Thünen-Series of Applied Economic Theory

Thünen-Reihe Angewandter Volkswirtschaftstheorie

Working Paper No. 66

Bridging the Technology-Gap in Economic Transition, the J-curve of Growth and Unemployment

by

Pascal Hetze

Universität Rostock

Wirtschafts- und Sozialwissenschaftliche Fakultät
Institut für Volkswirtschaftslehre
2006

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Pascal Hetze*

November 27, 2006

Abstract

The macroeconomic experience has been somewhat ambiguous during the historic experiment of economic transition in the former centrally-planed countries in Central and East Europe (CEE). The economic restructuring produced a notable catching-up in terms of productivity but also a J-curve shape of output growth accompanied by an increase in unemployment on a large scale. This paper models the transformation progress which leads to these contradictory outcomes. Before transition initiated catching-up, the economies suffered from two limits to growth: a gap of usable capital and a gap of technologies. Accordingly, a rapid technology transfer from the advanced Western economies led to a significant technological and structural change combined with high rates of labor reallocation. If we include frictions in the consequent matching between job seekers and jobs, the model reproduces the pattern of productivity, growth and unemployment that we find in the CEE countries.

JEL-classification: E24, O33, P20
keywords: catching-up, growth, unemployment, technological change, transition economies

*Rostock Center for the Study of Demographic Change and University of Rostock; Correspondence: Pascal Hetze, Rostock Center for the Study of Demographic Change, Konrad-Zuse Strasse 1, D-18057 Rostock, Germany, e-mail: hetze@rostockerzentrum.de

1 Introduction

At the end of the 1980s, the fall of the Iron Curtain initiated rapid changes in the Central and Eastern European (CEE) economies. The political revolution in these countries was accompanied by a revolution in institutional, organizational and technological knowledge. Deep changes in the industrial structure and the organization of firms followed from the removal of state control over economic activities and the sudden availability of international know-how, which political barriers blocked before. Free entrepreneurship and the new integration into the global market for ideas enabled a technology transfer from the advanced Western economies to the CEE countries, but the macroeconomic effects of the technological and organizational progress have not been as clearly positive as one might expect. Indeed, with the start of the economic transition in the 1990s labor productivity grew substantially in most industries and in most CEE economies. However, the sharp drop in the amount produced and the massive increase in unemployment contrasted the productivity gains at the beginning of the economic reforms.

Sachs (1996) summarizes the areas affected by economic transition in terms of four basic tasks of economic reform: systemic transformation, financial stabilization, structural adjustment, and the implementation of a framework to achieve catching-up growth. Although all four tasks are certainly interrelated, this paper has its focus on the two aspects structural adjustments and long-run growth. The link between both is that while new firms and industries arise and old ones disappear during the transition, this turnover is associated with the implementation of innovative technologies and new forms of organization which generate growth. We can understand this approach as the continuing production and productivity perspective of economic transition, under the assumption of already well established institutional reforms and financial stabilization.[1]

From the view of the growth literature, economies may have fallen behind in terms of relative income levels because of a gap in valuable objects, such as roads and factories, and an idea gap, which means that their citi-

[1] Institutional change in CEE did not always mean more individual freedom and higher economic efficiency as new regulations and new institutions have been established. These regulations sometimes had negative effects on employment and growth, which can be observed particularly in East Germany, where the West German legal and institutional framework has been adopted over night (see, for example, Sinn and Sinn, 1992, and Riphahn et al., 2001).

zens do not have access to the ideas that are used in the advanced economies to generate economic value (Romer, 1993). Capital accumulation, international knowledge-spillovers and education[2] can bridge the gaps and stimulate catching-up growth which enables the transition to a high income equilibrium. In contrast to other examples of catching-up growth, such as many Asian economies, the so-called "big-bang" reforms in many CEE countries initiated a shock therapy including the sudden access to the technology flows among the most advanced economies. The corresponding deep structural changes required economic responses at short notice. As this cannot always be the case, it is obvious that economic development will not follow a smooth path.

The CEE economies show a very similar pattern of the evolution of productivity, unemployment and growth. Hence, a theory of transition has to explain these apparently connected developments. The maybe most striking stylized fact about the macroeconomic pattern of transition is the J-Curve of output growth, that is highly negative rates of output growth at the beginning followed by a considerable recovery. Explanations for the output decline in the early stage of transition include, for example, demand and stabilization effects (e.g., Rosati, 1994) and frictions in establishing new trade relations after the price liberalization (Roland and Verdier, 1999). The high unemployment can be seen as the result of high labor flows and low matching rates during transition. Svejnar (1996) reviews this part of the literature. Aghion and Blanchard (1994) and Blanchard (1996, 1997) suggest reallocation from existing to new firms and restructuring of existing state firms as the basic mechanisms to account for both the increasing joblessness and the nonlinear growth dynamics in transition.

In this paper we refer to the idea that restructuring characterizes the transition economies and we assume that transition particularly means closing an idea gap and catching-up with frontier knowledge about technologies. The catching-up results from technology transfers and adjustments in the capital stock which involves elements of capital accumulation and capital restructuring. Furthermore, bridging the technology gap is a source of growth which is associated with structural adjustments and labor reallocation. As Haltiwanger et al. (2003) summarize the findings on job creation and job

[2]The idea that human capital is essential for catching-up growth via technological diffusion goes back to Nelson and Phelps (1966). Furthermore, see Keller (2000) for the role of international technology spillovers in less developed economies.

destruction in transition economies, the transition entails large-scale flows in the labor market, in particular at the beginning of the transformation process. From this it follows that employment declines if frictions hinder a perfect reallocation of workers from one to another employment.

The main purpose of the paper is to provide a united (macroeconomic) explanation for the output fall, the sharp rise in unemployment and productivity increases during economic transition. The innovative approach is to consider technological obsolescence and labor reallocation as major results of economic restructuring which lead to unemployment and an output fall as the integral part of the catching-up process during transition. We can show that the model reproduces the stylized facts of the CEE macroeconomic transition: The J-curve shape of output growth, the sharp increase in unemployment, and high but decreasing efficiency gains. We then run some simulations of the model which show how the transition process depends on the parameter specifications. While the basic pattern of the transition dynamics is robust to parameter changes, initial economic conditions, such as the size of the technology gap and frictions in the labor market, determine whether the macroeconomic responses to the technology transfer are more moderate or explosive. One can use this information to get an idea of why some transition economies experienced a higher and some a lower volatility in productivity, growth and unemployment.

The paper is organized as follows. In the next section, we discuss the macroeconomic effects of the economic transition in selected CEE countries. In section three, we develop the model of technology transfer and show how it affects employment and growth in the transition to a long-run equilibrium. Section four discusses variations in the growth and employment paths which yield from different parameter specifications in the simulation. Finally, section five concludes.

