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## Investment behavior in dynamic computable general equilibrium models for transition economies

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# Kieler Arbeitspapiere

# Kiel Working Papers

**KIEL WORKING PAPER NO. 879**

**Investment Behavior**  
**in Dynamic Computable General Equilibrium Models**  
**for Transition Economies**

by  
Daniel Piazolo



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## **Investment Behavior in Dynamic Computable General Equilibrium Models for Transition Economies**

### **Abstract**

This paper suggests a method of approximating the development of investment in transition economies through an amendment of the standard adjustment cost formulation for investment within dynamic Computable General Equilibrium (CGE) models. Letting adjustment cost depend on the difference between the investment levels of two periods (rather than only on the gross investment ratio) leads to an investment behavior of the representative household that resembles the observed time paths of investment in transition countries. In contrast to standard adjustment costs, which predict a sharp rise in investment due to the high marginal productivity of each unit of capital after a capital shock, augmented adjustment costs lead to a gradual rise in investment.

### **JEL Classification:**

D58 (Computable and Other Applied General Equilibrium Models),  
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**Key Words:** Computable General Equilibrium Model, Transition, Adjustment Costs, Investment Behavior.

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## 1. The Issue

In spring 1998, the historic process of Eastern enlargement of the European Union to include former centrally planned economies of Central and Eastern Europe (CEE) has begun. Five Central and Eastern European candidates, the Czech Republic, Hungary, Poland, Estonia and Slovenia, have been invited to enter into EU membership negotiations, and five more countries, Latvia, Lithuania, Bulgaria, Romania and Slovakia, have been promised membership negotiations in the not too distant future. The European Commission expects the entry date for the first round of new members to be as early as 2002 or 2003. With full membership, the process of political integration would catch up with the economic integration between Western and Eastern Europe that is already far advanced (Piazolo, 1997).

The economic effects of Eastern enlargement will be manifold and can be captured both by partial equilibrium analyses and Computable General Equilibrium (CGE) models. The latter seem to be the most suitable tool to trace the various linkages within and between economies and to capture the integration effects because these models can account for the diverse relations

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among all economic agents. However, CGE models encounter a fundamental problem in describing "transition" economies because certain structural characteristics that are normally assumed to be stable in the case of market economies, are strongly affected by the transition process. In particular, transition economies are clearly not on their long-term steady state growth path, and EU membership will affect both the speed of convergence to the steady state as well as the steady state itself.

Earlier studies using dynamic CGE models account for the transformation shock of the Central and Eastern European countries (CEECs) by combining national accounts data from the CEECs with structural characteristics of mature Western European economies such as input-output coefficients. Furthermore, the value of the capital stock within the transition country is adjusted to represent the gap between the mature and the transition economy. This approach is not entirely satisfactory because it implies a rapid rise in investment immediately after the transformation shock, i.e. a behavior that does not correspond to the observed development in the transition countries.

This paper proposes an amendment by modifying the investment modeling within the dynamic CGE setting. The standard formulation of installation costs for capital is extended through the inclusion of adjustment costs that depend on the change of the investment level. Such formulation of the installation costs

within the dynamic CGE model leads to an investment behavior that reflects the observed evidence of investment during the first years of the transition.

The paper starts by reviewing previous attempts of describing transition economies with CGE models (Section 2.1) as well as the modeling of investment behavior in CGE models (Section 2.2). A simple dynamic CGE model (Ramsey-type) is then set out in Section 3 to represent a transition economy and is used to show the shortcomings of the traditional modeling of investment behavior. The paper suggests a method of improving the dynamic CGE modeling by combining capital stock adjustment and installation costs for capital that depend on the changes in the investment level. Section 4 concludes and discusses potential research extensions.

## **2. The Transition Problem in CGE Modeling**

### ***2.1. Static versus dynamic models***

In all Computable General Equilibrium (CGE) models, the relationships between the variables are calibrated on a so-called benchmark equilibrium dataset. This calibration process computes intercept and share parameters to complement the exogenously supplied behavioral elasticities in such a way that



the equilibrium solution of the model reproduces the observed data.<sup>1</sup> The model can then be applied to simulate the consequences of various economic developments like trade policy changes by adjusting the relevant exogenous variables and computing the resulting new equilibrium. This approach has been frequently applied to analyze both the impact of individual policies and the net result of changes in sets of policy measures.

Until now, however, there are only few CGE models for transition countries. Orlowski (1996) constructs a static CGE model for the Polish economy on the basis of input-output data for 1990 and 1991 and examines the costs and benefits of alternative agricultural policies. Braber et al. (1996) use static CGE models with data relating to the years 1987 for Poland and 1990 for Hungary to analyze the effects of various government policies on the economies of these two countries. Hare et al. (1993) adjust within their static Hungarian CGE model the parameters in the trade functions derived for the base year 1990 to simulate the redirection and restructuring of the Hungarian foreign trade.

In the case of transition countries, however, it is questionable whether the structural characteristics of a given year can be assumed to remain constant for

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<sup>1</sup> A more detailed description concerning the calibration process and the construction of a consistent benchmark equilibrium dataset with the help of the Social Accounting Matrix (SAM) can be found in Reinert and Holst (1997).

a sufficient time to ensure the validity of the simulation results. In particular, enterprise restructuring, price and trade liberalization lead to changes in input-output coefficients and the exogenously determined behavioral elasticities.<sup>2</sup> This distortion within the CGE simulation amplifies with the length of the time period analyzed. This difficulty is also encountered when a transition economy is modeled by incorporating a two-tier price system to represent the co-existence of a centrally planned and a market sector, as done by Zhang (1998) for the Chinese economy with 1987 data.

