A Real Business Cycle Model for Panel Data: An Application for the Central European Transition Economies

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Abstract:

This paper has two objectives — a real business cycle model is analyzed for panel data over a short time period and the Central European transition experience is explained by RBC theory. In particular, the catch-up process of transition economies to the Western European level of development is described. The main contribution of the paper is a rigorous proof that transition data is consistent both with the standard stylized facts about macroeconomic fluctuations and with predictions from the proposed real business cycle model.

Abstrakt:

Tento článek sleduje dva cíle — analýzu modelu obchodního cyklu pro panelová data pokrývající pouze krátký časový úsek a vysvětlení průběhu transformace ve Střední Evropě pomocí teorie obchodního cyklu. Důraz je kladen především na proces popisující změny v transformujících se ekonomikách vzhledem k vývoji v západoevropských zemích. Význam tohoto článku spočívá v rigorozním důkazu konsistence dat z transformačních ekonomik jak se standardními znalostmi o chování makroekonomických ukazatelů tak s předpověďmi navrženého modelu obchodního cyklu.

Key words: Catch-up; Macroeconomic Fluctuations; Panel Data; Real Business Cycle; Transition

JEL classification: C13; E32; O11

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1. Introduction

The development of transition economies is based on their integration with the rest of the world. Given that market economies exhibit well-documented regularities in macroeconomic fluctuations, it is natural to ask to what extent these regularities also hold for transition economies. Indeed, even if these patterns hold, is it possible to identify them given that the transition period started only a few years ago? Is the transition experience sufficiently general that models omitting country-specific differences are useful? I claim that the answer to both questions is yes. To show this, I utilize a real business cycle model and imitate the transition experience of the CEFTA countries.[1]

This strategy differs substantially from standard transition literature.[2] The performance of transition economies is usually studied either by empirical analyses comparing results across countries (Rodrik 1996, Sachs 1996), or by theoretical models imitating the particular reform steps such as price liberalization, privatization, or macroeconomic stabilization (Goldberg and Karimov 1995, Hardy and Lahiri

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[1] Central European Free Trade Agreement—the Czech Republic, Hungary, Poland, Slovakia, and Slovenia.

[2] The detailed treatment together with the case studies and the numerous references can be found in Gros and Steinherr (1995).

1996). I propose a different way of analyzing the transition based on a standard real business cycle model.

Real business cycle models are based on two different approaches: the first approach utilizes a stochastic dynamic model. Rational expectations are assumed and the behavior of infinitely lived agents is optimal,[3] and the second class of models is based on stochastic overlapping generations.[4]

The model describing transition is restricted with the following conditions: the model should have favorable small sample properties, provide reasonable predictions for an open economy, and be consistent with the existence of several identical economies to allow use of the panel data.

The conditions presented above almost immediately suggest which class of models to use. Models based on overlapping generations are excluded because of the short time period analyzed. Models based on a two-country framework (Backus et al. 1994, Stockman and Tesar 1995) are not suitable because the transition experience of a panel of economies is studied (though such models could be used in analyzing the East-West relationship). The model describing transition on panel data can be based on the open economy extension of the model by Kydland and Prescott (1982), specifically, on the version presented in Correia et al. (1995). My modification aims to describe the catch-up process of transition economies to the level of development in Western European economies.

[3] The list of expanding literature includes Stockman and Svensson (1987), Mendoza (1991), Baxter and Crucini (1993), Backus et al. (1994), Stockman and Tesar (1995), or Correia et al. (1995). The recent detailed treatment with various extensions is presented in Cooley (1995).

[4] The early contributions include Frankel and Razin (1986) or Cardia (1989).

Correia et al. (1995) show that their model provides reasonably good predictions for the Portuguese economy, given the appropriate choice of production and consumption schemes. The model is consistent with the cyclical volatility of national account statistics and produces persistent exogenous shocks. The disadvantages are weak predictions of the volatility of investment and trade balance. Also, correlation structure for lagged variables is poor. However, as will be shown later, these factors are not crucial for the model selection.

There are a few well-known stylized facts describing macroeconomic fluctuations in developed economies. These facts are expressed using the variance-covariance matrix of basic macroeconomic indicators. One of the observed regularities is the procyclical character of most of the real indicators. The exception to this is trade balance, which is countercyclical. Furthermore, savings and investment are positively correlated. Finally, the volatility of investment is usually higher than the volatility of output, which is higher than the volatility of savings (King et al. 1991, Backus et al. 1994).

I focus on the sign of the correlation coefficients for transition data, rather than on volatility. The reason for this is that the time series from the transition economies are short, about one third of the time series used in standard real business cycle models. A comparative analysis is performed using the signs predicted by the standard stylized facts and the signs predicted by the proposed real business cycle model. The robustness of the achieved results is tested by a sensitivity analysis.

The paper continues as follows: In the second section, the data from transition economies are described. In the third section, the theoretical model is discussed in detail. In the fourth section, the parameters of the model are calibrated, the results of the simulation analysis presented, and the observed and simulated data compared. In the fifth section, an explanation of the transition experience based on a real business cycle model is discussed. Finally, the sixth section concludes the paper.

2. Data Analysis

The most surprising feature of the recent Central European reforms has been an initial decline in output. Nevertheless, several transition economies have returned to positive growth in the last few years. Also, a short period of capital outflows followed by significant capital inflows, trade balance deterioration, increase in private consumption, and initial decline in investment and savings may be observed. Government expenditures initially increased but then started to decline. Unemployment, which did not exist under central planning, has appeared. At first, unemployment rates rose rapidly and have only recently started to decline (Calvo et al. 1995; see also Figure 1 which features simple arithmetic means for the appropriate variable in a given year).

The time series for the transition period cover only a few years, with 6-7 annual or 24-28 quarterly observations from a single country. Some macroeconomic indicators have only recently become available on a quarterly basis. Also, the methodology of data collecting and processing has differed from standards in developed economies. Hence, I decided to focus on the CEFTA countries, which have the most reliable data[5] and feature very similar economic development.

It is possible to overcome the problem of the quality and length of the data with the following assumption: the economic structures and the transition experience

[5] Currently, the statistical offices of these countries publish a joint bulletin with main economic indicators. Nevertheless, in order to consistently cover the whole sample of economies over the analyzed period, the major source of data has been the World Bank, Washington D.C.

of analyzed economies are similar. In particular, the co-movements of variables are assumed to be similar. Under this assumption, one may perform a correlation analysis for the average Central European economy. The advantage is a lower number of auxiliary parameters than if the data from each economy were analyzed separately. In our case, the ratio of the auxiliary parameters to the number of observations decreases from 10/35 to 2/35.