2 The Evolution of Productivity, Growth and Unemployment during Transition

Economic transition in the CEE countries towards open and market-oriented economies had strong, but mixed, macroeconomic effects (see for example Winieki, 1993; Campos and Coricelli, 2002). Taking differences in the extent and the timing of the reforms into account, we can observe a pattern of the evolution of labor productivity, output growth, and unemployment, which is nearly the same in the CEE countries. Figures 1 to 3 show these developments for the Czech Republic (CZ), Hungary (HU), Poland (PL), Slovakia (SK), Slovenia (SI), and East Germany (EG). The maybe most distinctive feature in the figures, and according to Blanchard (1996, p. 117) "the major theoretical challenge facing economist working on transition", is the J-curve of output growth. After initial declines in output levels, often with double-digit negative growth rates, a recovery followed three to four years after the first steps have been undertaken to reform the CEE economies. The growth rates in the years after the output drop showed the usual variations but were higher on average than the rates in most other European countries. However, one can identify a slight decrease in the rates since the mid 1990s when GDP of the six countries grew up to 5% on average.

In contrast to GDP, labor productivity did not show a clear fall when economic transition began. Instead, productivity increased, or at least it decreased not very much, in the two years of the output drop.[3] Moreover, productivity growth peaked in the early phase of transition, when all countries could achieve rates of productivity growth of more than 10%, and followed a downward trend afterwards.

Related to the growth puzzle is the question of why unemployment in the CEE countries increased so much. Up to 10 per cent of the total population was jobless in Slovakia, Poland and East Germany. However, it seems that unemployment is not rising anymore and even has begun to decrease gradually in some economies, such as for example in Hungary and Slovenia. With the exception of the Czech Republic, unemployment jumped from a (state fixed) zero level to its maximum within only three or four years. It is straightforward to see that output can not grow in an economy which dramatically reduces the input of labor in production.

In this paper we analyze whether bridging the prior productivity gap with a massive technology transfer in economic transition can be the cause for the described evolution of productivity, output growth, and unemployment. In the early 1990s, the considered CEE economies had a relative productivity of less than half of the EU average. However, after a period of rapid catching-up some CEE economies left the economically weaker West-

[3] Even the negative numbers of initial productivity growth in Slovakia and the Czech Republic can not explain the much deeper fall in output. Moreover, the special situation with the separation of the two countries could have led to data problems.

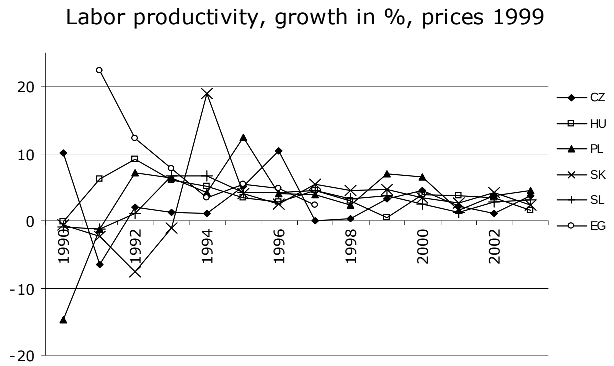

FIGURE 1: The evolution of labor productivity; Source: wiiw Annual Database on Eastern Europe, the Vienna Institute for International Economic Studies, and Deutsche Bundesbank Monatsberichte.

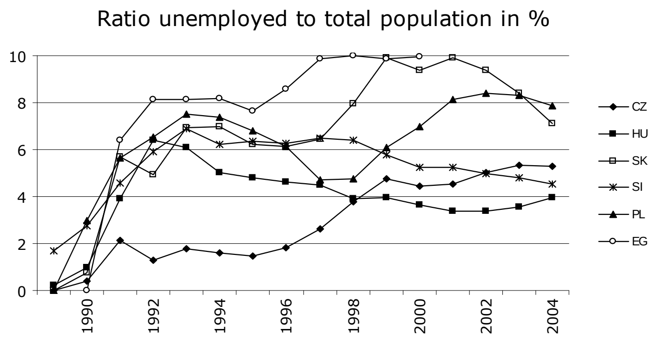

FIGURE 2: The evolution of unemployment; Source: See Figure 1.

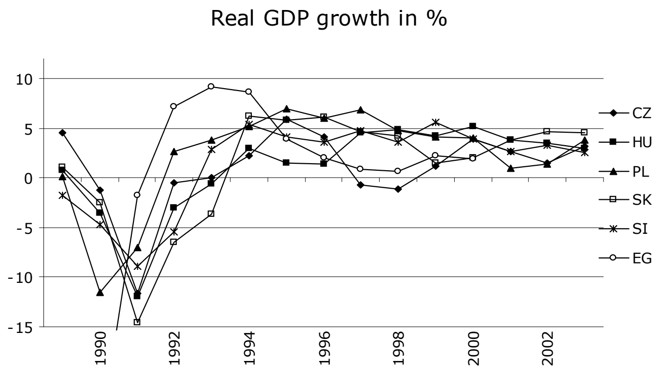

FIGURE 3: The evolution of GDP; Source: See Figure 1.

ern EU countries, such as Portugal and Greece, behind. The modernization of technologies and organizational change helped to close the productivity gap. This process was related to a restructuring of firms and structural adjustments with the new emergence and the decline of industries. For example, the agricultural sector and the heavy industry were downsized and replaced with new high-tech firms and an increasing service sector. This structural and technological adjustments entailed large scale labor reallocation. Evidence for the high job destruction, in particular in the early 1990s, and large worker flows in CEE countries can be found in a growing literature on labor turnover in transition economies (see, for example, Faggio and Konings, 2003, and Haliwanger and Vodopivec, 2003). Unemployment must be the consequence of labor reallocation if job creation is relative weak, for example because the allocation capacity of the labor market is not yet fully developed or workers represent still old and obsolete skills.

Investment, and in particular foreign direct investment (FDI), plays a central role in the process of structural and technological adjustments and knowledge diffusion (see Bedi and Cieślik, 2002, for a short review on this issue). Indeed, the enlargement and the renewing of the capital stock have been exceptional in the transition countries. The ratio of investments to GDP was much higher in CEE than in other European economies and, for example, in East Germany the ratio was twice as high as in the West during the 1990s (Pohl, 1999). If capital embodies technologies, investments drive the technological change. This implies that economic transition has been accompanied by a rapid implementation of current and highly productive technologies. For example, Lay (1999) shows for East Germany that the use of innovative production technologies, such as computer integrated manufacturing and computer aided design, diffused so quickly that the availability of these technologies among firms reached the West German level after a five-year period of catching-up. A further indicator for the new importance of technologies is the rise in the demand for the complementary skills, for example in the East German manufacturing sector (Fitzroy and Funke, 1995), also apparent in the coinciding increase in the returns to education (Gang and Yun, 2002).

3 The Model

Transition is modeled as the bridging of a technology gap of a backward economy which catches up with the global technological frontier via international technology transfers.[4] The technology transfer drives the productivity growth but we assume that, at the same time, it leads to a technology turnover and a reallocation of labor.[5] The reallocation of labor occurs as technological progress limits the lifetime of the existing sectors or industries and thereby causes job destruction, while the implementation of innovative technologies creates new sectors and vacancies. Frictions in the labor market, which hinder the immediate re-employment of job seekers, therefore result in unemployment. For the analysis of economic growth, we combine the two concepts of a gap in valuable objects in the form of a lack in capital and a gap in ideas in terms of antiquated technologies. We then explore how closing the technology gap relates to variations in employment.

