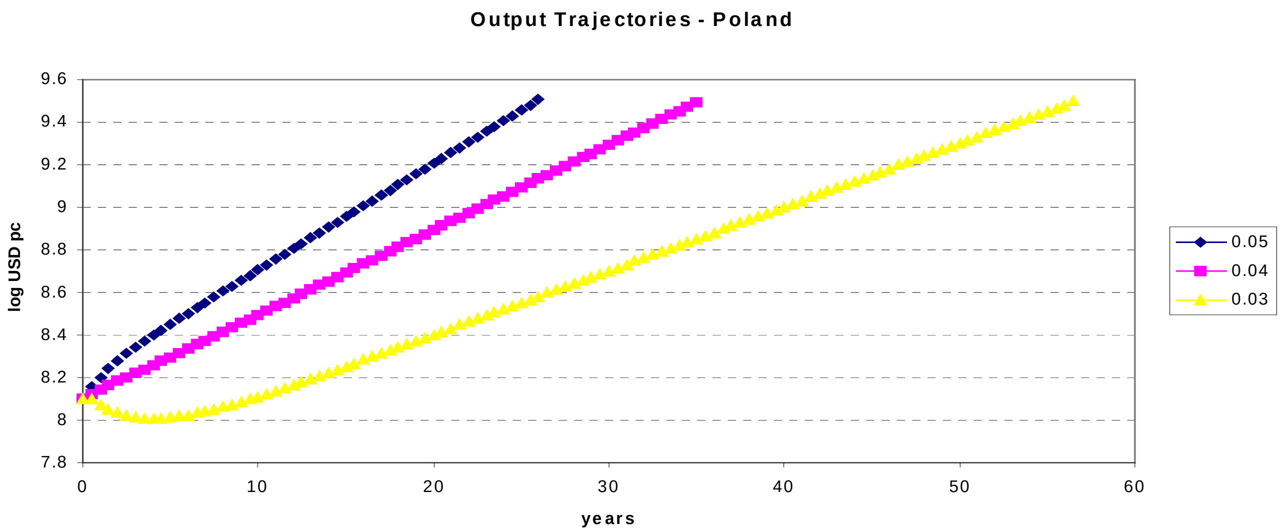
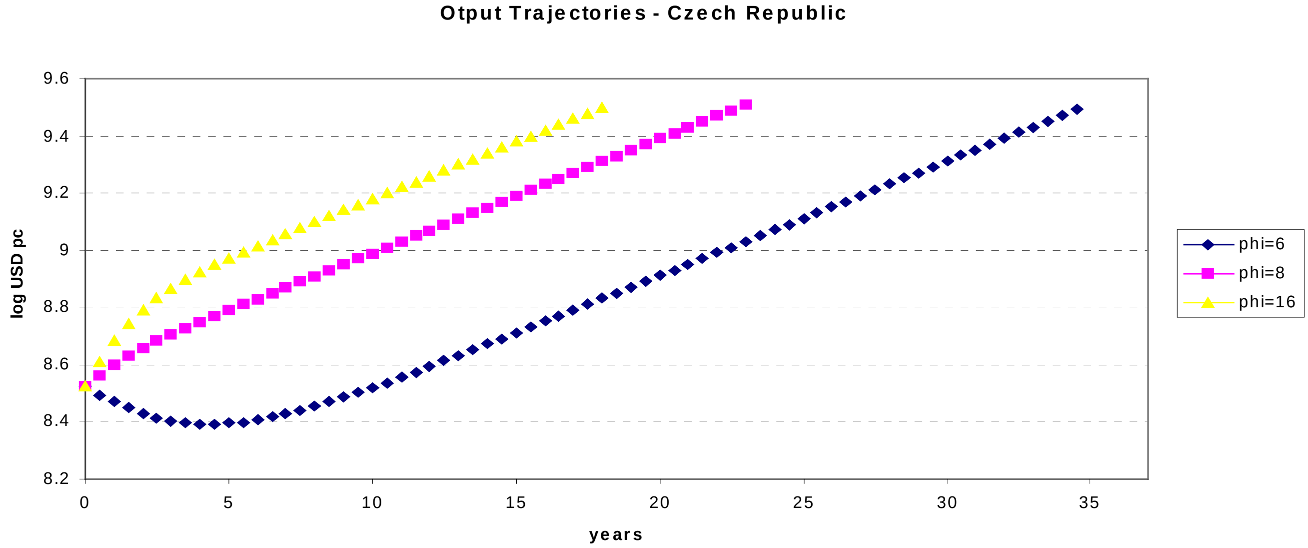