The similarity assumption from the previous paragraph implies equality of means across countries. This can be tested by analysis of variance—the standard statistical procedure (e.g., Malinvaud 1966, pp. 215-240). The null hypothesis is that the means of de-trended data are the same in the analyzed subset of transition economies. The alternative hypothesis is that the mean in at least one economy differs from means in the other economies (without specifying which one). The test of the null hypothesis is a standard *F-test.*

The results of the analysis of variance are presented in Table 1. The first differences are used to remove the trend, since the panel data over a short time period are employed.[6] The results for real values based on the two normalization assumptions (1989=100% and 1989-1995=100%) are similar. However, the average 1989-1995 = 100% is preferred because of possible sensitivity to the choice of base year.

The results of the analysis of variance suggest that the correlation coefficients can be computed from the panel data with the same number of auxiliary parameters as in the case of a single economy. An additional advantage is an improvement in the

[6] An alternative method is the Hodrick-Prescott filter, which is designed for pure time series. It should be noted that a filtering of the data in the real business cycle literature is criticized for creating spurious cycles and interactions between variables (Cogley and Nelson 1995).

data reliability. The annual data are less sensitive to errors of measurement due to their higher degree of aggregation. Also, they need not be filtered to remove seasonality as is the case for quarterly data.

It is the signs of the correlation coefficients which are of interest. The statistics estimated by the presented methodology are influenced by the different timing and speed of the transition process in each country.[7] Formally, $\sigma_t^j = \sigma_{\alpha(t)}^i$, where function α describes the relative timing and speed of the transition in countries *i* and *j*, and σ is the statistic of interest. The signs of the correlation coefficients are expected to be robust to the time path of transition (save for leads and lags of the macroeconomic indicators), but this is not the case for the variances. To indicate at least approximately relative volatilities, their estimates are presented in Table 1. They suggest that trade balance, followed by unemployment and then investment and savings, has been the most affected by reform shocks.

Next, I will present the correlation coefficients of the basic macroeconomic indicators for a typical Central European transition economy based on the similarity assumption. The similarity assumption can be written in the form

$$\mu^x = \mu_i^x = E_t[x_{it}] \quad \forall i \, , \tag{1}$$

and the sample analog of the formula

$$\begin{aligned} Corr(x_{it}, y_{it}) &= \frac{E_i E_t\left[\left(x_{it} - E_t[x_{it}]\right)\cdot\left(y_{it} - E_t[y_{it}]\right)\right]}{\sqrt{E_i E_t[x_{it} - E_t[x_{it}]]^2 \cdot E_i E_t[y_{it} - E_t[y_{it}]]^2}} = \\ &= \frac{E_i E_t\left[\left(x_{it} - \mu^x\right)\cdot\left(y_{it} - \mu^y\right)\right]}{\sqrt{E_i E_t[x_{it} - \mu^x]^2 \cdot E_i E_t[y_{it} - \mu^y]^2}} \end{aligned} \tag{2}$$

[7] See Adams and Krkoška (1996) for an extensive discussion of timing, speed and comprehensivness of the transition processes in the formerly centrally planned economies.

is used to estimate the correlation coefficients (see Table 2). Subscripts i and t refer to countries and time periods, E_i (respective E_t) denotes the expectation operator with respect to countries (respective time), and x_{it} and y_{it} are particular variables. An expectation operator with respect to i could be alternatively applied to the whole ratio, but such an approach would not affect the empirical findings (although not reported, the numerical results are available upon request). The results for investment, savings and unemployment rate are robust to the type of indicator.

The signs of the correlation coefficients differ significantly for output shares and real values in the case of macroeconomic indicators connected with consumption. These patterns might indicate non-standard behavior on the part of consumers during the period of transition due to price liberalization, improvements in the quality of goods available, the disappearance of queues typical of centrally planned economies, and the opening of borders to the import of consumption goods. Another possibility is that the observed differences are due to measurement errors or the quality poor of the data in general.

The quality of the data has been checked through a sensitivity analysis. The sample has been changed to exclude first or last year observations. The signs of the correlation coefficients have been compared for the three samples. The greater sensitivity to the first observation is caused by differences in the methodology of data collection and processing. Similarly, the greater sensitivity to the last observation is caused by the corrections of the reported data over time. The results of a sensitivity analysis (available upon request) suggest that the estimated signs of the correlation analysis are robust,[8] except for output share of private consumption and real value of trade balance.

The results of the correlation analysis for the Central European transition economies are compared with the stylized facts for the developed economies. The patterns are generally similar. In particular, a trade balance countercyclicality and a positive correlation between savings and investment hold. The negative correlation of unemployment rate with output is expected. On one hand, the transition economies experienced initial output collapses and have started to recover only recently. On the other hand, unemployment immediately jumped to high levels and then only slowly decreased. This result is consistent with cyclical properties of the unemployment rate, since unemployment rises during recessions and declines during booms.

3. Theoretical Model

Consider a small open economy inhabited by a large number of infinitely-lived households. The economy is characterized by its level of technological progress, and produces a composite tradable good. The good produced can be used for both private and government consumption, as well as for investment, and can be freely imported and exported. Government consumption is financed by lump-sum taxes. The credibility of the economy is sufficient for financing its trade deficit by an international flow of capital. All variables are expressed in per capita terms, and the time endowment of a representative household is set at one.

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[8] The sign of the correlation coefficient changed only for output share of private consumption and real value of trade balance. The maximum difference between the correlation coefficients for output shares is 0.12 in the case of private consumption (all the other differences are below 0.09, the average is 0.05). The maximum difference between the correlation coefficients for real values is 0.18 in the case of trade balance (all the other differences are below 0.08, the average is 0.05).

A Cobb-Douglass production function with constant returns to scale determines the level of output in time period t; such that

$$\mathrm{Y}_t = \mathrm{A}_t \cdot \mathrm{K}_t^{1-\alpha} \cdot \left(\mathrm{N}_t \cdot \mathrm{X}_t\right)^{\alpha} - \phi \cdot \left(\mathrm{K}_{t+1} - \mathrm{K}_t\right)^2 \cdot \mathrm{X}_t^{-1}. \tag{3}$$

A_t denotes exogenous stochastic productivity disturbances, K_t is capital stock, N_t denotes labor input into production, X_t is the exogenous deterministic level of technological progress, and α is labor share of output, $0 < \alpha < 1$. The last term describes the adjustment costs as a function of net investment, K_{t+1} - K_t, where $\phi > 0$ (Mendoza 1991).

The law of motion of capital K_t is

$$K_{t+1} = (1-\delta) \cdot K_t + I_t. \tag{4}$$

K_{t+1} is capital in time $t+1$, K_t is capital in time t, I_t denotes gross investment, and parameter δ is the rate of depreciation.

The level of technological progress evolved before the transition period according to

$$X_{t+1} = (1+\gamma_0) \cdot X_t, \tag{5}$$

where $1+\gamma_0$ is a constant growth rate. The rest of the world features the growth rate $1+\gamma$, where $\gamma > \gamma_0$ before the start of the transition period. This assumption implies an increasing difference between the respective levels of technological progress in the analyzed economy and the rest of the world.