3.1 The Production Side

Consider a transition economy which consists of a continuum of different sectors i indexed on the unit interval. The sectors produce a homogenous final good Y_t, which can be consumed and invested. The flow of the final good is manufactured in each sector with the input of labor $L_{i,t}$, basic components of capital goods $x_{i,t}$, and a continuous set of non-sinking intermediate goods z in the unit interval so that $\int_0^\infty z dz = 1$. The used technology specifies the quality of the intermediate goods which yields the sector specific productivity level $A_{i,t}$. The capital stock embodies the technology. This means that we evaluate the capital stock with the value it contains instead of counting physical units. Therefore, let $K_{i,t} = A_i x_{i,t}$ define the capital stock of sector i which includes the basic components $x_{i,t}$ and the corresponding technology in terms of its productivity $A_{i,t}$. Although different combinations of $x_{i,t}$ and $A_{i,t}$ can result in the same amount of capital, the actual mix matters in such

[4] The modeling adopts and combines elements from the multi-sector growth model of Aghion and Howitt (1992) and the convergence setting of Aghion (2005). The significance of technology transfers from highly developed to less developed countries has been proven in different studies (see, for example Coe and Helpman, 1995; Xu and Wang, 2000).

[5] A formalization of the idea that technological change and equilibrium unemployment are interrelated goes back to Pissarides (see, for example, Pissarides, 2000). Aghion and Howitt (1994) introduced the destructive effect of technological progress into a Schumpetrian growth model with search in the labor market.

a way that capital which represents current technologies is superior to the same stock with more antiquated technologies. This is introduced through some reject in production which is given by a fraction δ of the basic capital input $x_{i,t}$. Hence, the output loss is the larger the more basic capital goods instead of technology is used. Accordingly, the sector specific production function is

$$Y_{i,t} = L_{i,t}^{1-\alpha} \left(A_i x_{i,t}\right)^{\alpha} - \delta x_{i,t}. \tag{1}$$

The technology specifies a sector. A new sector arises as soon as a new technology becomes available as the outcome of a technology transfer (explained in the next section). However, the emergence of new technologies makes some old sector technologies obsolete because we assume that there exists a maximum distance to the current leading productivity level. The obsolescence ends the production and the sector disappears. This implies that the technology transfer establishes technological change accompanied by structural adjustments with the arising and the disappearance of technologies and sectors.

When a new sector enters the market, it can choose its technology which will be that with the highest productivity level available in the transition economy, which is $A_t^{\max}$. Afterwards, we take the sector technology as fixed and adjustments in the use of capital occur through variations in x_i. From the unchangeable sector technology and the increase in $A_t^{\max}$ over time it follows that the relative productivity of a sector, $a_{i,t} = A_i/A_t^{\max}$, gradually declines from $a_i = 1$ to the exogenously defined minimum level $a_i = a^{\min}$. This implies that different relative productivity levels exist coincidently because sectors emerge one after another. The cross sectional distribution of relative productivity is then given by the distribution function $H(a)$.

As long as the sector exists, firms maximize their profits $\pi_{i,t}$ at each point in time. In consideration of wages w_t as labor cost and capital costs r_t, the maximization problem in sector i is

$$\max_{L_{i,t}, K_{i,t}} \pi_{i,t} = Y_{i,t} - r_t K_{i,t} - w_t L_{i,t}. \tag{2}$$

First order conditions yield the demand for labor and capital, which is low if the relative sector productivity a_i is low. That is:

$$L_{i,t} = \left(\frac{1-\alpha}{w_t}\right)^{\frac{1}{\alpha}} K_{i,t}, \tag{3}$$

$$K_{i,t} = \alpha^{\frac{1}{1-\alpha}} \left(r + \frac{\delta}{a_i A_t^{\max}}\right)^{\frac{1}{\alpha-1}} L_{i,t}. \tag{4}$$

As A_i cannot be picked freely, firms accomplish to have the optimal K_i through varying the demand for the basic capital goods according to

$$x_{i,t} = \alpha^{\frac{1}{1-\alpha}} L_{i,t} \left(r a_i A_t^{\max} + \delta\right)^{\frac{1}{\alpha-1}} \left(a_i A_t^{\max}\right)^{\frac{\alpha}{1-\alpha}}. \tag{5}$$

Perfect mobility of labor implies that wages will always be equalized between the sectors. A market-clearing wage (not considering later frictions) indicates that w_t is set in such a way that aggregated labor demand is equal to total labor supply L:

$$\textstyle\int_0^1 L_{i,t} di = K_t \left(\frac{1-\alpha}{w_t}\right)^{\frac{1}{\alpha}} = L. \tag{6}$$

From this it follows that the wage is

$$w_t = (1-\alpha)\left(k_t\right)^{\alpha}, \tag{7}$$

where $k_t = K_t/L$ denotes the capital-labor ratio. Using (7) and (3), we see that each sector employs a share of the total labor supply equal to the sector share of the total capital stock. Let $\sigma(a_i) = K_i/K$ denote this ratio which yields

$$L_{i,t} = \sigma(a_i) L. \tag{8}$$

Labor input in the sectors varies with the operating technology. An innovative technology with a high relative productivity indicates a high proportion of total capital and labor input, $\sigma'(a) > 0$.

The amount produced in the economy yields from aggregating output of the different sectors. After substituting the first order conditions into the sector production function, total output can be written as:

$$Y_t = \int_0^1 L_i \left(a_i A_t^{\max} \frac{r a_i A_t^{\max} + \delta}{\alpha} \right)^{\frac{\alpha}{1-\alpha}} \left[1 - \delta \frac{\alpha}{r a_i A_t^{\max} + \delta} \right] di. \tag{9}$$

Some simplifying operations facilitate the interpretation of equation (9) and identify the sources of growth. Identical shares of capital and labor input of a sector ($K_i/K = \sigma(a_i) = L_i/L$) imply that all sectors produce with the same capital-labor ratio k_t. From this it follows that according to the production function the output per worker in sector i is $Y_{i,t}/L_i = k_t^{\alpha} - \delta k_t / \left(a_i A_t^{\max}\right)$. Alternatively, the output of sector i is given by $Y_{i,t} = \sigma(a_i) L \left[k_t^{\alpha} - \delta k_t / \left(a_i A_t^{\max}\right)\right]$. This term is equal to $Y_{i,t} = L^{1-\alpha} K_t^{\alpha} \sigma(a_i) \left[1 - \delta k_t^{1-\alpha} / \left(a_i A_t^{\max}\right)\right]$. If we now classify sectors by relative productivity a, we can sum over a as long as we multiply each single output by the density $h(a)$. These considerations let us reformulate the expression for Y_t so that we get the nearly standard production function $Y_t = L^{1-\alpha} K_t^{\alpha} \varsigma_t$, or in per capita units

$$y_t = k_t^{\alpha} \varsigma_t. \tag{10}$$

However, we add to the standard result that output depends on a measure for the stage of technological development ς, with

$$\varsigma_t = \int_{a^{\min}}^1 \sigma(a) \left[1 - \frac{\delta}{a A_t^{\max}} k_t^{1-\alpha} \right] h(a) da. \tag{11}$$

The value of ς depends positively on the progress made in increasing the productivity level $A^{\max}$. Hence, capital accumulation and technological progress are the sources of growth. However, note that capital accumulation has a negative second order effect because more capital without technological progress increases the reject in production. Consider furthermore that the returns to technological change are decreasing as the value of ς asymptotically approaches unity, $\lim_{A_t^{\max} \to \infty} \varsigma = 1$. This is because equation (11) reduces to $\varsigma = \int_{a^{\min}}^1 \sigma(a)$, which is equal to one if the growth in the productivity level is unrestricted over an infinite time horizon.