One attempt to solve this problem is to substitute another countries' data for the changing data of a transition country. Breuss and Tesche (1993) combine static CGE models of Hungary for the years 1977 and 1986 with one of Austria for the year 1976 to represent a continuum of a small open economy in transition (i.e. Hungary). Consequently, Austria in the late 70's is taken as a substitute for the Hungarian economy in the 90's in order to approximate and analyze the effects of policy changes in modern Hungary. Similarly, Brown et al. (1997) combine 1992 sectoral employment and trade data for Czechoslovakia,

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<sup>2</sup> For example, Roberts (1994) shows with an aggregated model of the Polish economy for the years 1986 to 1990 that the model response is quite sensitive to the choice of elasticities such as the trade substitution elasticity. Castanheira and Roland (1996) demonstrate also in their analysis of general equilibrium interactions between capital accumulation and the speed of transition that the choice of the elasticity of substitution within the production function influences considerably the speed of restructuring.

Hungary and Poland with the 1980 input-output table for Portugal to approximate the economic structure of these countries for simulations with a static CGE model.<sup>3</sup>

All these presented models are static. Within static models the behavior concerning savings, investment or resource extraction is exogenously determined, whereas dynamic models include functions for savings, investment or extraction, that allow to account for the intertemporal substitution of consumers and firms.<sup>4</sup> The development of the transition countries over a longer time period can only be represented in a meaningful way with a dynamic CGE model: The inclusion of intertemporal preferences of households (savings) and intertemporal optimization of firms (investment) permit the description of the time path of investment and the current account development as well as a more satisfactory welfare analysis (see also section 2.2). Keuschnigg and Kohler

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<sup>3</sup> Another suggestion for modeling transformation was forwarded, but not implemented by Norén (1998). Norén proposes a vintage model to incorporate the industrial transformation process into a multisectoral CGE model of an open economy. Norén suggests that the domestic sectoral operational surplus ratio, endogenously determined by labor costs, value added and the exchange rate, determines the flows of investment between the sectors and thereby the structure of the transformation process. It is assumed that the financial resources are free to flow between the different sectors of an economy and between different countries. This approach could also be applied to transition countries. However, the implementation of this model probably will encounter problems since the observed financial flows between sectors in transition countries are far lower than the model would suggest. One way to try to employ this model would be to drop the assumption of perfect mobility of resources and to incorporate adjustment costs.

<sup>4</sup> Klepper et al. (1994) and Keuschnigg and Kohler (1998) discuss various approaches to include intertemporal optimization into CGE models.

(1998) model "the" transition country with the help of the assumption that this country is like "the" Western European country (i.e. a mature economy without a planned-economy-system legacy and benefiting from West-European integration), but with an ad-hoc and essentially arbitrary reduction in several stock variables like physical and human capital and the knowledge stock. The authors then calculate the transition path to the post-transformation steady-state. As the authors admit themselves, this adjustment of the variables is somewhat subjective. Additionally and more importantly, the time path of investment does not correspond at all with the observed data: The model predicts a sharp increase in investment after the transition shock, whereas the actual time path reveal a slow gradual increase in investment activity. Nevertheless, this approach is a useful bottom line since it can be amended through an augmented formulation of adjustment costs in such a way that the CGE model yields a time path of investment within the first years of the transition that approximates more closely the observed development. A better representation of the investment behavior will be especially important for the analysis of the effects of EU membership which given the sequencing of accession can be expected to trigger investment gradually. Such an amended approach is the focus of this paper.

Despite these modeling problems, the simulation of transition countries is an important issue for trade policy analysis. The growth effects of trade policy changes like through regional integration can be considerable, especially for developing and transition countries: Francois, Nordström and Shiells (1998) demonstrate that trade liberalization that yields the same effect in a static framework may have a considerably higher impact on growth for countries off their steady state than for countries near their steady state. The acceleration of transitional growth to the steady state allows higher income to be realized at an earlier date. The present value in income gain due to being set on a steeper transitional growth path is the higher the more the economy initially deviates from its steady state potential. The effects of policy reforms, therefore, depend on the initial state of development, an issue that has often been overlooked until now in applied modeling and which is particularly significant for modeling transition countries.

## ***2.2. Accounting for investment behavior in CGE models***

In the static CGE models, there are various ways of describing investment behavior: On the one hand, the aggregate capital stock may be fixed and relative price changes will induce changes in the sectoral allocation of capital, but not in the total capital stock. On the other hand, the real return to capital may be held at the benchmark level and investment and capital stock adjust

accordingly. In the latter case, the investment behavior can be combined with a fixed savings rate closure rule or with an endogenous savings rate closure, since only the assumptions about the households have to be changed for these two closure rules (cf. Francois, McDonald and Nordström 1997: 375).

However, there are considerable advantages in moving from the mere inclusion of capital stock adjustment to dynamic modeling that involves intertemporal optimization of firms and intertemporal preferences of households. Since growth has to be fueled by investment, i.e. by forgone consumption (or by increased capital inflows leading to accumulated liabilities to foreigners that have to be serviced in later periods), a meaningful analysis of the welfare effects of policy changes requires the explicit modeling of intertemporal allocation of resources. Intertemporal optimization permits the simulation and examination of alternative adjustment policies to minimize the adjustment costs. Additionally, since trade policy changes are typically phased in over several periods, the time profile of adjustment can be tracked down. Furthermore, intertemporal optimization permits to show how the pattern of savings and investment leads to a certain pattern of current account dynamics (cf. Keuschnigg and Kohler, 1997: 385).