When the transition period starts (at $t=0$), the economy experiences an initial reform shock while opening to imports of new technologies. During the transition period, the economy converges toward a higher level of technological progress, $\overline{X_t} > X_t$, observed in the rest of the world. The transition period is characterized by a time-varying growth of the level of technological progress. The growth culminates in τ^{th} period after the start of the transition period (see Figure 2).

The evolution of the level of technological progress in a transition economy for $t \geq 0$ is described by the modified Raleigh function, where

$$Ln(X_t) = Ln(X_0) + \left[Ln(1+\gamma)\right] \cdot t + \left[Ln\left(\overline{X_0}\right) - Ln\left(X_0\right)\right] \cdot \left[1 - Exp\left(-\frac{t^2}{2 \cdot \tau^2}\right)\right]. \qquad (6)$$

Parameter τ characterizes the speed of adjustment. The growth rate of technological progress in a transition economy is defined as

$$Ln(1+\gamma_0) = \frac{dLn(X_t)}{dt} = Ln(1+\gamma) + \left[Ln\left(\overline{X_0}\right) - Ln\left(X_0\right)\right] \cdot \left(\frac{t}{\tau^2}\right) \cdot Exp\left(-\frac{t^2}{2 \cdot \tau^2}\right). \qquad (7)$$

The particular form of the function describing growth rate during transition has been chosen to coincide with other sources (Giustiniani et al. 1992).

A representative household maximizes its expected lifetime utility function over a contingent plan of consumption, C_t, and leisure, L_t,; that is,

$$\max_{C_t, L_t} E\left[\sum_{t=0}^{\infty} \beta^t \cdot u\left(C_t, L_t\right)\right], \qquad (8)$$

where β is the discount factor describing the rate of time preferences, and u is an instantaneous utility function.

The preferences chosen are based on the study by Correia et al. (1995). Correia et al. analyze the choice of utility functions and outline the advantages of the time-separable utility function presented in Greenwood et al. (1988). The preferences incorporate the level of technological progress, X_t,, and have the form

$$u\left(C_t, L_t\right) = u\left(C_t, 1 - H_t\right) = \frac{\left[C_t - \psi \cdot X_t \cdot H_t^{\rho}\right]^{1-\sigma} - 1}{1 - \sigma}. \qquad (9)$$

C_t is the consumption level, H_t are the total hours worked, H_t=N_t in equilibrium. Parameter ψ denotes the marginal rate of substitution between consumption and labor, σ is the coefficient of relative risk aversion, and ρ determines the intertemporal elasticity of substitution of labor supply, $\varepsilon = \frac{1}{\rho - 1}$.

The aggregate resource constraint is

$$C_t + I_t + TB_t + G_t = Y_t , \tag{10}$$

where C_t is private consumption, TB_t is the trade balance, and G_t is government consumption. The smoothing of consumption is enabled by access to perfectly competitive international capital markets in standard real business cycle models. In the model describing transition, it is due to the existence of external liabilities, B_t, which follow the law of motion

$$B_{t+1} = (1 + r) \cdot B_t + TB_t + TR_t . \tag{11}$$

TR_t are exogenous net capital transfers from abroad, and the parameter r denotes the constant rate of return. All stochastic fluctuations on the international capital markets are expressed by fluctuations of net capital transfers from abroad, TR_t.

The economy is assumed to be neither a net lender nor a net borrower in the long run. The value of the rate of return, r, is given by the rate of time preferences, β, and the growth rate, γ, i.e., $\frac{1}{1+r} = \beta \cdot (1+\gamma)^{-\sigma}$. The external liabilities of the economy are restricted by constraint $|B_t| < \Delta$, which holds for all t and $\Delta > 0$.

The dynamic optimization problem[9] for the economy defined above is described by a recursive competitive equilibrium. The numerical solution is based on

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[9] A summary of dynamic optimization methods in economics is presented in, e.g., Stockey et al. (1989), Cooley (1995), or Hansen and Sargent (1996).

a quadratic approximation of the objective function in the neighborhood of the steady state.[10] Thereafter, the implied equilibrium laws of motion are used for simulations. In the rest of this section, I define a recursive competitive equilibrium and compute its deterministic stationary solution, closely following Hansen and Prescott (1995).

The stationary solution assumes that the growth factor, X_t, is removed if necessary, and the transformed variables are denoted by lower case letters. This approach implies that the transformed discount factor has the form $\breve{\beta} = \beta \cdot (1+\gamma)^{1-\sigma}$. The exogenous state variables are assumed to be stationary.[11]

The general form of a dynamic optimization problem is

$$v(z,s) = \max\Big(r(z,s,d) + \breve{\beta} \cdot E\big[v(z',s') | (z,s)\big]\Big), \tag{12}$$

subject to

$$z' = Q(z) + e \quad \text{and} \quad s' = \mathrm{B(z,s,d)} \tag{13}$$

Primes denote next period values, *v(z, s)* is an optimal value function, *r(z, s, d)* is a return function, *z* is a vector of the exogenous state variables, *s* is a vector of the endogenous state variables, and *d* is a vector of the decision variables. Functions *Q* and *B* are assumed to be linear. A vector of random shocks is denoted *e.* It is identically distributed with mean *0* and variance-covariance matrix *W*, and independent across time.

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[10] The numerical method is used because an analytical solution does not exist. Other possible approximations are restricting the domain of the variables to a finite subset of state space (Mendoza 1991), or linearizing the equations which characterize the competitive equilibrium around the steady state (Correia et al. 1995).

[11] This is the conventional assumption in real business cycle models. It should be noted that pre- and post-transition levels of these variables can differ. Nevertheless, the stationarity assumption seems to be realistic for both steady states, before and after the transition period.

In this case, *z=(a, g, tr)*, *s=(k, b)*, and *d=(l, i, tb)*. The function *B* is given by the laws of motion for capital and external liabilities, i.e.,

$$B(z,s,d)=\begin{pmatrix} 0 & 0 & 0 & \frac{1-\delta}{1+\gamma} & 0 & 0 & \frac{1}{1+\gamma} & 0 \\ 0 & 0 & \frac{1}{1+\gamma} & 0 & \frac{1+r}{1+\gamma} & 0 & 0 & \frac{1}{1+\gamma} \end{pmatrix}\cdot\begin{pmatrix} z \\ s \\ d \end{pmatrix}. \qquad (14)$$

The return function *r* is given by the definition of the economy, i.e.,

$$r(z,s,d)=u(c,1-h)= \qquad (15)$$

$$=\frac{\left[c-\psi\cdot h^{\rho}\right]^{1-\sigma}-1}{1-\sigma}=\frac{\left[y-i-g-tb-\psi\cdot h^{\rho}\right]^{1-\sigma}-1}{1-\sigma}=$$

$$=\frac{\left[a\cdot k^{1-\alpha}\cdot(1-l)^{\alpha}-\phi\cdot\left(-\frac{\delta+\gamma}{1+\gamma}\cdot k+\frac{1}{1+\gamma}\cdot i\right)^{2}-i-g-tb-\psi\cdot(1-l)^{\rho}\right]^{1-\sigma}-1}{1-\sigma}.$$