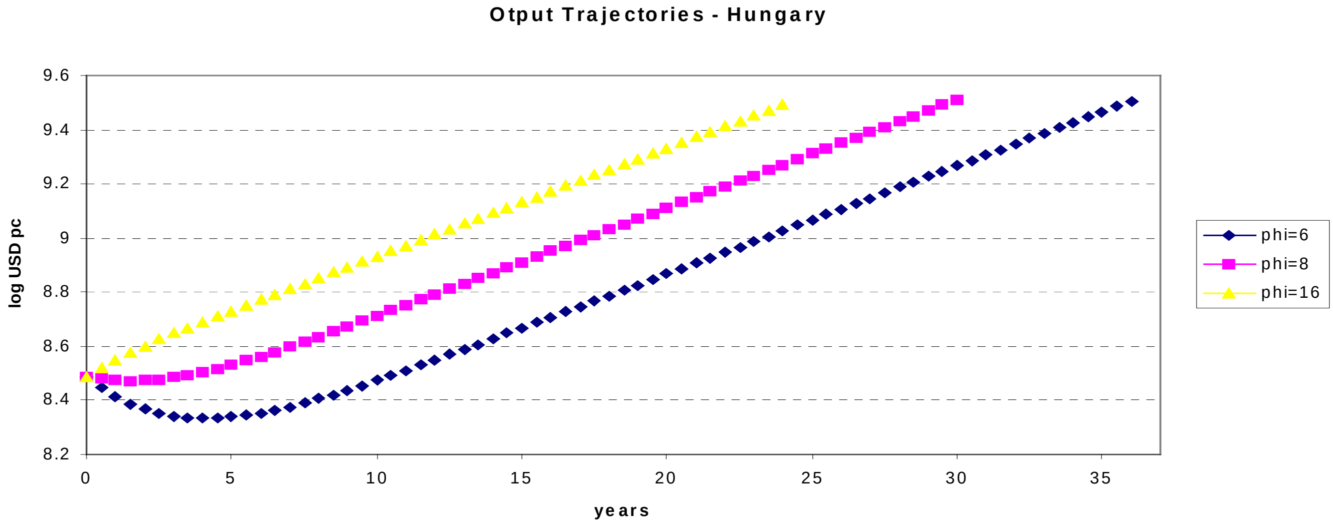