3.2 The Technology Transfer

The transition economy exhibits a technology gap but during transition a technology transfer from abroad closes the gap. The gap appears in the difference between the maximum home productivity level $A_t^{\max}$ and the international frontier level $\bar{A}_t$. The technology transfer increases the productivity level of the technology pool defined by the set of intermediate goods. The productivity level A_z of a single intermediate good z varies but the integral set defines the productivity level $\int_0^\infty A_z dz = A_t^{\max}$. The Poisson arrival rate of a technology transfer over all intermediate goods is μ with $\mu \in [0,1]$. We assume that the technology transfer let the productivity of an intermediate good jump to the international frontier level $\bar{A}_t$. Although the arrival rates of technology transfers for the different intermediate goods are independent from each other, they contribute to the shared pool of technological knowledge. In a share $(1-\mu)$ of the intermediate goods no technology transfer takes place. This leaves their contribution to the available technology pool at the pre-period level $A_{t-1}^{\max}$. As the influx of foreign knowledge into the technology pool is thus $\mu\bar{A}_t$, the current maximum productivity level is

$$A_t^{\max} = \mu\bar{A}_t + (1-\mu)A_{t-1}^{\max}. \tag{12}$$

Suppose that the global technology frontier $\bar{A}_t$ grows at the constant rate $\bar{g}$ which we take as exogenous for simplicity. Let then

$$\beta_t = \frac{A_t^{\max}}{\bar{A}_t}. \tag{13}$$

denote the relative proximity to this frontier which measures the technology gap during transition. It follows immediately that the distance variable evolves over time according to:

$$\beta_t = \mu + \frac{1-\mu}{1+\bar{g}}\beta_{t-1}. \tag{14}$$

It is straightforward to see that the economy approaches the global technology frontier if $\mu > \bar{g}\beta_{t-1}/(1+\bar{g}-\beta_{t-1})$. In the case of the European transition countries, we can say that μ switched from zero to a positive value at the moment when the fall of the iron curtain allowed for an inward technology transfer. The technology transfer gradually closes the technology gap if the value μ is large enough. However, the economy will not reach or even move the frontier $\bar{A}_t$ unless home research contributes to the global technology pool. Instead, the difference equation has

$$\beta^* = \mu \frac{1+\bar{g}}{\bar{g}+\mu} \tag{15}$$

as a unique fixed point which indicates the end of economic transition. But beforehand, the rate of change in $A_t^{\max}$, which is g_t, exceeds the global rate $\bar{g}$ and the convergence to the global frontier can be written as

$$g_t = \mu \left(\frac{1+\bar{g}}{\beta_{t-1}} - 1 \right). \tag{16}$$

We can interpret μ in the equation as the arrival rate of technological improvements while the following term indicates their magnitude. The value of g_t is obviously the larger the more the economy is behind the global technology level, namely the smaller β_{t-1} is. This is because the jump in the productivity level of each intermediate good is large if the difference in the levels $\bar{A}_t$ and $A_t^{\max}$ is large. Consequently, the rate g_t decreases over time and becomes equal to its global counterpart $\bar{g}$ as soon as $\beta_t = \beta^*$.

3.3 Growth and the Long Run Equilibrium

While the technology transfer and capital accumulation generate growth during transition, the long-run equilibrium is characterized by a steady state with a constant output level in per capita units. From the production function $y_t = k_t^{\alpha} \varsigma_t(A_t^{\max}, \cdot)$ it follows that output per capita grows as long as the capital-labor ratio and the stage of technological development increase. Technological progress is a continuous process, even though the output effect of a growing $A_t^{\max}$ decreases. As the steady state we have $\varsigma = 1$ and technological progress has no further effect on growth. This implies that the production function converges to the case $y_t = k_t^{\alpha}$.[6] Moreover, the capital-labor ratio will approach its equilibrium value k^* if we assume the standard properties of the neoclassical growth model.

We consider a closed economy in which saving is equal to investment.[7]

[6] This holds only if $A_t^{\max}$ grows fast compared to k, that is if $g > (1-\alpha)\left(k_t - k_{t-1}\right)/k_{t-1}$. This is true in the steady state as the rate of technological progress is positive, whereas $k_t = k_{t-1}$.

[7] We ignore here FDI which played an important role in the transition process of the CEE countries. The introduction of FDI would not change the main results of the model but it would have implications for welfare and the speed of transition.

Individuals consume a share of their income and use the remainder for savings, which should be a constant fraction s of income during transition but is subject to preferences in the long-run. Investments lead to capital accumulation but capital depreciation opposes the increase in the capital stock. Capital that represents outdated technologies suffers a higher depreciation. This is modeled in the way that depreciation affects only basic capital units x. The difference equation of the capital-labor ratio therefore is

$$k_t - k_{t-1} = sy_t - \frac{\varphi x_t}{L_t}. \tag{17}$$

Consider that $A_t^{\max}$ increases over time which substitutes the use of basic capital units. Finally, the demand for x disappears in equilibrium and equation (17) reduces to $k_t - k_{t-1} = sk_{t-1}^{\alpha}$.

As soon as economic transition is over, transition towards a steady state can be considered. Savings are assumed to be constant during economic transition. However, we introduce a steady state as a long-run basing point to illustrate that the model converges to the neoclassical growth model under the assumption of utility maximization. Hence, only the long-run equilibrium considers preferences and that a variable share of income can be used for consumption. Consumption generates the utility $v(c_t)$ and, with ρ as the discount factor of the representative individual, the infinitely-lived consumer has a present value utility of $V = \sum_{t=T}^{\infty} \rho^{t-T} u(c_t)$ at time T after economic transition. Then, the optimization problem is to maximize V subject to $k_t = k_{t-1} + s_t k_{t-1}^{\alpha}$. In the end, the standard procedure of dynamic optimization yields an equilibrium capital-labor ratio independent of savings:

$$k^* = \left[\alpha\left(\frac{\rho}{1-\rho}\right)\right]^{\frac{1}{1-\alpha}}. \tag{18}$$

The model converges to the simple neoclassical growth model in the long run. Technological progress in the steady state leads only to an extension of the sector interval but has no effects on growth. Therefore, the long-run equilibrium of the model is a steady state without growth in output and consumption. However, significant growth effects arise during transition as long as capital is accumulated, the stage of technological development changes, and the employment level varies over time.

3.4 Growth during Transition and Labor Reallocation

Growth and employment during transition depend on the speed of the technology transfer. While the direct effect of the technology transfer on productivity growth is strictly positive, bridging the technology gap combined with technology obsolescence may involve negative consequences for employment, capital formation, and growth. A fall in employment and capital depreciation that exceeds new investments cause a output loss. In combination with the productivity increases it yields the macroeconomic pattern of transition.

Fluctuations in employment result from the continuous reallocation of labor. In particular early stages of economic transition are accompanied by technological change and structural adjustments that produce a degree of job destruction which is higher than the corresponding job creation.[8] Job destruction arises due to the fact that gradual technological obsolescence in combination with a minimum technology level causes the closure of the firms affected by the obsolescence of their technologies, and the dismissal of the firm's employees. As the wage freely balances demand and supply of labor, no unemployment occurs if dismissals face the same amount of reemployment. In contrast to this, we henceforth consider frictions in the matching process between unemployed and jobs which prevent dismissed workers from immediately reentering the workforce. This means that aggregate labor input is only a share of total labor supply N,

$$L_t = (1 - u_t)N, \tag{19}$$

where u denotes the unemployment rate.