Dynamic CGE models often include adjustment costs for the installation of capital (see also section 3.3). In their modeling of long term growth in a

transition economy, Keuschnigg and Kohler (1998) use the traditional formulation of adjustment costs (depending on the ratio of investment to the existing capital stock – set out in more detail below). After this formulation investment jumps after the transformation shock to a high level and declines smoothly thereafter: Since the capital stock is low and since each additional capital unit yields a high marginal return, investment right after the establishment of the new market framework should be particularly productive.

However, such investment behavior was not observed in the transition countries. Figure 1 and 2 show the development of the Gross Domestic Product and of Gross Investment since 1989 for the four advanced transition countries, the Czech Republic, Hungary, Poland and Slovenia. These figures reflect the transformation shock in CEE and a gradual increase after the nadir in economic and investment activity. For this paper, the pattern of the investment data at the right side from the nadir (time = 0) is particularly important and will be approximated with an amendment: The observed time path of investment can be reproduced much better within a dynamic CGE model if *changes* in the investment level involve adjustment costs, i.e. if investment in period  $t$  depends on investment in the preceding period,  $t-1$ . In this case, investments will only gradually increase after the shock to a higher level and will then fall slowly towards the new equilibrium value (cf. Thimann, 1996: 91).

With this modified approach, the recent development of investment in the advanced transition countries can be approximated more closely. Consequently, the future development towards a steady state can be modeled more realistically and be forecast more reliably. This move towards the steady state can also be used as the baseline scenario for the analysis of alternative policies for EU enlargement. Full EU membership will affect the transitory developments towards the steady state as well as the level of the steady state. The welfare effects of the various policies for the economy of a transition country can then be derived by a comparison of the different scenarios.

### **3. The Transition-Country-Ramsey (TransRams) Model**

#### ***3.1 Basic features***

The focus of this paper is to clarify the implications of allowing for a particular type of adjustment costs for investment for the representation of transition economies in dynamic CGE models. The basis of the analysis is a growth model with consumer optimization as developed by Ramsey (1928) and further modified by Cass (1965) and Koopmans (1965). The Ramsey model contains one infinitely-living household that chooses consumption and investment to



maximize the dynastic utility, subject to an intertemporal budget constraint.<sup>5</sup> The household has perfect foresight and acts rationally. All markets are perfectly competitive and there are no tax-induced distortions. The rate of technological progress is exogenously specified. Furthermore, the economy is closed and is represented by only one sector. These two assumptions can be relaxed later in further extensions of the model. Labor supply is exogenous over time. Labor and capital are used as inputs to produce the output that can be either consumed or invested.<sup>6</sup>

The household wishes to maximize overall utility,  $U$ , as given by

$$U = \sum_{t=0}^{\infty} \left( \frac{1}{1+\rho} \right)^t u(C_t)$$

$\rho$  is the time preference rate,  $C_t$  is aggregate consumption in year  $t$ , and  $u(C_t)$  stands for utility reached at in the year  $t$ . This formulation assumes that the household's utility at time 0 is a weighted sum of all future flows of utility, which depends on the quantity of consumption in each period. The function

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<sup>5</sup> Barro and Sala-i-Martin (1995) pp. 59 as well as Blanchard and Fischer (1989) pp. 38 offer a general description of the Ramsey model. Manne (1986) and Lau et al. (1998) set out the Ramsey model for the use in Computable General Equilibrium models with the General Algebraic Modeling System (GAMS).

<sup>6</sup> Under these premises it can be shown that the allocation of resources in an undistorted decentralized economy is the same as the one chosen by a central planner maximizing the utility of the representative household (c.f. Barro and Sala-i-Martin, 1995: 71).

$u(C)$  is increasing in  $C$  and concave:  $u'(C) > 0, u''(C) < 0$ . Due to the concavity of the utility function, the household will try to smooth consumption over time and to achieve a relatively uniform pattern of consumption. A positive value of  $\rho$  means that "utils" are valued the less the later they are received, i.e. they are discounted.

The representative household maximizes the dynastic utility subject to the constraint that output in each period is either consumed or invested:

$$f_t(K_t) = C_t + I_t.$$

$f_t''(K_t) < 0$ .  $K_t, C_t, I_t$  represent capital, consumption and investment in period  $t$ .

The production function  $f_t(K_t) = C_t + I_t$  is a short-hand version of a production function with constant returns to scale in capital and in the exogenously supplied factor labor.

$$f_t(K_t) = F(K_t, \bar{L}_t)$$

The production function exhibits diminishing returns to scale for capital alone.

The capital stock in each period is the sum of the capital stock of the previous period less depreciation and the investment in the previous period.

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

Investment is non-negative in each period, the capital stock in period  $t = 0$  is specified exogenously and  $\delta$  is the annual rate of depreciation.

The Ramsey growth model is implemented with the General Algebraic Modeling System (GAMS) as a dynamic CGE model. The parameters are given in table 1. Since the CGE model simulates the utility maximization of the household over all specified time periods, the infinite time horizon has to be approximated through the combination of a suitably long time period and a "terminal condition". The terminal condition summarizes the development after the specified time period up to infinity. The CGE model formulated here runs over 60 time periods. In the steady-state, there is a balanced growth of the relevant variables (figure 3): Consumption C, Investment I, Output Y and Capital Stock K grow with the steady-state growth rate of 2 percent, that equals and is determined by the rate of technological progress.