Figure 9 Output trajectories for different values of the diffusion parameter





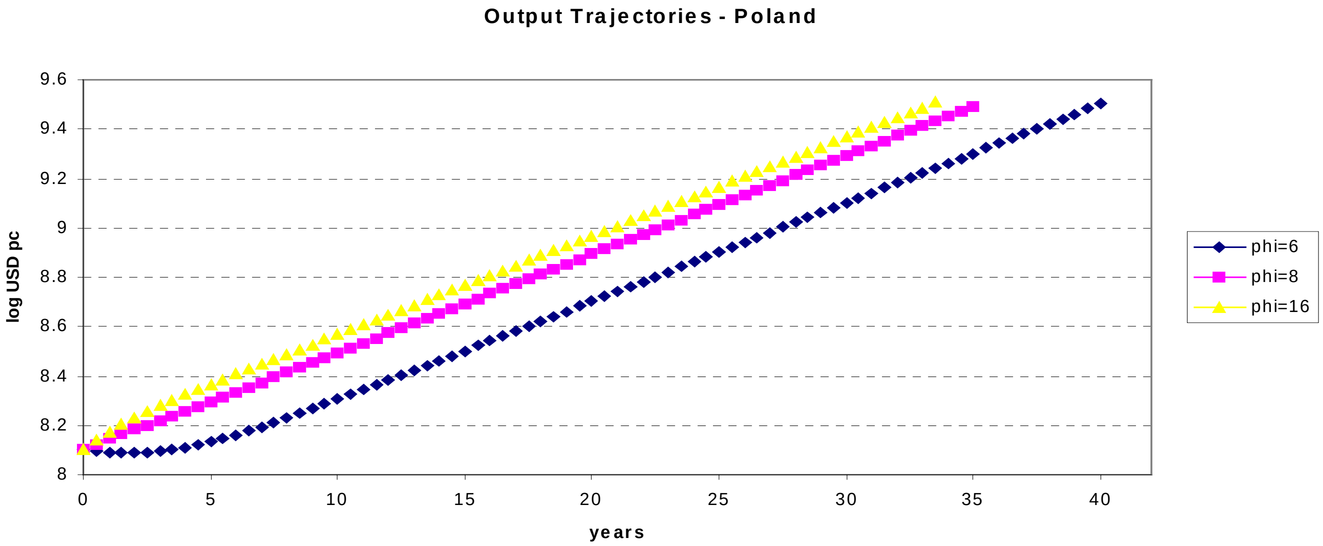