Sectors with a productivity level that reaches a value below $a^{\min}$ stop production and dismiss all their former employees. The inward technology transfer continuously raises the maximum productivity level $A_t^{\max}$ of the latest technology, but this implies that relative productivity a of the other technologies declines over time. At some stage the level of a sector i falls below $a^{\min}$ and the sector disappears. Hence, only those sectors survive the technological change at date t which had a relative productivity of $a_{i,t-1} \geq (1+g)a^{\min}$ in the previous period $t-1$. The faster maximum productivity grows, i.e. the higher g_t is, the fewer sectors survive a period. This means that a large technology transfer produces a high sector turnover. Workers

[8] See Haltiwanger, Lehmann and Terell (2003).

that were employed in sectors with $a^{\min} \geq a_{i,t-1} < (1+g_t)a^{\min}$ at date $t-1$ fall victim to the structural change at t because their firms cannot hold a level above or equal to $a^{\min}$. As sectors employ a share $\sigma(a)$ of the total labor input $L = (1-u_t)N$, the integral over the sectors between $a^{\min}$ and $(1+g_t)a^{\min}$ yields the total number of destroyed jobs:

$$U_t^+ = (1-u_t)N \int_{a^{\min}}^{(1+g_t)a^{\min}} \sigma(a)da \tag{20}$$

The re-entry into employment is always lower than the number of unemployed workers as we consider frictions in the matching between job seekers and jobs. For simplicity we assume a linear matching technology, where a constant share γ of the unemployed finds a new job:

$$U_t^- = \gamma u_t N. \tag{21}$$

This simple form of the matching implies that γ is the indicator for the magnitude of the frictions. The relative effect of technological change and sector turnover on employment is the higher the lower γ is.

Unemployment will rise as long as U_t^+ exceeds U_t^-, and the other way around. The unemployment rate therefore evolves according to $u_t - u_{t-1} = (U^+ - U^-)/N$, which yields

$$u_t = u_{t-1} + \int_{a^{\min}}^{(1+g_t)a^{\min}} \sigma(a)da - u_t \left[\int_{a^{\min}}^{(1+g_t)a^{\min}} \sigma(a)da + \gamma \right]. \tag{22}$$

Changes in the employment level as well as variations in the quantity and technological quality of the capital stock cause economic fluctuations. Output per capita (instead of per worker) results from the production function with unemployment $Y_t/N = y_t^N = (1-u_t)\, k_t^{\alpha} \varsigma_t$. While bridging the technology gap continuously increases the stage of technological development ς and contributes strictly positive to output growth during transition, it is not clear whether the capital-labor ratio and the employment rate increase or decrease. The depreciation of obsolete capital works against investments and the labor reallocation can result in a rise or a decline in employment. Accordingly, we examine in the next step under which condition $\Delta u_t = u_t - u_{t-1}$ and $\Delta k_t = k_t - k_{t-1}$ produce a positive or negative impact on growth.

Deviations from equilibrium unemployment $\widetilde{u}_t$ determine whether Δu

is positive or negative. Equilibrium unemployment is defined as the identity between job creation U^- and job destruction U^+ so that the share of employed and unemployed workers is constant, even though there are continuous flows between employment and unemployment. Set $u_t = u_{t-1}$ in equation (22) to see that equilibrium unemployment is given by

$$\widetilde{u}_t = \frac{\int_{a^{\min}}^{(1+g_t)a^{\min}} \sigma(a)da}{\gamma + \int_{a^{\min}}^{(1+g_t)a^{\min}} \sigma(a)da}. \tag{23}$$

Equivalently, deviations from a constant capital-labor ratio $\widetilde{k}_t$ give information about the direction of changes in k. The temporary equilibrium[9] ratio $\widetilde{k}_t$ follows from the identity between investments and the capital depreciation. Setting $k_t = k_{t-1}$ in equation (17) yields the identity $sy_t = \varphi x_t / L_t$. After substituting y_t with the production function, we have:

$$\widetilde{k}_t = \left(sA_t^{\max} \frac{\varsigma_t}{\varphi} \right)^{\frac{1}{1-\alpha}}. \tag{24}$$

The dashed lines $\widetilde{u}$ and $\widetilde{k}_t$ in Figure 4 show the locus of constant unemployment and a constant capital-labor ratio in the (β, u)-space and the (β, k)-space, respectively. As the technology transfer continuously increases β_t over time, the horizontal axis is also the time axis. The $\widetilde{u}-$locus is downward sloped because the value of the integral in equation (23) declines as soon as g falls with an increase in β.[10] Therefore, we know that equilibrium unemployment $\widetilde{u}_t$ will be high if the distance to the global technology frontier is still large. The intuition behind this is that a large technology gap indicates that much structural adjustment is necessary to bridge the gap, which causes job destruction and unemployment. In addition to this, we have the $\widetilde{k}_t-$locus which is upward sloped. If the transition economy approaches the global technology frontier, i.e. β increases, output and investments grow and the relative capital depreciation decreases as the capital stock contains fewer (accelerated obsolescing) basic capital goods. More investment and less depreciation correspond to an increase in the equilibrium capital-labor ratio during transition.

The loci of equilibrium unemployment and the equilibrium capital-labor

[9] In contrast to the long-run equilibrium k^*, the temporary equilibrium $\widetilde{k}_t$ does not consider individual preferences and its value shifts over time.

[10] The fact that g and β are inversely correlated follows directly from equation (16).

ratio are stable. To see this consider that

$$\frac{\partial \Delta u_t}{\partial u} = -\int_{a^{\min}}^{(1+g_t)a^{\min}} \sigma(a)da - \gamma < 0. \tag{25}$$

Taking into account that $\Delta\widetilde{u} = 0$, the inverse relationship $\partial\Delta u_t/\partial u$ implies that unemployment will increase as long as it is below the equilibrium value, $u_t < \widetilde{u}_t$, and fall if $u_t > \widetilde{u}_t$. Furthermore

$$\frac{\partial \Delta k_t}{\partial k} = (\alpha - 1)\, s k^{\alpha-2} \varsigma < 0 \tag{26}$$

indicates an increase in the capital-labor ratio for ratios below equilibrium, $k_t < \widetilde{k}_t$, and a decrease if $k_t > \widetilde{k}_t$.

We interpret the evolution of k and u as the short-term adjustment to the equilibrium path right after the start of the transition process, and the movement along the equilibrium path afterwards. The solid lines in Figure 4 show this evolution under the assumption that the transition economy starts with $u_0 < \widetilde{u}_0$ and $k_0 > \widetilde{k}_0$. While unemployment in the centrally-planed CEE countries was fixed at the zero level, the use of rather outdated capital was high. This and the fact that the technology gap was large in the beginning (i.e. $\widetilde{k}_0$ is small) let us argue that the transition started with unemployment lower than $\widetilde{u}_0$ and with a capital-labor ratio higher than $\widetilde{k}_0$. From this it follows that unemployment moves quickly from zero to the high equilibrium value $\widetilde{u}_t$. However, from that point on, unemployment follows the decreasing $\widetilde{u}_t-$locus when the technology gap gradually closes. Furthermore, the value of k_t above equilibrium leads to a downward adjustment through the fast depreciation of obsolete capital. As soon as the falling k_t hits the $\widetilde{k}_t$-locus, the capital-labor ratio follows the upward path and capital accumulation exceeds depreciation again.