### ***3.2. Implementation for a transition economy***

The model described above is further adjusted to represent a transition country. The systemic transformation is approximated through the reduction of the capital stock and through the introduction of adjustment costs incurred by new investment. This approach uses insights from Keuschnigg and Kohler (1998), but permits a better approximation of the development of the transition

economy by augmenting the adjustment cost function. The capital stock of the transition economy relative to the "mature" economy on a balanced growth path is reduced by fifty percent. This is the value used by Keuschnigg and Kohler and approximates the findings by Sinn and Sinn (1992) in their comparative analysis of East and West German capital stock. The gap of capital stock is likely to have been of similar magnitude for the advanced transition countries.

### *3.3. Standard adjustment cost formulation*

Installing new capital is costly. The production process has to be halted until the new machinery is installed, the workers have to be trained in the new technology etc. The enterprises incur expenses not only for the purchase of the investment good but also for the installation. The importance of these "internal adjustment costs" was first emphasized in the 1960's.<sup>7</sup> Since then, they have become integral parts of most investment models.

In the standard formulation, capital installation costs depend on the rate of investment relative to the existing capital stock (Uzawa, 1969). For a given level of investment, the cost of new capital decreases when the capital stock increases and vice versa.

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<sup>7</sup> Lucas (1967) and Gould (1968) set out rigorously installation costs incurred by firms, following earlier studies by Eisner and Strotz (1963). The introduction of decreasing returns to scale in the installation of new capacities is necessary to overcome the problem of "bang-bang behavior" (investment takes place in a single period) that might arise due to linearity in the investment function (cf. Ginsburgh and Keyzer, 1997: 258).

$$I_t = J_t \left( 1 + \phi \frac{J_t}{2K_t} \right)$$

This installation cost function includes  $I_t$  as gross investment,  $J_t$  as net investment and  $\phi$  as the adjustment cost parameter.<sup>8</sup> Rapid changes in the capital stock are costly and the speed of adjustment to the new steady state declines when the installation costs increases (cf. Barro and Sala-i-Martin, 1995: 119–128). For a representation within a CGE model, gross investment has to be incorporated into the market clearance condition for output and net investment has to be included into the intertemporal market clearance condition for capital.<sup>9</sup>

The inclusion of adjustment costs raises the steady-state price for capital compared to the case without adjustment costs. In the TransRams model, the representative household maintains the same net investment level as in the steady-state case of no adjustment costs: Since the investment outlays are higher than the net investment due to the adjustment costs, the household optimizes its utility by reducing the consumption level in every period by a small amount and by maintaining the same net investment level.

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<sup>8</sup> The "2" in the denominator is commonly included to facilitate the handling of the derivative.

<sup>9</sup> McLaren (1991) offers an introduction to the integration of adjustment costs into CGE models. The incorporation of the standard adjustment cost function for investments can be found in Lau et al. (1998: 17).

The standard installation cost function predicts that additional net investment (above depreciation and capital widening due to technological progress) surges in the first period after the "transformation shock", and subsequently levels off in a monotonic fashion (figure 4). However, this pattern is inconsistent with the development of investment in the transition countries.<sup>10</sup> The data of the advanced transition countries clearly show a slow start for investment activity in the economy (figure 2).

### ***3.4. Augmented adjustment cost formulation***

The standard adjustment cost function assumes that adjustment costs depend mainly on the value of new investment relative to the capital stock. By contrast, the level of investment itself can be altered from one period to the next without any additional adjustment costs. Thus, investment in one period,  $I_t$ , does not affect the installation costs for new investment in the next period,  $I_{t+1}$ . Thimann (1995: 145) puts the validity of this approach into doubt for the analysis of investment in East Germany, where the desired, steady-state capital stock was three times larger than the actual one at the time of unification. The standard formulation of the installation cost would only be plausible if the changes in  $K_t$  per period are small, since then the changes in the investment level are also

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<sup>10</sup> This point is analyzed by Thimann (1995 and 1996) for the East German case.

modest. However, in reality the planning and implementation of investment absorbs resources depending on the volume of the investment. If, for example, a firm wants to increase the amount of managerial services devoted to investment activities it may have to employ new personnel that has to be trained to adapt to the new firm environment. Hence, at any one point of time, a firm is limited in the amount of investment it can undertake. The adjustment of these resources is costly and, consequently, the changes in the investment are also costly for the firms.

Such adjustment costs can be introduced into a model through the assumption of convexity in the change of investments. Inertia in investment activity was used already by Phillips (1965) to incorporate the insight that the level of investment adjusts only gradually to the desired level. Consequently, the adjustment costs in an investment model should incorporate not only costs stemming from a change in the capital stock, but also costs arising for the change in the level of the investment:

$$I_t = J_t \left( 1 + \phi \frac{J_t}{2K_t} \right) + \xi (J_t - J_{t-1})^2$$

As before,  $I_t$  is gross investment,  $J_t$  is net investment and  $\phi$  and  $\xi$  are the adjustment cost parameters. Now, rapid changes in the investment level as well as in the capital stock absorb installation costs. Hence, the speed of adjustment

towards the planned investment level declines when installation costs go up. Again, the newly specified gross investment has to be incorporated into the market clearance condition for output whereas net investment has to be included into the intertemporal market clearance condition for capital.<sup>11</sup>

Investment behavior now comes closer to the observed investment development in the transition countries (figure 5). After the transformation shock, modeled through the reduction in the capital stock and in the investment level in the proceeding period (i.e. in the time period  $-t_1$ ), the investment level rises steadily for several time periods. The amount of investment that exceeds the depreciation and capital widening due to technological progress, rises for six time periods, levels off slowly and approximates very slowly the steady-state condition, where investment equals capital depreciation and capital widening.