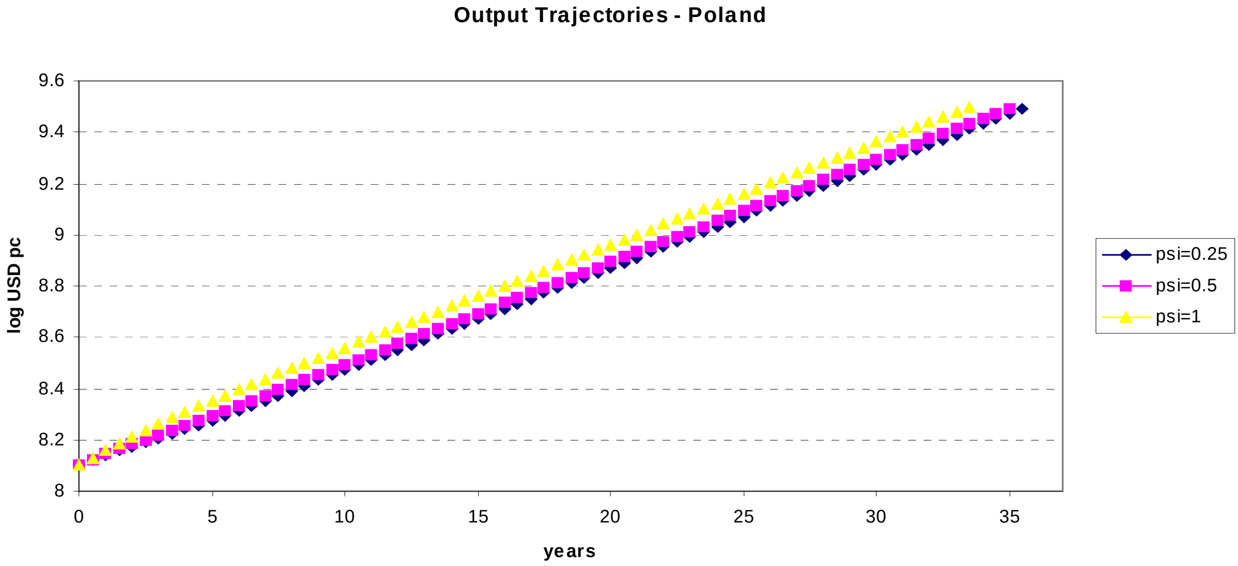
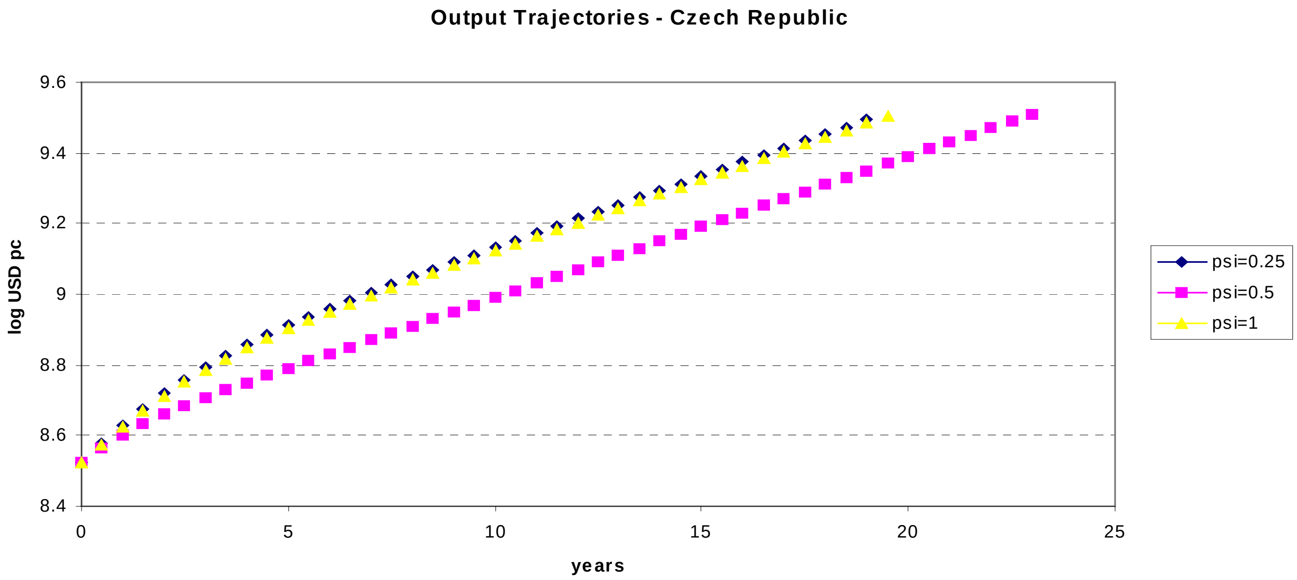