The steady state is analytically computed in Appendix 1. The resulting formulas are

$$\frac{k}{y}=\frac{\beta\cdot(1-\alpha)}{(1+\gamma)^{\sigma}-\beta\cdot(1-\delta)},\qquad \frac{b}{y}=0,\qquad \frac{1-l}{y}=\frac{\alpha}{\rho\cdot\psi}\cdot(1-l)^{1-\rho},$$

$$\frac{i}{y}=\frac{(\gamma+\delta)\cdot\beta\cdot(1-\alpha)}{(1+\gamma)^{\sigma}-\beta\cdot(1-\delta)},\qquad \frac{tb}{y}=-\frac{tr}{y}. \qquad (16)$$

The first formula describes the relation between the capital–output ratio and the parameters describing production and consumption schemes. The second formula describes the steady state balance of external liabilities and assets. The third formula describes the relationship between the marginal productivity of labor and the marginal rate of substitution between consumption and labor. The fourth formula joins the law of motion of capital with the steady state capital-output ratio. Finally, the fifth formula is based on the relationship between the trade balance and net capital transfers from abroad, given a zero level of external liabilities in the long run.

4. Calibration of Parameters and Simulation Analysis

In this section, I calibrate the parameters and the initial reform shocks. I also perform a Monte-Carlo experiment and simulate the panel data mimicking the behavior of the archetypal transition economy. The results of the simulations are compared both with stylized facts for the developed economies and with the data from the transition economies. I focus in particular on the consistency with the output and unemployment dynamics, the positive correlation between savings and investment, and trade balance deterioration.

In the case of parameters describing the theoretical model — α, β, δ, σ, ρ, ϕ, and ψ — the values from other empirical studies (Kydland and Prescott 1982, Greenwood et al. 1988, and Correia et al. 1995) are used as the initial estimates. Then, the distance between the estimated steady state values and the average macroeconomic indicators is minimized. Such a metric has been used since it is impossible to estimate post-transition steady state values from the observed data or estimate the exact volatility of the macroeconomic indicators in the transition economies (as has been explained in section 2).

The VAR process describing dynamics of the exogenous state variables is restricted in order to decrease the number of estimated parameters. Both matrices Q and W are diagonal, having the form $q \cdot I$ and $w \cdot I$, where I is the identity matrix. The preliminary estimates of the parameters q and w are set at 0.5 and 0.01.

In the case of parameters connected with the transition process, the estimation procedure allows a large disparity between preliminary and final estimates (the maximum change allowed is $\pm 50\%$ of the preliminary estimate). The preliminary estimates are set ad hoc at the average of values used elsewhere (Gros and Steinherr 1995, Giustiniani et al. 1992). The level of technological progress is described in

Notes for Figure 2; the preliminary estimate of the steady state output share of net capital transfers from abroad is 5%; the estimate of capital-output ratio is set at the values presented in Giustiniani et al. (1992); the initial values of government consumption, net capital transfers from abroad, and external liabilities are estimated from the data (the simple arithmetic means across all the analyzed economies in the first two years of observations are used); the initial value of the exogenous stochastic productivity disturbances, $\bar{a}$, is set to normalize output to one at the start of the transition period.

The major reform shock is a negative shock to productivity (see Appendix 2 for a detailed description of this). To further decrease the number of estimated parameters, the reform shock occurs only in the first period. The preliminary estimate of initial reform shock is u_1=0.75.

The preliminary estimates of transition parameters are corrected using the estimated correlation coefficients. The final parameter values are chosen by minimizing the difference between the correlation coefficients computed from the data and predicted from the model. The minimization is performed using a grid search over the finite set of candidate estimates, which covers the neighborhood of the preliminary estimates, given maximum change allowed. The step length is 5% of the preliminary estimate.

The aggregated effect of the initial reform shock over the first six periods is presented in Table 5. To compare the alternative values, I also show the aggregated effect for large (0.50) and small (0.95) initial reform shocks. The aggregated effects are already similar after four periods. This suggests the irrelevance of the discussion of the size of the initial reform shock. Nevertheless, the persistency of the reform shock does not need to coincide with the persistency of the stochastic productivity.[12]

Given the calibrated parameters and the initial values of the state variables,[13] the deterministic impulse response functions for the basic macroeconomic indicators are analyzed (see Figure 3). This means that the reaction of the macroeconomic indicators to the initial reform shock is studied, relative to the steady state values. The simulated economy experiences the shock at the end of the first period when productivity decreases to 80% of its level in the pre-transition period. In the stylized economy the response of the macroeconomic indicators to the reform shock seems to be consistent with the patterns observed in transition data (the results for output shares are presented; the impulse response functions for real values are available upon request).

The negative productivity shock causes an output collapse and then a fast recovery. The output share of private consumption immediately increases and then declines toward a steady state value. Both savings and investment shares immediately fall. Thereafter, savings continuously increase toward a steady state. The investment share overshoots the steady state level in the third and the fourth periods, and then slowly decreases to a steady state level. The output share of the trade balance immediately deteriorates to 12% during the first period after the initial shock. After this, the trade balance improves with a continuing indebting of the economy. The

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[12] Different experiments with the persistency parameter Q have been performed. However, the structure of the model has to be altered substantially to change these results. It should be noted that the fit of the model increases with a rising number of parameters. Hence, simplicity of the model is preferred to perfect fit of the model.

[13] A sensitivity analysis was performed with results of the simulations being robust to small changes in the calibrated parameters ($\pm 5\%$).

unemployment rate immediately increases above the steady state level and decreases only slowly.

It should be noted that the immediate reactions to the simulated reform shock are consistent with the data. However, the impulse response functions do not coincide well with Figure 1, which describes the average transition experience of the CEFTA countries. A possible explanation will be proposed in the fifth section.

Finally, the results of a correlation analysis for a stylized economy are presented to show the effect of imitated fluctuations over the transition period. A Monte-Carlo experiment is performed by simulating 100 replicates of the panel of five identical economies.[14] The correlation coefficients are computed (see Table 2) and their signs are compared with the signs estimated from the data as well as with the standard stylized facts.

The results indicate that the real business cycle model generally performs well, even for panel data over a short time period. Predictions when simulating the panel data confirm the standard predictions from real business cycle models. Also, the estimates of the correlation coefficients based on the proposed model are consistent with the transition data.

The trade balance is countercyclical, while savings and investment are procyclical and positively correlated. The correlation between unemployment and output is negative. A negative correlation of government consumption and output is expected due to the combination of external shocks used (negative productivity shock and an initially higher level of government consumption). The only discrepancies exist for government consumption in real values and the output share of private

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[14] A normal distribution of random term is assumed.

consumption. These facts are probably caused by an oversimplified process driving the exogenous state variables in the theoretical model.