The pattern of investment adjustment is determined by two effects. First, as in the case of standard adjustment cost, the marginal productivity of investment, i.e. of each unit of new capital, is high due to the low capital stock. The marginal productivity of each additional unit of capital levels off as the capital stock increases. Second, the greater the adjustment cost for the change in the

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<sup>11</sup> In order to ensure that the adjustment costs grow with the same rate as the other relevant variables in the steady state, the term  $(J_t - J_{t-1})$  has to be divided by  $(1 + \text{the rate of technological progress})^t$ , i.e.  $(1 + \gamma)^t$ , in the CGE model.



investment level represented by the parameter  $\xi$ , the more costly is the deviation from the investment level of the previous period. In other words, the higher  $\xi$ , the flatter will be the adjustment curve of investment. For the case of transition countries after the capital shock, the second effect initially dominates the higher marginal returns promised by each additional unit of capital. Investment increases only gradually until a maximum is reached. With the increasing capital stock, the decreasing marginal return of investment motivates only a decreasing amount of investment that is above capital depreciation replacement and capital widening.

Figure 6 and figure 7 show the development of the investment outlays and of the capital stock for 20 time periods for the three scenarios 1) mature economy, 2) transformation economy (i.e. characterized by a reduced capital stock) with the standard adjustment costs formulation and 3) transformation economy with the augmented adjustment costs formulation. The development of the investment outlays in the second scenario (transformation economy with the standard adjustment costs formulation) is similar to the one of the mature economy, except that the investment outlays are higher in every period to build up the capital stock (figure 6). The investment outlays in the third scenario (transformation economy with the augmented adjustment costs formulation) start at a low level, but grow until the level of the investment for scenario 2 is

reached. As discussed before, the investment development of scenario 3 resembles better the observed investment data within the transformation countries than the one of scenario 2. Due to the sluggish start of the investment activities, the capital stock for scenario 3 grows slower than the capital stock in scenario 2 (figure 7).

The augmented adjustment costs formulation acts to a certain extent as a proxy for other important determinants of investment during the transition process. At the beginning of the transformation, the economic agents are uncertain about the development of the economy and have a high discount rate that levels off as transformation progresses. Consequently, investment activity is low and rises with the decline of uncertainty. However, it is very difficult to determine the development of the discount rate of the economic agents within the transition economy for the CGE model. The augmented adjustment cost formulation is able to capture the effect of a sluggish start of the investment behavior and can therefore approximate the consequences of several aspects of transformation.

#### **4. Conclusions**

The use of Computable General Equilibrium (CGE) models for transition countries encounters problems since it is questionable whether the standard assumption is fulfilled, that the base year data represent stable structural

characteristics or even the steady state of an economy are fulfilled. This paper reviews attempts to deal with this problem and proposes a method of approximating the development of investment in transition economies through an augmented adjustment cost function for investment within dynamic CGE models. Adjustment costs are assumed to depend on the difference between the investment levels of two periods as well as the traditional ratio of investment and capital stock. As a result, the savings and investment behavior of the representative household / firm approximates more closely the observed time path of investment in transition countries. In contrast to the standard adjustment cost formulation, which predict a sharp rise in investment after a capital shock, augmented adjustment costs lead to a gradual rise in investment and, ultimately, to a leveling off towards its steady-state value.

This approach could be extended to a multisectoral model and offers the possibility of plausible simulations of policy changes (e.g. by introducing intersectoral differences in capital stock and adjustment parameters or by following proposals by Norén (1998) about the determination of investment flows between sectors). In particular, the effects of EU membership on of the advanced transition economies will be a suitable and promising issue that can be handled with the help of this proposed method.

## 5. References

- Barro, Robert J. and Xavier Sala-i-Martin, 1995, *Economic Growth* (McGraw-Hill).
- Blanchard, Olivier J. and Stanley Fischer, 1989, *Lectures on Macroeconomics* (MIT Press, Cambridge, Mass.).
- Braber, M., S. Cohen, T. Révész and Z. Zólkiewski, 1996, Policy Modeling Under Fixed and Flexible Price Regimes: SAM-CGE Transitional Applications to Poland and Hungary, *Journal of Policy Modeling* 18, 495-529.
- Breuss, Fritz and Jean Tesche, 1993, Hungary in Transition: A Computable General Equilibrium Model Comparison with Austria, *Journal of Policy Modeling* 15, 581-623.
- Brown, Drusilla, Alan V. Deardorff, Simeon D. Djankov and Robert M. Stern, 1997, An Economic Assessment of the Integration of Czechoslovakia, Hungary and Poland into the European Union, in: Stanley W. Black, ed., *Europe's Economy looks East* (Cambridge University Press, Cambridge) 23-60.
- Brooke, Anthony, David Kendrick and Alexander Meeraus, 1996, *GAMS – A User's Guide*, GAMS Development Corporation, Washington.
- Cass, David, 1965, Optimum Growth in an Aggregative Model of Capital Accumulation, *Review of Economic Studies* 32, 233-240, July.
- Castanheira, Micael and Gérard Roland, 1994, Restructuring and Capital Accumulation in Transition Economies: A General Equilibrium Perspective, CEPR Working Paper 1372.