Figure 10 Output trajectories for different values of the adjustment parameter





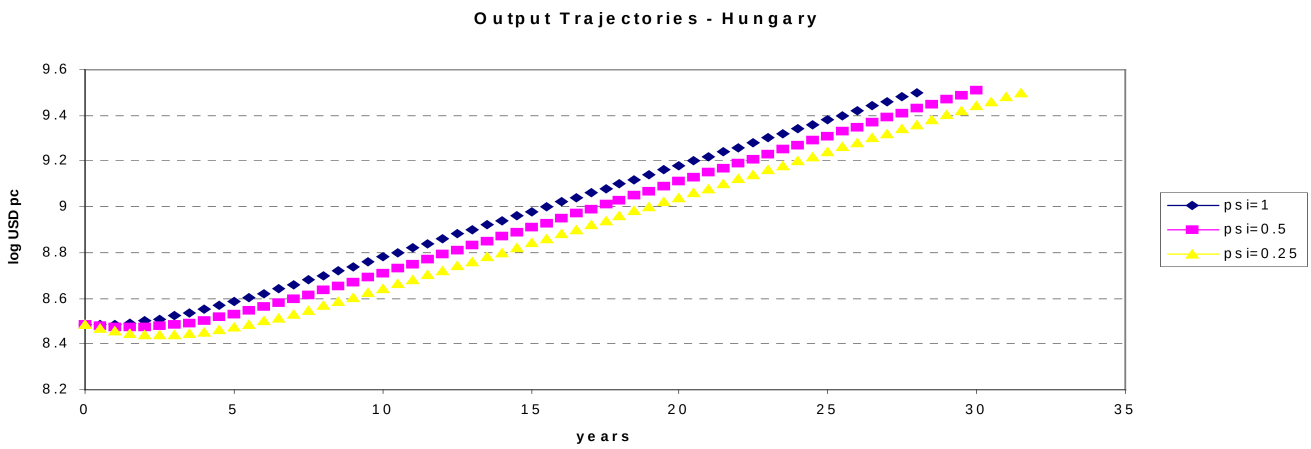


Table 1 Evolution of knowledge capital per capita in the EU periphery

	Greece	Spain	Ireland	Portugal	Average	Germany
1960	1.7	1.4	3.3	1.8	2.1	3.5
1960-65	1.8	1.5	3.7	2.0	2.2	4.0
1965-70	1.9	1.6	4.2	2.1	2.4	4.5
1970-75	2.0	1.6	4.6	2.3	2.6	5.0
1975-80	2.1	1.7	5.2	2.5	2.9	5.6
1980-85	2.3	1.8	5.9	2.8	3.2	6.3
1985-90	2.5	2.0	7.7	3.4	3.9	6.7
1990-95	2.7	2.3	10.0	4.1	4.8	7.1
1995-2000	3.0	2.6	13.2	5.1	6.0	7.5

Source: Own Computations

Table 2 Evolution of physical capital per capita in the EU periphery

	Greece	Spain	Ireland	Portugal	Average	Germany
1960	109.0	147.8	156.5	100.3	128.4	302.8
1960-65	124.9	185.9	168.4	125.5	151.2	355.8
1965-70	160.7	262.9	201.9	166.4	198.0	408.0
1970-75	210.8	354.0	249.8	223.7	259.6	461.9
1975-80	253.7	410.0	306.7	263.2	308.4	505.4
1980-85	261.7	431.8	347.7	290.2	332.8	534.6
1985-90	266.9	509.7	368.0	334.7	369.8	576.9
1990-95	274.7	587.1	397.7	396.9	414.1	581.9
1995-2000	308.3	694.1	530.7	493.8	506.7	588.1

Source: Own Computations

Table 3: Evolution of consumption to physical capital per capita

	Greece	Spain	Ireland	Portugal	Average	EU15	Germany
1960-65	0.56	0.49	0.56	0.46	0.52	0.41	0.38
1965-70	0.61	0.46	0.55	0.45	0.52	0.40	0.40
1970-75	0.59	0.42	0.49	0.46	0.49	0.39	0.40
1975-80	0.60	0.38	0.46	0.39	0.46	0.39	0.43
1980-85	0.58	0.33	0.38	0.34	0.41	0.38	0.42
1985-90	0.61	0.35	0.40	0.35	0.43	0.40	0.44
1990-95	0.65	0.33	0.43	0.36	0.44	0.37	0.36
1995-2000	0.66	0.31	0.45	0.35	0.45	0.37	0.38

Source: Own Computations

Table 4 Initial conditions for transition countries in 1995

	Real GDP per capita USD	Relative to EU 15	Physical capital per capita	Knowledge capital per capita	u	A	CA % GDP	FDI % GDP	Cumulative FDI % GDP	Net Investment Position % GDP
Poland	3299.2	24.5	0.61	2.88	0.38	0.28	0.7	2.9	6.2	-21.5
Czech Rep.	5025.9	37.3	0.93	2.81	0.49	0.32	-2.6	4.9	14.2	5.9
Hungary	4850.8	36.0	0.90	2.58	0.36	0.39	-3.4	4.6	32.4*	-56.2*

Source: European Economy (1999) , IFS, own computations
Note: 1997

Table 5A **Long run growth**

	3%	4%	5%
Poland	**56.7**	35.4	26.1
Czech Republic	**43.2**	23	16
Hungary	**41.3**	**29.9**	20.3

Table 5B **Diffusion process**

	16	8	6
Poland	33.5	35.4	**40.1**
Czech Republic	18.2	23	**34.9**
Hungary	24.4	29.9	**36**

Table 5C **Depreciation rate**

Depr. rate	0.06		0.10	
LR growth	3%	4%	3%	4%
Poland	**53.3**	**39.9**	57.6	35.4
Czech Republic	**41.7**	24.8	43.2	23
Hungary	**38.5**	**33.1**	45.4	29.9

Table 5D **Capital adjustment costs**

	0.25	0.5	1
Poland	35.9	35.4	33.7
Czech Republic	19.4	23	19.6
Hungary	**31.7**	29.9	**28.2**

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