5. Explaining Transition Experience Using a Real Business Cycle Model

The consistency of the data and the model has been analyzed by a correlation analysis and impulse response functions. The signs of correlation coefficients based on the panel data do not depend on the timing or the speed of transition. In contrast, the impulse response functions cannot be used immediately to explain the average transition experience unless the time paths of transition are identical.

Hence, it is necessary to adjust the impulse response functions to allow for different timing and speed of the reform processes. In particular, the data from five transition economies are available. Therefore, the panel data for five economies is simulated (see Appendix 2 for a discussion of the initial reform shock for the panel data).

There are many possible combinations of the initial reform shocks. The shocks could occur at the same time and last only one year. Or, the shocks could happen in different time periods and influence each economy for several years. In the performed simulations, the set of assumed combinations has been restricted. The initial reform shocks occur over fewer than five periods in the whole region. Also, the shocks cannot be spread over more than two periods in a single economy.

An extensive analysis of different combinations of initial reform shocks has been done. In Table 6, the average aggregated effects of the initial reform shocks are presented for the three possibilities.

In the first panel, the start of the transition period is symmetrically distributed over four periods. The first economy experiences the shock in the first period, the second economy in the second period. The third economy has the reform shock spread over the second and third periods. Finally, the fourth economy experiences the shock in the third period, and the fifth economy in the fourth period.

In panel 2, each reform shock affects one period only. The shocks for the first and second economies happen in the first period, for the third and fourth economy in the second period, and for the fifth economy in the third period.

The third panel has the shock for each economy distributed over two periods. The first economy starts its transition in the first period. The second and the third economies experience the start of their reforms in the second period, and the fourth and fifth economies undergo the reform shocks starting in the third period.

The average aggregated effects suggest the importance of the timing and speed of the transition. However, their importance holds only for the simple description of the initial reaction to the reform shocks. The regularities in the macroeconomic fluctuations do not depend on these features. This observation adds an additional argument to the discussion of the relevance of timing and speed of the reform processes (e.g., Hiemenz and Funke 1994, Adams and Krkoška 1996, Sachs 1996).

Given the same estimated parameters and initial values as in the previous section, the impulse response functions for Panel 1 from Table 6 are presented. The observed macroeconomic indicators (Figure 1) and simulated variables (Figure 4) now show a striking similarity.

Trade balance and investment are the most sensitive to the distribution of the shocks. It is possible to alternate their impulse response functions by a different distribution of the initial reform shocks. Also, introducing time-to-build lag (Kydland and Prescott 1982) has been tried, but it does not substantially change the predictions of the model (not reported, available upon request). It should be noted that the high sensitivity of trade balance and investment coincides with the data.[15]

In the remainder of the section, I propose an explanation of the transition experience of the typical Central European economy based on a real business cycle model. Initially, the economy is stabilized. Its growth rate is lower than the growth rate for the rest of the world. Unemployment does not exist, although there is to some extent hidden unemployment as reported hours worked are greater than actual hours worked. Despite this, an assumption of full-employment can still be imposed. The economy is open to trade with the goods it produces, but closed to imports of advanced technologies.

When the transition period starts, the economy experiences an exogenous negative shock to productivity. This shock is caused by the end of the production of obsolete goods, the start of restructuralization and privatization programs, and increasing competition. The obsolete goods are substituted by imported goods. Also, the economy starts to import new technologies, previously not available. The imports are largely financed by increased net capital transfers from abroad. Another characteristic of transition is a rise in the growth rate (after an initial period of decline), which exceeds that of the rest of the world.

The transition economy features standard macroeconomic fluctuations along its path toward full integration with the rest of the world. Their effect is marginal if compared to the initial reform shock. In the long-run, the transition economy reaches a new stabilized state and becomes fully integrated into the world economy.

[15] The volatility of the trade balance is the highest of all observed macroeconomic indicators (see Table 1).

The real business cycle theory has several policy implications for transition economies. Initial deterioration in trade balance and considerable trade deficits over the transition period are unavoidable, given the initial negative shock to productivity. This observation is consistent with the focus on external trade in the development literature.[16] A high level of unemployment during the initial period of transition is also natural. This prediction of the model supports the importance of analyzing labor market policies (e.g., Gros and Steinherr 1995). Finally, the RBC theory predicts that investment rates during the transition period exceed investment rates in the rest of the world. Nevertheless, this pattern is conditioned by significant capital inflows from abroad (e.g., Giustiniani et al. 1992, Sachs 1996).[17]

[16] Liberalizing trade, promoting exports and attracting foreign direct investment (together with undervalued and unified exchange rates and higher degree of regional cooperation) are widely recognized and highly priced factors of rapid economic growth. (Adams and Davis 1994, Adams and Krkoška 1996).

[17] The additional condition is macroeconomic stabilization, which has been stressed in all policy recommendations by international organizations (EBRD, IMF, OECD or World Bank).

6. Conclusion

My paper contains two main contributions to literature about macroeconomic fluctuations. I show that a real business cycle model provides satisfactory predictions for the panel data over a short time period. In addition, I show that a real business cycle model can be utilized to imitate and explain the transition experience of the Central European economies.

Initially, I propose an econometric methodology which allows the use of highly aggregated panel data over a short time period. A correlation analysis for the average Central European economy is performed. It shows a consistency of macroeconomic fluctuations during the transition period with the standard stylized facts.

Furthermore, I present a modification of a standard real business cycle model. The transition economies are supposed to feature a catch-up process to the expected level of development. A simulation analysis is performed focusing on a correlation analysis and impulse response functions.

The predictions from the theoretical model are favorable. The correlation analysis of the real business cycle model for the panel data is consistent both with the standard stylized facts and with transition data. The impulse response functions are consistent with the observed patterns in macroeconomic indicators in the average Central European transition economy.

In future research, the simplifying assumptions of the model should be weakened. A complex model based on a dynamic general equilibrium approach would be of interest. An analysis of nominal variables could highlight other patterns of transition economies than those studied in my paper. In particular, consumer behavior during the transition period is worth deeper analysis.

Appendix 1 - Analytical Solution for the Steady State

The steady state values of the exogenous state variables, $z=(a, g, tr)$, are the solutions of the system of equations $z=Q(z)$. The constraint on the stock of external liabilities, $\left|B_t\right| < \Delta$, implies that its steady state output share is zero, $b=0$. Consequently, the steady state value of trade balance, *tb*, is uniquely determined by the law of motion for external liabilities, and therefore, $tb=-tr$.