The model reproduces the experiences of macroeconomic transition in the CEE economies. Bridging the technology gap generates a ∪-shaped pattern of the capital-labor ratio and a inverted-∪-shaped pattern of unemployment. The mechanism behind this is the structural adjustment which causes the depreciation of some outdated capital and results in an accelerated reallocation of labor. The productivity gains from the technology transfer cannot outweigh the lack of inputs if the decline in employment and useful capital is substantial. From this it follows that output growth is low and even negative in the beginning but turns to positive rates in the sub-

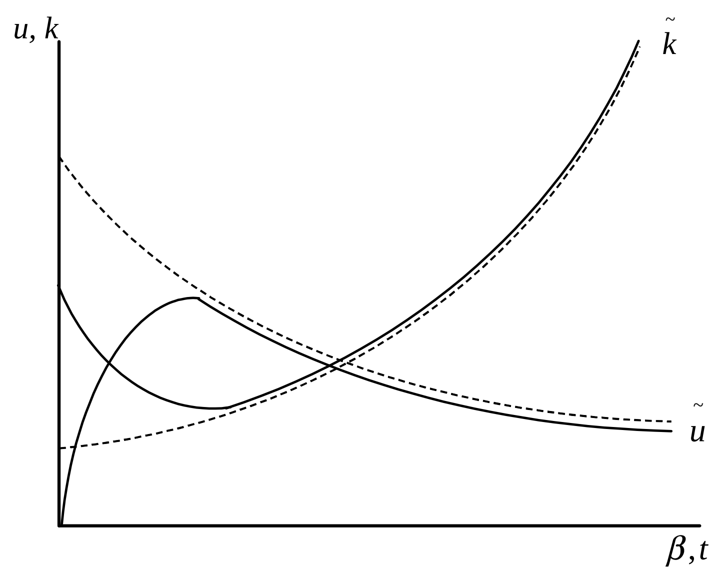

FIGURE 4: Dynamics of capital and unemployment along a closing $\beta-$gap

sequent catching-up. Hence, after the shock-like adjustments with the initial collapse in production, a moderate evolution to the long-run equilibrium is accompanied by a reduction in unemployment and continuous growth.

4 Transition Scenarios

This section compares the trends of productivity and output growth, unemployment and the capital-labor ratio under the assumption of different initial and transition conditions. To illustrate the possible variations in the general shape of the transition paths, we simulate the evolution over time of g_t, u_t and k_t given by the difference equations (16), (17), and (22) and the consequent rate of output growth $g_{y,t} = \left(y_t^N - y_{t-1}^N\right)/y_{t-1}^N$.

For the baseline scenario we specify the set of parameters $\{k_0, \beta_0, u_0, \gamma, a^{\min}, \mu, \alpha, \bar{g}, \delta, \varphi, s\}$. As the main initial conditions, we assume that the capital-labor ratio is $k_0 = 2$ and the technology gap yields $\beta_0 = 0.5$. This combination yields a realistic capital-output ratio of about 2.5 and reflects the fact that relative productivity of the CEE countries has been at maximum half of the EU average in the early 1990s. Furthermore, the economy of the simulation starts with full employment. We choose the parameters affecting the reallocation of labor in such a way that the numbers reproduce a level of about 3% to 5% job creation and 5% to 10% job destruction which has been found in the transition countries during the 1990s (see Faggio and Konings, 2003). Hence, frictions are given by $\gamma = 0.3$ and the minimum productivity by $a^{\min} = 0.7$. The rate of technology transfer is assumed to bridge 30 per cent of the previous gap ($\mu = 0.3$). This number generates rates of productivity growth of more than 10% at the beginning and reproduces the real catching-up process in the CEE economies. For the remaining parameters of the model we assume that the capital share takes the usual value $\alpha = 0.3$, the ratio of investments to output is 20% (roughly the actual value during the 1990s), and the global rate of technological progress is $\bar{g} = 0.03$, equal to the average over the last decades. Finally, some parameters cannot be based on real observations but we have to make reasonable guesses. Therefore, we assume that the reject due to antiquated technologies δ is equal to a share of 10% of the basic components of the capital input and the depreciation rate of capital φ is 0.1.

After the choice of parameters, and then at each point in time again, we identify the corresponding employment share, the output level, and the technology gap. In a next step, we determine how much productivity in terms of the technology stage ς converges to equilibrium and to what extent this changes job creation and job destruction, the capital-labor ratio, and output growth. Table 1 reveals the results and confirms the findings of the previous section. The speed of technological change slows down over time, while the capital-labor ratio decreases first but increases afterwards, whereas the opposite holds true for unemployment. The adjustments are strong in the beginning and more moderate afterwards. The transition phases out as soon as the period of structural adjustments is over (after about 50 periods in the simulation). Then unemployment is in equilibrium and the technology gap remains at a constant level. In subsequent periods, the growth rate of output declines further and approaches zero, which characterizes the long-run equilibrium.

Variations in the parameter values, see Table 2, proof the relative robustness of the results. Furthermore, they provide an insight into why some countries in transition have higher rates of changes in output and employment than others. Figures 4 to 7 refer to this analysis. Selected results from the comparative simulations are discussed below.

The first scenario shows that unemployment during the transition is

Table 1: Dynamics of capital, output, unemployment, and the technology gap

t	k_t	β_t	ς_t	u_t	$\frac{y_t^N - y_{t-1}^N}{y_t^N}$	$\frac{\varsigma_t - \varsigma_{t-1}}{\varsigma_{t-1}}$
1	2.28	0.5	0.61	0.21	- 0.09	0.11
2	2.20	0.63	0.68	0.28	- 0.03	0.06
3	2.08	0.73	0.73	0.29	0.02	0.05
4	1.96	0.79	0.76	0.27	0.05	0.04
5	1.88	0.84	0.79	0.24	0.06	0.03
...						
50	2.26	0.94	0.89	0.03	0.01	0.01
...						
1000	396.4	0.94	1	0.03	0	0

lower if the initial technology gap is smaller. This is because less structural adjustment is necessary which corresponds to less labor reallocation, the cause of unemployment. A less restrictive level of the minimum technology in scenario two works in the same direction as it lowers job destruction. Additionally, this is accompanied by a clearly lower growth depression. Obviously, if basic capital units are depreciated at a higher rate, the larger loss of capital transmits into an additional loss of output (scenario three). A reduction in the inflow rate of the technology transfer in scenario four produces a growth path which is more moderate during the whole transition because less structural adjustment occurs accompanied by lower flows in the labor market. This means a lower depression in the beginning but also less growth in subsequent periods. Scenario five reveals that a higher initial capital-labor ratio helps to avoid the deep depression. Though depreciation is high, the renewing of the capital stock is particularly effective as a high capital-labor ratio in the early stage of transition indicates more out-dated technologies. While the acceleration of the exogenous technological progress in scenario six has only little effects during the transition, it affects equilibrium unemployment because the long-term labor reallocation and sector turnover are higher under this assumption. As expected, the increased ratio of investments to output in scenario seven accelerates capital accumulation and involves positive effects on growth during transition. Anything which improves job creation, such as training, administrative support for job seekers et cetera, absorbs to some extent the negative employment effects of the structural adjustments. Hence, less frictions in scenario eight generate more employment and growth. Scenario nine analyzes a rise in the capital share and shows that the evolution of output growth is less fluctuating because employment variations lose impact.

