A Comparative Analysis of Productivity Growth, Catch-Up and Convergence in Transition Economies

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ABSTRACT

The paper examines the macroeconomic performance of 25 transition economies using a comparable data set for 1991-2000. Centrally planned economies were criticized for wide-spread economic inefficiency and low total factor productivity growth. In order to see whether transition to market based economy increased economic efficiency, technical progress, and total factor productivity, we estimate efficiency measures for East European, Baltic, and the other Former Soviet Union Countries using Stochastic Frontier Analysis and Data Envelopment Analysis. The average annual efficiency level for 25 transition economies is 0.559 over the period 1991-2000. The average annual growth in technical efficiency is 2.8 percent over the same period. This efficiency change (or catch-up) in transition economies suggests that there is a mixture of increasing and decreasing efficiency levels for the whole period. The average annual technical change in transition economies is -19 percent over the period examined. That is, there is no technological progress, but over the whole period there has been technological decline. As a result, the average annual total factor productivity change for each of 25 transition country has declined due to huge negative technical change and a slight positive efficiency change. The sum of technical and technical changes is –16.2 percent. That is, the average annual total factor productivity has declined by 16.2 percent over the period 1991-2000. These results suggest that, on average, technical efficiency change or catch-up is overcompensated by the declining technical change.

Keywords: Technical efficiency, total factor productivity, transition economies, convergence, stochastic production frontiers, data envelopment analysis.

1. Introduction

The competitiveness and welfare level of people of any country is clearly related to the performance of its potential economic growth. Without economic growth there can be no long-term poverty reduction. Economies that have not grown have experienced stagnant or increasing poverty rates. The keen interest in economic growth or productivity growth is the objectives of economic polices. Therefore, recent literature on regional and cross-country studies has paid a great deal of attention to the performance differential across regions in a country and nations across the world (see, for example, Bannister and Stolp, 1995; Albert, 1998; Dinc and Haynes, 1999; Driffield and Munday, 2001; Onder, Deliktas, and Lenger 2001).

The economic performance of regions, countries, and the world as a whole has formed the subject matter of numerous studies over the last three decades. Broadly based empirical analyses such as Maddison (1987, 1989, and 1995) provide a general framework for studying and evaluating the economic performance of countries. Fare, Grosskopf, Norris, and Zhang (1994) studied the productivity growth and its components in OECD countries. Rao and Coelli (1998a, 1998b) studied catch-up and convergence in global agricultural productivity and analysis of GDP growth based on cross-country study, covering all the regions of the world and accounting for a major portion of global output and population. Osiewalski, Koop, and Steel (1998) studied GDP growth, efficiency change and technical change in Poland and Western Economies.

Our study examines transition economies. The concept of transition economies emerged in 1990's after the collapse of the USSR. About 25 countries of the former Soviet Union (FSU) countries which are now called transition economies, have decided to transform from centrally planned economy to market economy. The underlying economic reason of the transition was the ever worsening economic inefficiency in the pre-transition period and expectation that economic efficiency would increase after transition to market economy. However, this expectation did not realize since beginning of transition. Most of transition countries are still experiencing recession and economic contraction. Since 1988 the region has experienced a sharp drop in GDP growth rate. Most transition economies recovered pre-transition GDP levels only after 2000. Table 1 shows average annual percentage growth of transition economies over the period 1990-2000.

<Table 1 here>

Table 1 indicates that average annual growth rate of transition economies is –1.92 over the period 1990-2000. This shows that, on average, transition economies indeed experienced an economic contraction over this period. Only, Albania, Croatia, Czech Republic, Hungary, Poland, Slovenia, and Slovak Republic have positive growth rates. Poland has the highest average annual growth rate among transition economies, with an average growth rate of 4.6 percent.

Three major strands of literature can be identified in analysis of economic performance of nations (Rao and Coelli, 1998b). The first, and most typical, approach focuses on growth in real per capita income or real GDP per capita. This indicator can be considered as a proxy for the standard of living achieved in a country. The second approach is to examine the extent of convergence achieved by the poor countries and measure disparities in the global distribution of income. The third and recent approach, which is also used in our paper, is to consider productivity performance based on partial measure, such as output per person employed or per hour worked, and multi factor productivity measures based on the concept of total factor productivity and its components, such as technical efficiency change and technical change. Total factor productivity is considered as an important indicator of economic performance of nations. Technical efficiency change is also an indicator of the level of catch-up and convergence among the countries.