The steady state given by optimizing behavior of a representative agent is consistent with any value of trade balance. Therefore, the original dynamic optimization problem is changed by assuming restricted vectors of endogenous variables, $s_1=(k)$, and decision variables, $d_1=(l, i)$. Given the steady state values of $z=(a, g, tr)$, *b*, and *tb*, the remaining steady state values of restricted endogenous variables, s_1, and restricted decision variables, d_1, are the solution for the following system of equations (Hansen and Prescott 1995):

$$\left(r_l, r_i\right) + \breve{\beta} \cdot r_k \cdot \left(I - \breve{\beta} \cdot BB_s\right)^{-1} \cdot BB_d = 0, \qquad s_1 = BB\left(z, s_1, d_1\right), \tag{17}$$

where

$$BB(z, s_1, d_1) = \begin{pmatrix} 0 & 0 & 0 & \dfrac{1-\delta}{1+\gamma} & 0 & \dfrac{1}{1+\gamma} \end{pmatrix} \cdot \begin{pmatrix} z \\ s_1 \\ d_1 \end{pmatrix}, \tag{18}$$

$$r_k = a \cdot \left(1-\alpha\right) \cdot k^{-\alpha} \cdot \left(1-l\right)^{\alpha} \cdot \zeta^{-\sigma}, \tag{19}$$

$$r_l = -a \cdot \alpha \cdot k^{1-\alpha} \cdot \left(1-l\right)^{\alpha} \cdot \zeta^{-\sigma} + \rho \cdot \psi \cdot \left(1-l\right)^{\rho-1} \cdot \zeta^{-\sigma}, \tag{20}$$

$$r_i = -\zeta^{-\sigma}, \tag{21}$$

$$BB_s = \left(\frac{1-\delta}{1+\gamma}\right), \tag{22}$$

$$BB_d = \left(0, \frac{1}{1+\gamma}\right), \tag{23}$$

and where

$$\zeta = a \cdot k^{1-\alpha} \cdot \left(1-l\right)^{\alpha} - i - g - tb - \psi \cdot \left(1-l\right)^{\rho}. \tag{24}$$

Substituting (18)–(23) into (17), and assuming $\zeta \neq 0$, we get the system of three equations with three unknowns, (k, l, i), that is

$$0 = -a \cdot \alpha \cdot k^{1-\alpha} \cdot (1-l)^{\alpha} \cdot \zeta^{-\sigma} + \rho \cdot \psi \cdot (1-l)^{\rho-1} \cdot \zeta^{-\sigma}, \tag{25}$$

$$0 = -1 + a \cdot (1-\alpha) \cdot k^{-\alpha} \cdot (1-l)^{\alpha} \cdot \frac{\beta}{(1+\gamma)^{\sigma} - \beta \cdot (1-\delta)}, \tag{26}$$

$$k = \frac{1-\delta}{1+\gamma} \cdot k + \frac{1}{1+\gamma} \cdot i. \tag{27}$$

The solutions of this system are the formulas for steady state values of remaining variables of the model, i.e.,

$$\frac{k}{y} = \frac{\beta \cdot (1-\alpha)}{(1+\gamma)^{\sigma} - \beta \cdot (1-\delta)}, \quad \frac{1-l}{y} = \frac{\alpha}{\rho \cdot \psi} \cdot (1-l)^{1-\rho}, \quad \frac{i}{y} = \frac{(\gamma+\delta) \cdot \beta \cdot (1-\alpha)}{(1+\gamma)^{\sigma} - \beta \cdot (1-\delta)}. \tag{28}$$

Appendix 2 - Initial Reform Shock

The initial reform shock in the economy *i* is summarized by the process $\{u_t^i\}_{t=1}^{T}$. The VAR process describing the evolution of the stochastic productivity disturbances is modified; that is

$$\log(a_t^i) = \log(\overline{a}) + q \cdot \log(a_{t-1}^i) + \log(u_t^i) + \varepsilon_t^i \tag{29}$$

where the last term is a random term. The aggregated effect of the initial reform shock in the k^{th} period is

$$e_k^i = (u_1^i)^{q^{k-1}} \cdot (u_2^i)^{q^{k-2}} \cdot \ldots \cdot u_k^i, \tag{30}$$

where the random factor, ε_t^i, is equal to zero for sake of simplicity.

The average VAR process for panel data is computed as follows: The VAR process describing the evolution of the exogenous stochastic productivity disturbances has the form (29), where the index *i* denotes particular economy, $i = 1, \ldots, n$. The formulas (29) for the VAR processes for *n* individual economies are summed together and divided by n, which implies

$$\frac{1}{n}\sum_{i=1}^{n} \log(a_t^i) = \frac{1}{n}\sum_{i=1}^{n} \log(\overline{a}) + q \cdot \frac{1}{n}\sum_{i=1}^{n} \log(a_{t-1}^i) + \frac{1}{n}\sum_{i=1}^{n} \log(u_t^i) + \frac{1}{n}\sum_{i=1}^{n} \varepsilon_t^i. \tag{31}$$

Then, the average exogenous stochastic shock, $\tilde{a}_t$, is defined by the formula

$$\tilde{a}_t = \left(\prod_{i=1}^{n} a_t^i\right)^{1/n}. \tag{32}$$

The average steady state value of the exogenous stochastic shock, $\overline{\tilde{a}}$, average initial reform shock for whole region, $\tilde{u}_t$, and the average stochastic disturbances, $\tilde{\varepsilon}_t$, are defined accordingly.

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Table 1 - Transition data analysis

Variable	Mean[1]	F-stat. (s)[2]	F-stat. (r)[2]	F-stat. (ra)[2]	Corr (s, r)[3]	Corr (s, ra)[3]	Corr (r, ra)[3]	Volatility (s)[4]	Volatility (r, ra)[4]
Output	—	—	0.16 (0.95)	0.18 (0.95)	—	—	0.99	—	1.00
Public consumption	18.56	0.06 (0.99)	0.25 (0.91)	0.25 (0.91)	0.83	0.81	0.99	3.35	2.75
Private Consumption	57.08	0.41 (0.80)	0.44 (0.78)	0.46 (0.76)	0.70	0.69	0.99	1.17	2.17
Total Consumption	75.65	0.61 (0.66)	1.48 (0.24)	1.10 (0.38)	0.62	0.60	0.99	1.18	1.46
Investment	23.45	1.30 (0.30)	0.67 (0.62)	1.04 (0.41)	0.91	0.97	0.90	15.51	18.86
Savings	24.44	0.57 (0.68)	0.23 (0.92)	0.41 (0.80)	0.94	0.94	0.98	10.55	13.43
Trade Balance	-1.48	0.10 (0.98)	0.04 (0.99)	0.08 (0.99)	0.80	0.39	0.85	560.55	560.06
Unemployment Rate	8.43	—	—	0.40 (0.81)	—	—	—	—	142.89

Notes to Table 1

Remark 1: Most variables are expressed as output shares. The unemployment rate is in % of labor force at the end of the period. The means have been computed as simple arithmetic means across all economies over all available observations (1989-1995).

Remark 2: The analysis of variance has been performed for de-trended data (by first differences). Index **s** denotes output shares. Index **r** denotes real values normalized by setting 1989 = 100%. Index **ra** denotes real values normalized by average 1989-1995 = 100% and unemployment rate, un, which is in % of labor force. The values in parentheses are standard P-values.

Remark 3: Correlation coefficients are for de-trended data.