TABLE 2: Parameter variations

	β_0	$a^{\min}$	φ	μ	k_0	$1+\bar{g}$	s	γ	α	δ
baseline scenario	0.5	0.7	0.1	0.3	2	1.03	0.2	0.3	0.3	0.1
scenario 1	0.6	.	.	.	.	.	.	.	.	.
scenario 2	.	0.6	.	.	.	.	.	.	.	.
scenario 3	.	.	0.3	.	.	.	.	.	.	.
scenario 4	.	.	.	0.2	.	.	.	.	.	.
scenario 5	.	.	.	.	3	.	.	.	.	.
scenario 6	.	.	.	.	.	1.05	.	.	.	.
scenario 7	.	.	.	.	.	.	0.3	.	.	.
scenario 8	.	.	.	.	.	.	.	0.5	.	.
scenario 9	.	.	.	.	.	.	.	.	0.5	.
scenario 10	.	.	.	.	.	.	.	.	.	0.05

The simulations show that it is not a simple task to find the right responses to the economic challenges during transition. First, initial conditions, such as the magnitude of the technology gap, determine the following evolution of employment and growth to a large extent. Secondly, the often arising trade-off between early depression and later output growth implies that there are no unambiguous growth policies. A deep depression is the sign of heavy structural adjustments, which, in turn, are the source of future growth. However, two findings may be important to achieve a good performance in terms of growth and employment during economic transition. Investments help to diffuse technologies and work against the capital depreciation because of technological obsolescence. And, finally, a reduction in the frictions in the labor reallocation between old and modern sectors, for example through extensive training and schooling, is very beneficial in terms of both employment and growth.

Moreover, the comparative simulations might be used to account for some differences in the evolution of unemployment and growth in the CEE countries. We cannot evaluate different policies in detail, such as privatization progress, labor market reforms and the like. However, in an exemplary way, confronting the simulations with the real macroeconomic transition, as it is displayed in section two, shows how the results gained from the parameter variations above fit the existing diversity of the transition paths. For example: In comparison to the average, the Czech Republic had less productivity growth and less increase in unemployment in the early 1990s. This is in line with the predictions of the model in simulation four. If there is, for some reason, less inward technology transfer, only few structural adjustments occur and job destruction is low. This avoids jumps in joblessness, but at the price of lower rates of productivity and output growth.

The counter-example is East Germany. The high political and economical pressure to restructure the economy in order to achieve equalization between West and East and the rapid technology transfer make East Germany being the ideal case of a transition economy with a rapid obsolescence and a high innovation of technologies. The loss of employment was higher than on average, the initial increase in productivity was remarkable high, and the rates of output growth fluctuated more than in other CEE countries. It is fair to argue that the technology transfer was exceptional high from West to East Germany. This is again in line with scenario four, in which a higher speed of transition produces a higher rate of productivity growth, but higher unemployment and a deeper depression at the same time. Moreover, one can argue that the minimum technological level was particularly restrictive in East Germany due to the high competition from West German firms. As fast increasing wages did not compensate for productivity disadvantages, only the highly productive East German firms survived. According to scenario two this also explains the high degree of labor reallocation with its side effects unemployment and the initial output fall.

Finally, Slovenia had a moderate evolution in all macroeconomic variables. At the same time, the relative high productivity level in the 1990 indicates that Slovenia was the most developed CEE economy before transition. According to scenario one, a smaller technology gap means a lower depression, lower unemployment, but also less productivity growth during transition. All this is applies to Slovenia.