- Eisner, Robert and Robert Strotz, 1963, Determinants of Business Investment, in: Commission on Money and Credit, ed., Impacts of Monetary Policy.
- European Bank for Reconstruction and Development (EBRD), 1997, Transition Report, London.
- Francois, Joseph F., Bradley J. McDonald and Hakan Nordström, 1997, Capital Accumulation in Applied Trade Models, in: Joseph F. Francois and Kenneth A. Reinert, eds., Applied Methods for Trade Policy Analysis – A Handbook (Cambridge University Press, Cambridge) 364–382.
- Francois, Joseph F., Hakan Nordström and Clinton R. Shiells, 1998, Transition Dynamics and Trade Policy Reform in Developing Countries, in: Richard Baldwin and Joseph F. Francois, eds., Dynamic Issue in Applied Commercial Policy Analysis (Cambridge University Press, Cambridge), forthcoming.
- Ginsburgh, Victor and Michiel Keyzer, 1997, The Structure of Applied General Equilibrium Models (MIT Press, Cambridge, Mass.).
- Gould, John P., 1968, Adjustment Costs in the Theory of Investment of the Firm, *Review of Economics Studies* 35, 47–55.
- Hare, Paul, Tamás Révész and Ernő Zalai, 1993, Modeling an Economy in Transition: Trade Adjustment Policies for Hungary, *Journal of Policy Modeling* 15, 625–652.
- Keuschnigg, Christian and Wilhelm Kohler, 1997, Dynamic of Trade Liberalization, in: Joseph F. Francois and Kenneth A. Reinert, eds., Applied Methods for Trade Policy Analysis – A Handbook (Cambridge University Press, Cambridge), 383–434.

- Keuschnigg, Christian and Wilhelm Kohler, 1998, Innovation, Capital Accumulation and Economic Transition, in: Richard Baldwin and Joseph F. Francois, eds., *Dynamic Issues in Applied Commercial Policy Analysis* (Cambridge University Press, Cambridge) forthcoming, (published as Arbeitspapier, 1996, No. 96–07, Johannes Kepler University Linz).
- Klepper Gernot, Jens-Oliver Lorz, Frank Stähler, Rainer Thiele, Manfred Wiebelt, 1994, Empirische allgemeine Gleichgewichtsmodelle - Struktur und Anwendungsmöglichkeiten, *Jahrbuch für Nationalökonomie und Statistik* 213/5, 513-544.
- Koopmans, Tjalling C., 1965, *On the Concept of Optimal Economic Growth, The Econometric Approach to Development Planning*, Amsterdam (North Holland).
- Lau, Morten I., Andreas Pahlke and Thomas F. Rutherford, 1998, *Modeling Economic Adjustment, A Primer in Dynamic Equilibrium Analysis*, Economics Department Working Paper (University of Colorado).
- Lucas, Robert, 1967, Adjustment Costs and the Theory of Supply, *Journal of Political Economy* 75, 321–334.
- Manne, Alan S., 1986, *GAMS/MINOS: Three examples*, Department of Operations Research (Stanford University), May.
- McLaren, Keith R., 1991, *The Use of Adjustment Cost Investment Models in Intertemporal Computable General Equilibrium Models*, Preliminary Working Paper No. IP-48 (Monash University).
- Norén, Ronny, 1998, Industrial Transformation in the Open Economy: A Multisector View, *Journal of Policy Modeling* 29, no. 1, 111–117.

- Orlowski, Witold, 1996, Price Support at any Price? Policy Research Working Paper No. 1584 (World Bank, Washington).
- Phillips, Alban W., 1961, A Simple Model of Employment, Money, and Prices in a Growing Economy, *Economica* 28, 360–370.
- Piazolo, Daniel, 1997, Trade Integration between Eastern and Western Europe: Policies Follow the Market, *Journal of Economic Integration* 12, no. 3, 259–297.
- Reinert, Kenneth A. and David W. Roland-Holst, 1997, Social Accounting Matrices, in: Joseph F. Francois and Kenneth A. Reinert, eds., *Applied Methods for Trade Policy Analysis – A Handbook* (Cambridge University Press, Cambridge) 94–121.
- Ramsey, Frank P., 1928, A Mathematical Theory of Saving, *Economic Journal* 38, 543–559, December.
- Roberts, Barbara M., 1994, Calibration Procedure and the Robustness of CGE Models: Simulations with a Model for Poland, *Economics of Planning* 27, 189-210.
- Sinn, Gerlinde and Hans-Werner Sinn, 1992, *Jump-start: The Economic Unification of Germany* (MIT Press, Cambridge, Mass.).
- Thimann, Christian, 1995, A Model of Investment Dynamics in Eastern Germany: Gradual Climb instead of Sudden Jump, *Journal of International and Comparative Economics* 4, no. 1, 137–159.
- Thimann, Christian, 1996, *Aufbau von Kapitalstock und Vermögen in Ostdeutschland*, *Schriften zur angewandten Wirtschaftsforschung*, no. 74 (J.C.B. Mohr (Paul Siebeck) Tübingen).

Uzawa, Hirofumi, 1969, Time Preference and the Penrose Effect in a Two-Class Model of Economic Growth, *Journal of Political Economy* 77, 628–652.

Zhang, Xiao-guang, 1998, Modeling Economic Transition: A Two-Tier Price Computable General Equilibrium Model of the Chinese Economy, *Journal of Policy Modeling* 20, 483–511.