Remark 4: The volatility for de-trended data has been computed relative to the volatility of output.

Table 2 - Estimated correlation coefficients[1] for observed[2] and simulated data

Correlation Between:	Output Shares - Observed Data	Output Shares - Simulations	Real Values - Observed Data	Real Values - Simulations
Output and Public Consumption	-0.40	-0.79	0.15	-0.10**
Output and Private Consumption	0.01*	-0.50**	0.72	0.11
Output and Total Consumption	-0.30	-0.66	0.58	0.10
Output and Investment	0.36	0.37	0.55	0.37
Output and Savings	0.28	0.19	0.55	0.22
Output and Trade Balance	-0.16	-0.50	-0.15*	-0.46
Output and Unemployment Rate	-0.72	-0.37	-0.72	-0.23
Savings and Investment	0.46	0.91	0.60	0.91

Remark 1: One star denotes non-robust signs of the correlation coefficients for observed data. Two stars indicate inconsistent signs for observed and simulated data.

Remark 2: Results for real values are for average 1989-1995=100%.

Table 3 - Calibrated parameters

Parameter		Value
α	Labor share of output	0.6
β	Discount factor	0.99
δ	Depreciation rate	0.07
σ	Coefficient of relative risk aversion	2
ρ	Parameter determining the intertemporal elasticity of labor supply	1.7
ϕ	Parameter describing adjustment costs	0.025
ψ	Marginal rate of substitution between consumption and labor	2.34
q	Persistency of exogenous shocks	0.3
w	Volatility of exogenous shocks	0.01

Table 4 - Calibrated initial values of state variables and size of an initial reform shock

Variable		Value
g/y	Output share of government consumption	0.20
tr/y	Output share of net capital transfers from abroad	-0.025
k/y	Capital-output ratio	2.46
b/y	Output share of external liabilities	-0.35
u_1	Initial reform shock	0.80

Table 5 - The impact of the size of an initial reform shock

Time Period	1	2	3	4	5	6
Aggregated Effect (50%)	50.00 %	81.23 %	93.95 %	98.15 %	99.44 %	99.83 %
Aggregated Effect (80%)	80.00 %	93.52 %	98.01 %	99.40 %	99.82 %	99.95 %
Aggregated Effect (95%)	95.00 %	98.47 %	99.54 %	99.86 %	99.96 %	99.99 %

Table 6 - The aggregated effect of initial reform shocks for panel data

Time Period	1	2	3	4	5	6
Panel 1	95.64 %	92.28 %	91.30 %	93.06 %	97.86 %	99.35 %
Panel 2	91.46 %	89.04 %	92.36 %	97.65 %	99.29 %	99.79 %
Panel 3	97.79 %	92.90 %	89.46 %	92.49 %	97.69 %	99.30 %

Figure 1 - Average transition experience of the CEFTA countries

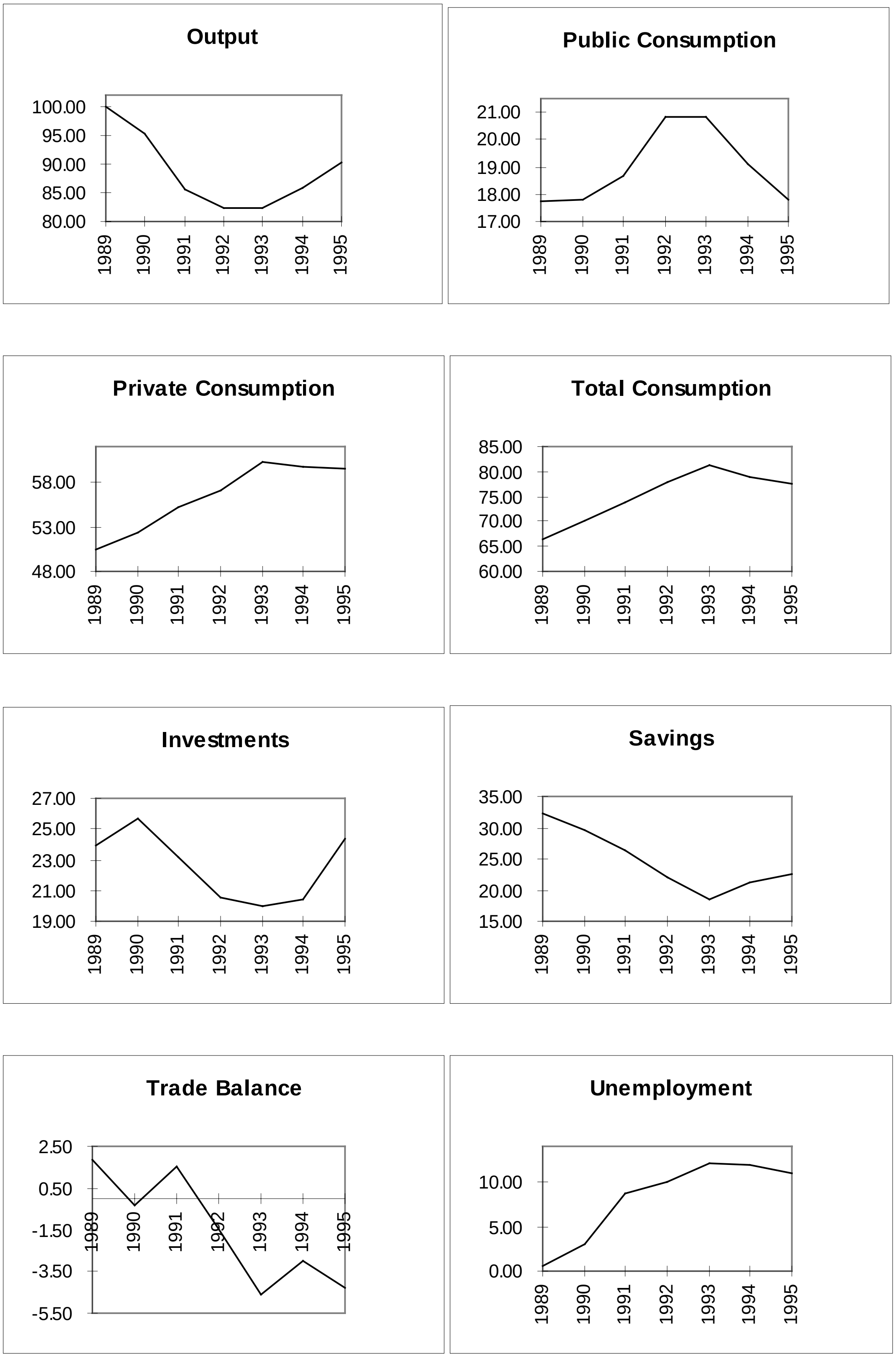
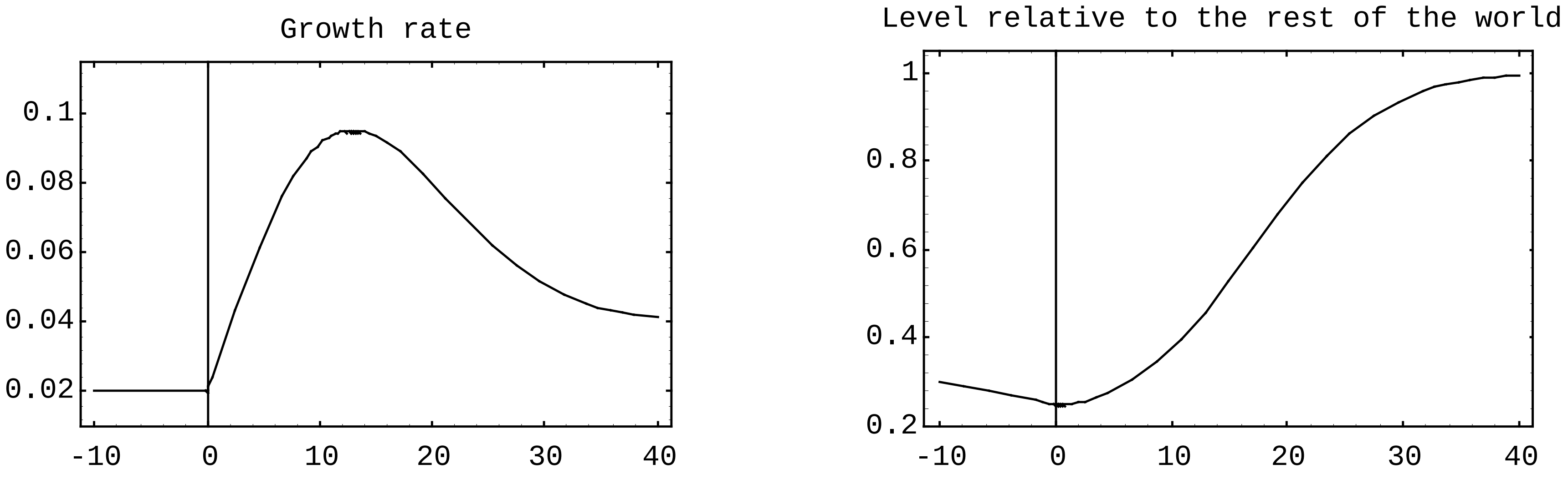