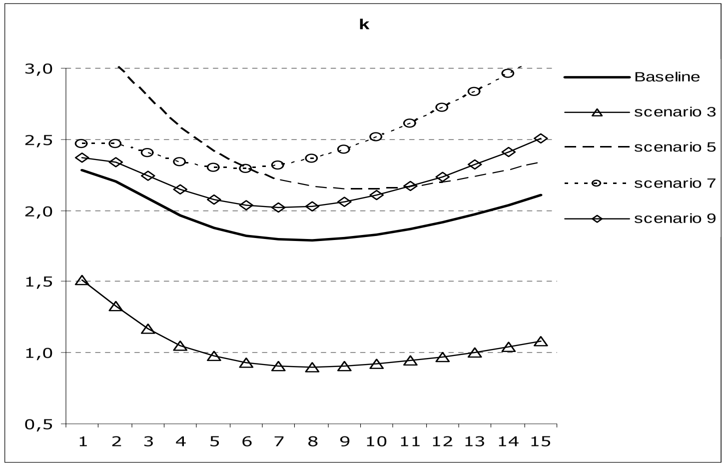

Figure 4: Evolution of the capital-labor ratio

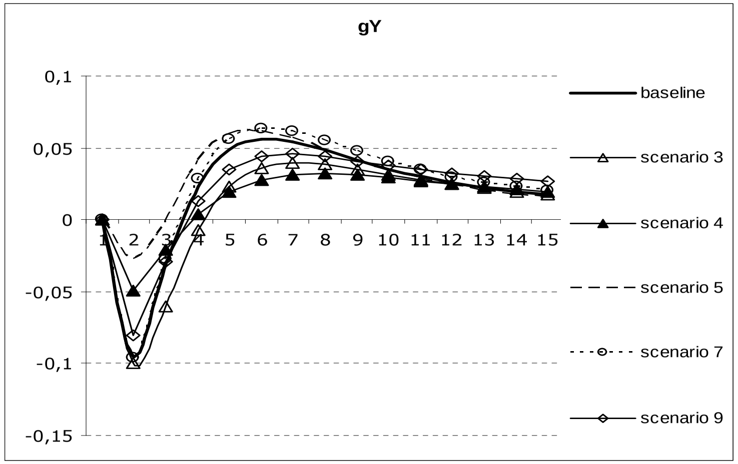

Figure 5: Evolution of output growth

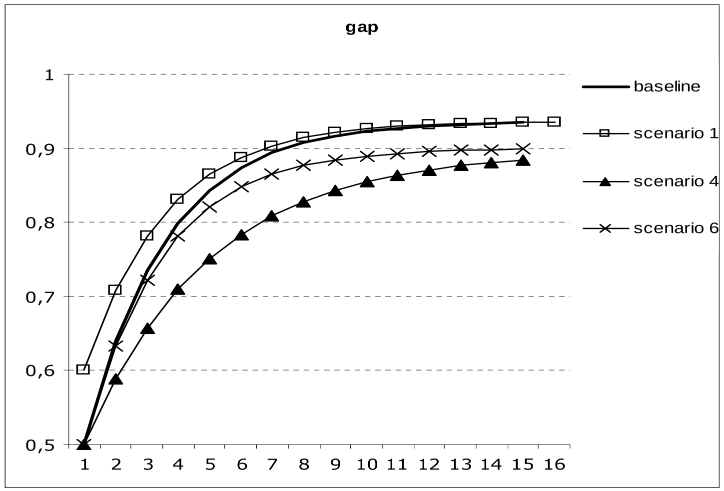

Figure 6: Evolution of the technology gap

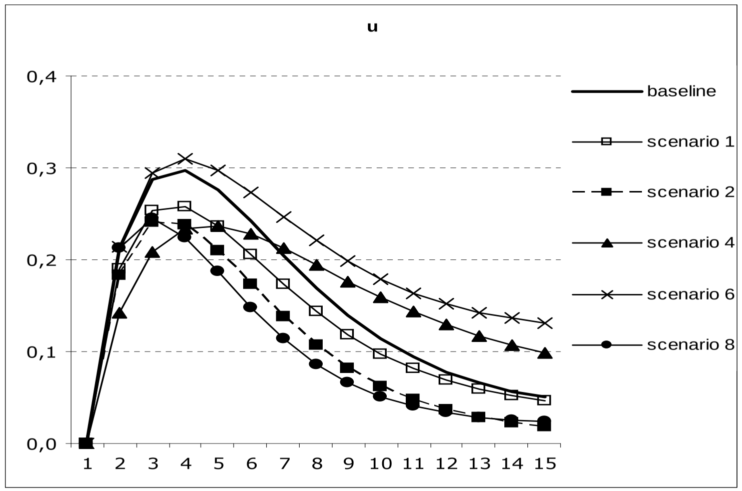

Figure 7: Evolution of unemployment

5 Conclusions

In the early 1990, the Central and Eastern European economies established so-called "big-bang" reforms in nearly every economic area. The consequences could be seen in the evolution of the three central macroeconomic indicators: Productivity increased rapidly but unemployment jumped to very high levels and output growth followed the shape of a J-curve with an initial collapse of production. This paper presents a model which reproduces the fluctuating transition paths analyzing the link between structural adjustment, technology replacement, and labor reallocation.

We consider economies that show a technology gap at the beginning of transition. Bridging the gap is accompanied by increases in productivity and sectoral change. The high rate of labor reallocation one can observe in the CEE countries, in particular at the beginning of transition when job destruction dominated job creation (Haltiwanger et al., 2003), is an indicator for the deep structural transformation during the 1990s. We argue that this transformation was initiated by the new availability of a pool of superior (Western) technologies. While the inward technology transfer has positive effects on productivity, the consequent obsolescence of old technologies includes some negative side-effects on capital accumulation and employment. From this we get the paradox result of technology updating during transition, which is that bridging the technology gap increases productivity but reduces output growth and even leads to negative growth rates due to the initial sharp rise in unemployment.

The results of our simulations imply that the policy impact on the macroeconomic variables during transition is weak because much of the fluctuation is subject to initial conditions such as the magnitude of the technology gap. However, the efficiency of reallocating labor between old and new jobs could be identified as one of the major keys to achieve a better performance in terms of employment and growth during transition. As the characteristics of the newly created jobs, such as in the services, differ substantially from the destroyed ones, for example in the heavy industry, the retraining of workers is supposed to be a necessary condition to reduce the frictions in the labor market. But further research on the role of skills, skill formation and the technology-skill complementarity during economic transformation is needed to identify the frictions in the labor market and to evaluate the role of skill shortages as a cause of the output fall in transition.

References

Aghion, P. and P. Howitt (1992): A Model of Growth through Creative Destruction, *Econometrica*, 60 (2), pp. 323 - 351

Aghion, P. and P. Howitt (1994): Growth and Unemployment, *Review of Economic Studies*, 61, pp. 477-94.

Aghion, P. and O. Blanchard (1994): On the Speed of Transition in Central Europe, *NBER Macroeconomics Annual*, pp. 283 - 320

Aghion, P. (2005): Growth and Institutions, *Empirica,* 32, pp. 3- 18.

Bedi, A. S. and A. Cieślik (2002): Wages and Wage Growth in Poland: The Role of Foreign Direct Investment, *Economics of Transition*, 10 (1), pp. 1 -27.

Blanchard, O. (1996): Theoretical Aspects of Transition, *American Economic Review,* 86 (2) pp. 117 -122

Blanchard, O. (1997): *The Economics of Post-Communist Transition*, Oxford University Press, Oxford

Campos, N. F. and F. Coricelli (2002): Growth in Transition: What we Know, What we Don't, and What we Should, *Journal of Economic Literature,* 40 (3), pp. 793 - 836

Coe, D. T. and E. Helpman (1995): International R&D Spillovers, *European Economic Review*, 39 (5), pp. 859 -887.

Faggio, G. and J. Konings (2003): Job Creation, Job Destruction and Employment Growth in Transition Countries in the 90s, *Economic Systems*, 27 (2), pp. 129-154.

Fitzroy, F. and M. Funke (1995): Skills, Wages, and Employment in East and West Germany, *Regional Studies*, 32 (5), pp. 459-467

Gang, I. N. and Yun, M. S. (2002): Decomposing Male Inequality Change in East Germany during Transition, IZA discussion paper No 579.

Haltiwanger, J., H. Lehmann, and K. Terrell, (2003): Job Creation and Job Destruction in Transition Countries, *Economics of Transition,* 11 (2), pp. 205-219.

Haltiwanger, J. and M. Vodopivec (2003): Worker Flows, Job Flows and Firm Wage Policies: An Analysis of Slovenia, *Economics of Transition*, 11 (2), pp. 253 - 290.

Keller, W. (2002): Trade and the Transmission of Technology, *Journal of Economic Growth*, pp. 5-24.

Lay, G. (1999): *Innovation in Production: The Adoption and Impacts of New Manufacturing Concepts in German Industry*, Pysica, Heidelberg.

Nelson, R. and E. S. Phelps (1966): Investments in Humans, Technological Diffusion, and Economic Growth, *American Economic Review*, 56 (1), pp. 69-74.

Pohl, R. (1999): The Macroeconomics of Transformation, IWH discussion papers No. 109.

Pissarides, C. A. (1990): *Equilibrium Unemployment Theory*, Basil Blackwell, Oxford.

Riphahn, R., D. J. Snower, and K.F. Zimmermann (2001): *Employment Policy in Transition, Springer*, Heidelberg.

Romer, P. (1993): Idea Gaps and Object Gaps in Economic Development, *Journal of Monetary Economics*, 32, pp. 543 - 573.

Roland, G. and T. Verdier (1999): Transition and the Output Fall, *Economics of Transition*,7 (1), pp. 1 -28.

Rosati, D. (1994): Output Decline during Transition from Plan to Market, *Economics of Transition*, 2 (4), pp. 419-442

Sachs, J. (1996): The Transition at Mid Decade, *American Economic Review,* 86 (2), pp. 128 - 133

Sinn, H.W. and G. Sinn (1992): *Jump-start - The Economic Unification of Germany*, MIT Press, Cambridge.

Svejnar, J. (1996): Enterprises and Workers in the Transition: Econometric Evidence, *American Economic Review, Papers and Proceedings, 86 (2), 123 - 127*

Winieki, J. (1993): *The Macroeconomics of Transition: Developments in East Central Europe*, Routledge, London

Xu, B. and J.Wang (2000): Trade, FDI, and Technology Diffusion, *Journal of Economic Integration*, 15 (4), pp. 585 - 601.