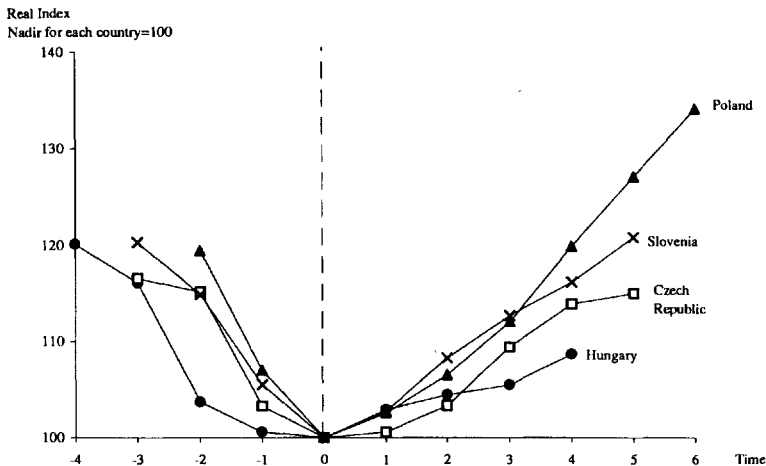


Table 1 — Variable and Parameter Values for the TransRams Model

$\rho$	Time Preference Rate	0.05
$\delta$	Depreciation Rate	0.07
$\gamma$	Growth Rate (Technological Progress)	0.02
$\varphi$	Adjustment Cost Parameter (Standard Formulation)	0/0.3
$\xi$	Adjustment Cost Parameter for Changes in the Investment Level	0/8
$K_0$	Capital Stock ("Mature Economy")	3
$K_{ATS}$	Capital Stock ("After Transformation Shock")	1.5

Source: Lau et al. (1998); Keuschnigg and Kohler (1998); Thimann (1996).

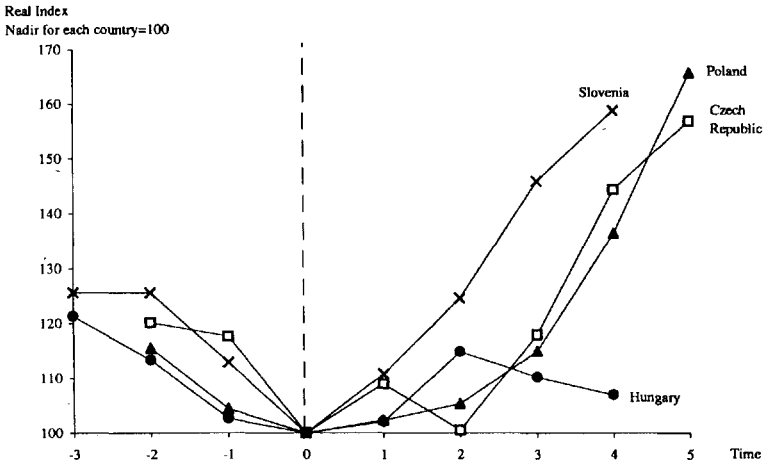
Figure 1 — Changes in the Real Gross Domestic Product of Four Advanced Transition Countries, 1989-1997



The Gross Domestic Product of the year with the lowest value is set equal to 100 for each transition country. The nadir year (time = 0) was for the Czech Republic 1992, for Hungary 1993, for Poland 1991 and for Slovenia 1992. All years from 1989 to 1997 are included in the graphical representation. The data for 1996 and 1997 are estimates from the EBRD.

Source: EBRD (1997), own calculations.

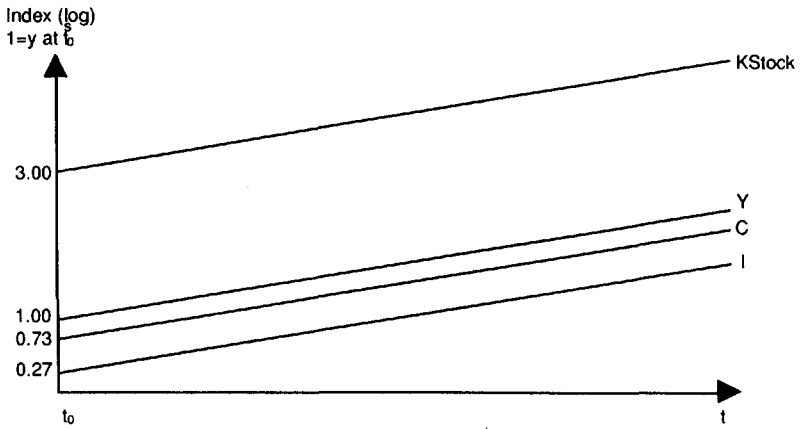
Figure 2 — Changes in Gross Fixed Investment of Four Advanced Transition Countries, 1989-1996



The Gross Fixed Investment of the year with the lowest value is set equal to 100 for each transition country. The nadir year (time = 0) was for the Czech Republic 1991, for Hungary 1992, for Poland 1991 and for Slovenia 1992. All years from 1989 to 1996 are included in the graphical representation. The data for 1996 are estimates from the EBRD.