Figure 2 - Time path of the level of technological progress in a transition economy



Notes for Figure 2:

The graphs are based on comparisons of labor productivity in Central European transition economies and in Western European economies. On average, the ratio of productivity is 25%, although the estimates vary from 21% to 40%. The period during which the transition economies will reach 95% of productivity in the developed economies is supposed to last 14-30 years, so the upper estimate is used. Both estimates are based on Giustiniani et al. (1992), but they are consistent with other sources, e.g., Gros and Steinherr (1995). The pre-transition growth rate is assumed to be 2%; the constant growth rate of the rest of the world is assumed to be 4%. Time 0 denotes start of the transition period.

Figure 3 - Impulse response functions for a simulated reform shock

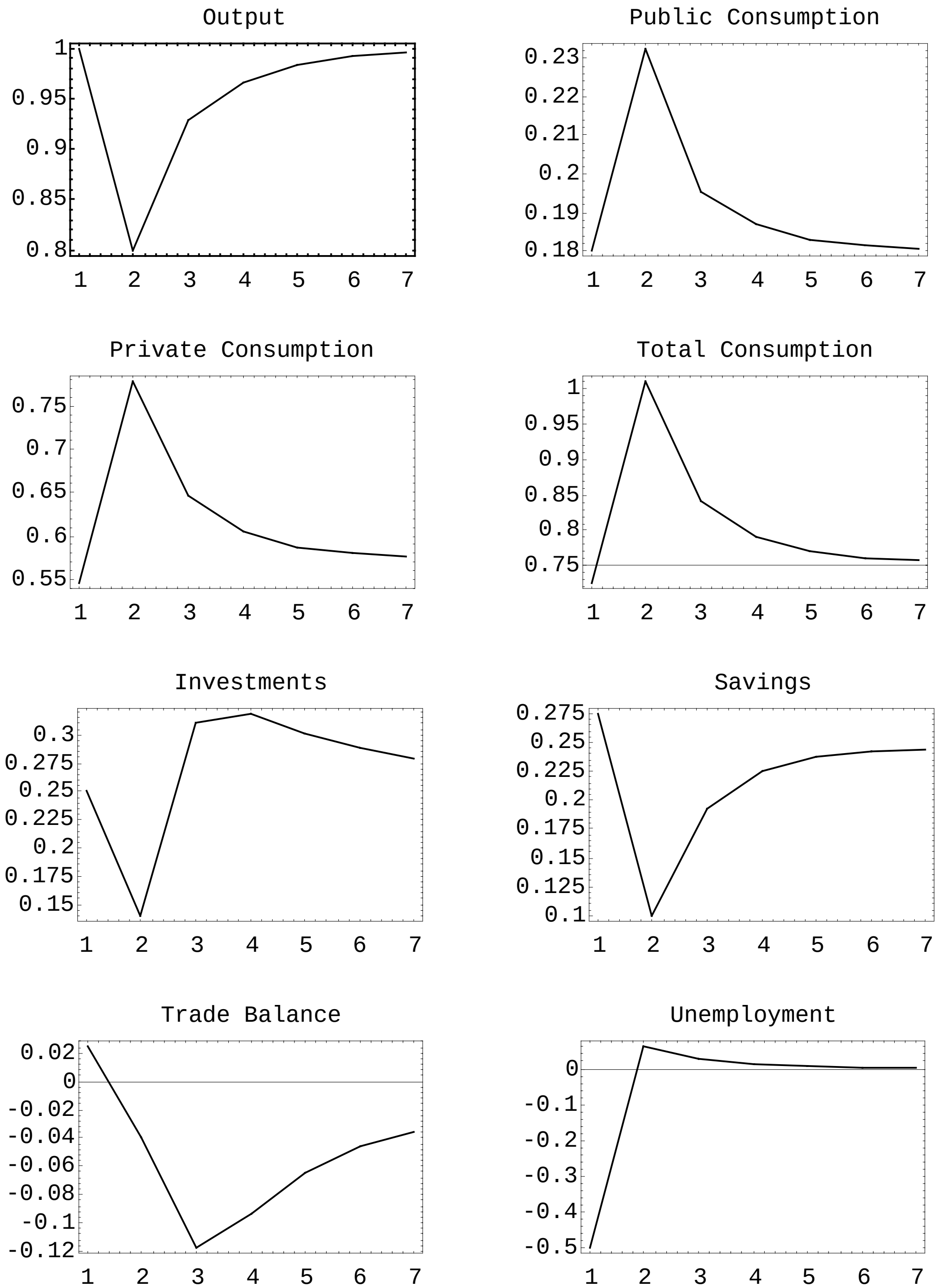


Figure 4 - Average impulse response functions for a panel of transition economies