In this respect, the main objective of this study is to examine economic performance of transition economies in terms of technical efficiency, efficiency change or catch-up and convergence, technical change, and total factor productivity (TFP) change and to investigate some probable sources of technical inefficiencies. Total factor productivity growth and its components, namely efficiency change and technical change are the most widely used criteria for economic performance measures. In this performance measures, the level of efficiency, efficiency change, technical change and the TFP change in transition economies were estimated using the Stochastic Frontier Analysis (SFA) and Data Envelopment Analysis (DEA) based on panel data for 25 transition countries for the period of 1991-2000. DEA is mainly used for confirmatory analysis and supplements the SFA. Technical inefficiency effects are modeled as a function of country-specific socioeconomic factors, liberalization and democratization indices, and time period under Soviet Union.

In this paper, the idea of a production frontier is applied in a macroeconomic context in which transition countries are producers of output (e.g. real GDP) given inputs (e.g. capital and labour). Accordingly, countries can be thought of as operating either on or within the frontier; and the distance from the frontier as reflecting inefficiency. Over time, a country can become less efficient or more efficient and "catch-up" to the frontier or the frontier itself can shift over time, indicating technical progress. In addition, a country can move along the frontier by changing inputs used in production. Hence, output growth can be thought of in terms of three different components: efficiency change, technical change, and input change. Economists often refer to the first two components collectively as "total factor productivity change" Osiewalski, Koop, and Steel (1998).

The major issues considered in this study is to compare efficiency and productivity performance among the transition countries as well as groups of Middle and East European (MEE) and other former Soviet Union (OFSU), and Baltic countries. The paper also investigates of the roles of natural resources, income distribution (Gini coefficient), urbanization rate, liberalization, time period under Soviet Union, and population size of the countries on the technical efficiency and total factor productivity of the countries.

The remainder of the paper is as follows: Section 2 briefly outlines the major sources of data and describes all the variables in the study. Section 3 defines the methodology used in the analysis. The fourth section presents empirical results and the paper finishes with conclusions.

2. Data

Measurement of total factor productivity usually requires either data on input and output prices or the input and output shares for production. But, it is difficult to collect data on input and output prices. Thus the input and output shares are used in this study. Input and output data set related to the each country was obtained from World Development Indicators 2002 (WDI) published by the World Bank. The data covers the time period of 1991-2000 and includes 250 observations in total.

Aggregate output (Q) is measured by real GDP (constant 1995 US dollars) for each country. Inputs used in our model are labour (L) and, capital (K). Labour input is measured as the total labour force**.** The capital stock for each country was cumulatively calculated from gross capital formation (constant 1995 US dollars) by taking 1989 as a base year. Time trend includes ten years period for 1991-2000. A quadratic trend was also included in the production function for the same period.

Following the variables are considered as conditions that can explain (in)efficiency differentials: Natural resources, income distribution, urbanization, liberalization index, time under the Soviet Union, population size, level and degree of reforms, foreign direct investment (percent of GDP), aid (percent of GNI), export of goods an services (percent of GDP), school enrolment, domestic credit provided by banking sector (percent of GDP), inflation rate, and the distance from Dusseldorf.

3. Methodology

In order to analyze the relative technical efficiencies and country specific efficiency change, technical change, and total factor productivity growth in the transition economies, we use the the SFA. In addition to the SFA, we also use DEA as a confirmative analysis. These two methods are commonly used in the literature for estimating frontiers. While the SFA is an econometric method, DEA is a non-parametric mathematical programming method. The econometric methods can be classified as (1) those that assume all deviations from the frontier are due to inefficiencies and (2) those that allow some variation around the frontier due to factors that cannot be controlled by the firm. In the first method, a deterministic frontier and in the second a stochastic frontier is prescribed. Econometric methods allow flexible functional forms for the frontier and impose some restriction on the statistical properties of efficiency terms (Balcılar and Cokgezen, 2000).

Since stochastic frontier production models were proposed by Aigner, Lovell, and Schmidt (1977) and Meeusen and van den Broeck (1977), there has been a vast range of application in the literature. The model was originally defined for an analysis of cross-sectional data, but various models to account for panel data have also been introduced by Pitt and Lee (1981), Cornwell, Schmidt, and Sickless (1990); Kumbhakar (1990), and Kumbhakar, Ghosh, and McGuckin (1991).

Battese and Coelli (1995) proposed a stochastic frontier production function for panel data, in which firm effects are assumed to be distributed as truncated normal random variables. Firm effects are also permitted to vary systematically with time. In this model, the inefficiency effects are directly influenced by the number of variables.