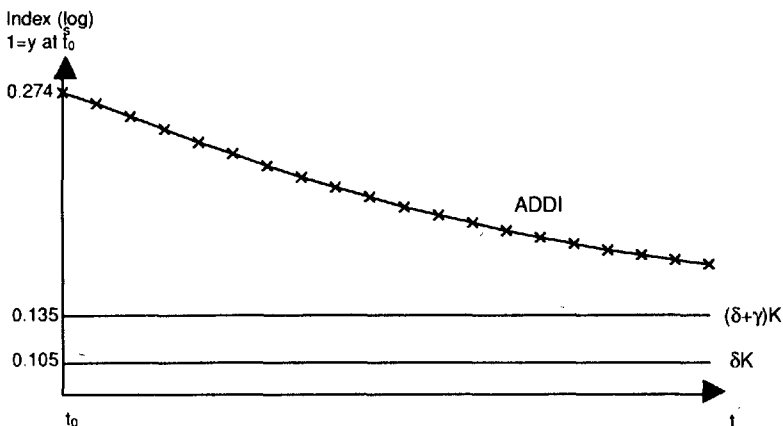
Source: EBRD (1997), own calculations.

Figure 3 — Balanced Growth of the Economy



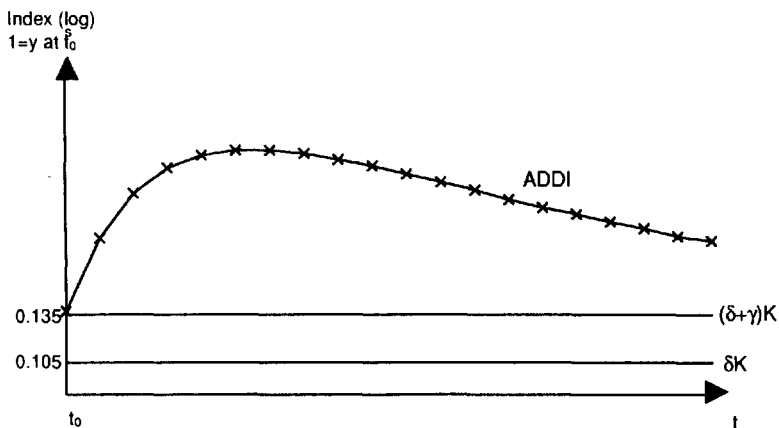
The economy is in steady-state and grows with 2 percent per year due to technological progress.

Figure 4 — Investment after the Capital Reduction Shock: Standard Adjustment Cost Formulation



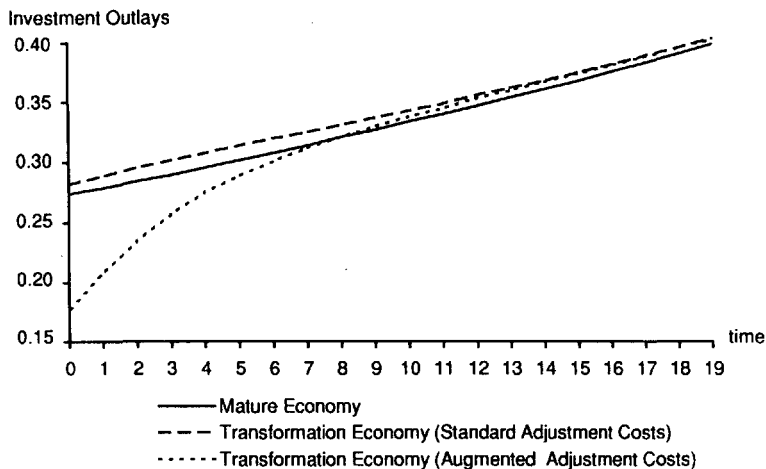
The area between the curve ADDI ("additional investment") and the line  $(\delta + \gamma)K$  indicates the amount invested that is above the investment needed to replace capital depreciation ( $\delta K$ ) and to widen the capital stock due to technological progress ( $\gamma K$ ). For illustration purpose the growing capital stock is depicted as constant.

Figure 5 — Investment after the Capital Reduction Shock: Augmented Adjustment Cost Formulation



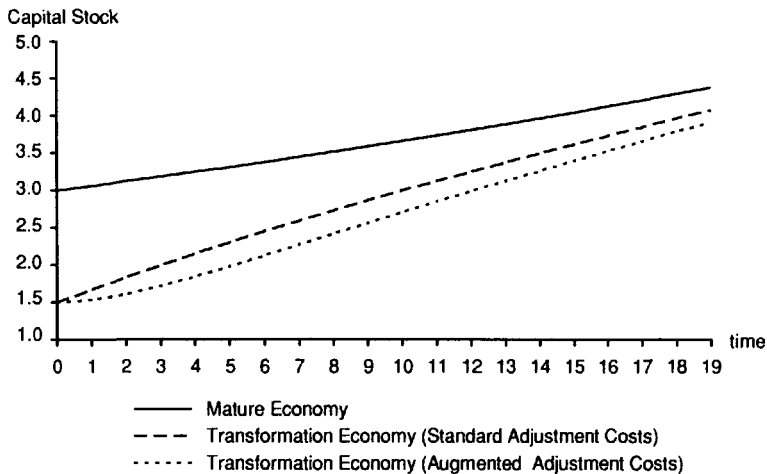
The area between the curve ADDI ("additional investment") and the line  $(\delta + \gamma)K$  indicates the amount invested that is above the investment needed to replace capital depreciation ( $\delta K$ ) and to widen the capital stock due to technological progress ( $\gamma K$ ). For illustration purpose the growing capital stock is depicted as constant.

Figure 6 — Development of Investment Outlays



Investment outlays include the adjustment costs for investment. The transformation economy is modeled through the reduction of the mature economy capital stock at time  $t_0$ .

Figure 7 — Development of Capital Stock



The transformation economy is modeled through the reduction of the mature economy capital stock at time  $t_0$ .