Using panel data has some advantages over cross-sectional data in the estimation of stochastic frontiers models. The application of panel data increases the number of degrees of freedom in the estimation procedure. It also makes it possible to investigate both technical change and technical efficiency change over time simultaneously (Coelli, Rao, and Battese, 1998).

In this paper, we use a panel data of the transition economies to estimate the translog stochastic production function for the period 1991-2000. By using the time-varying inefficiency model developed by Battese and Coelli (1995), we seek to measure the technical efficiency and technical change in the transition countries.

For the stochastic frontier approach, a translog stochastic frontier production function is specified. The output (GDP) of a country is assumed to be a function of two inputs capital and labour. We assume a non-neutral technical change is specified and the error term is assumed to have two components, with properties as discussed below.

The translog production frontier is defined by

$$\begin{aligned} \ln(Q_{it}) &= \beta_0 + \beta_1 \ln(K_{it}) + \beta_2 \ln(L_{it}) + (1/2)[\beta_{11}(\ln K_{it})^2 + \beta_{22}(\ln L_{it})^2] \\ &\quad + \beta_{12}\ln(K_{it})\ln(L_{it}) + \beta_{13}\ln(K_{it})t + \beta_{23}\ln(L_{it})t + \beta_{33}t^2 + v_{it} - u_{it} \end{aligned} \tag{1}$$

$$i = 1, 2, \ldots, N, \quad t = 1, 2, \ldots, T$$

where Q_{it} denotes the real GDP. The subscripts i represent the *i-th* country; N is equal to 25 accordingly, whereas t represents year and so T is equal to 10. K_{it} and L_{it} represent capital and labour, respectively. The $\beta's$ are unknown parameters to be estimated. The $v_{it}'s$ are random errors and are assumed to be independently and identically distributed as $N(0,\sigma_V^2)$. They are also assumed to be independently distributed of $u_{it}'s$ that are technical inefficiency effects and are non-negative random variables. The $u_{it}'s$ are assumed to be independently distributed. The distribution of u_{it} is obtained by truncation at zero of the normal distribution with mean m_{it} and variance σ_u^2, where m_{it} is defined as technical inefficiency associated with

$$\begin{aligned} m_{it} = {} & \delta_0 + \delta_1 \text{Natural resources}_{it} + \delta_2 \text{Gini}_{it} + \delta_3 \text{Urbaniztion}_{it} \\ & + \delta_4 \text{Liberalization}_{it} + \delta_5 \text{Time under USSR}_{it} + \delta_6 \ln(\text{population})_{it} \\ & + \delta_7 \text{Advanced\&High intermediate reformers}_{it} + U_{it} \end{aligned} \tag{2}$$

As inefficiency effects, *natural resources* represents each country's natural richness. *Gini* index variable is an indicator of income distribution or as the scalar index of inequality within each country. Urbanization variable is the rate of urban population to total population. This rate represents urbanization level of the countries. Liberalization is general liberalization index (LI), which is weighted average of three indices. These three indices represent privatization and financial sector reforms (LIP), openness of market to foreign sector (LIE), and internal liberalization degree of markets (LII). The shares of LIP, LIE, and LII in the LI are 40, 30, and 30 percents, respectively (Balcılar, 2002). Time period under USSR represents the number of years that the country was under Soviet regime. ln(population) represents the natural log of population for each country. Advanced and high intermediate reformers variable is a dummy variable based on the cumulative liberalization index, which measures the degree and rapidity of reforms (Deliktaş and Emsen, 2002).

The other inefficiency variables, such as low and slow reformers, foreign direct investment (percent of GDP), aid (percent of GNI), export of goods an services (percent of GDP), school enrolment, domestic credit provided by banking sector (percent of GDP), inflation rate, and the distance from Dusseldorf are omitted from equation (2) due to lack of statistical significance.

Technical efficiency of the *i*-th country at the *t*-th period of observation is defined by

$$TE_{ijt}=\exp(-u_{it}). \quad (3)$$

Efficiency change between the periods *s* and *t* can be calculated as

$$\text{Efficiency change} = TE_{it}/TE_{is}\,. \quad (4)$$

The technical change index between periods *s* and *t* for the *i*-th country can be calculated directly from the estimated parameters of equation (1). If technical change is non-neutral, then this technical change index may vary with different input vectors. Hence, a geometric mean be used to estimate the technical change index between adjacent periods s and t. (Coelli, Rao, and Battase, 1998). That is,

$$\text{Technical change} = \left[\left(1+\partial\ln E(Q_{is})/\partial s\right)x\left(1+\partial\ln E(Q_{it})/\partial t\right)\right]^{0.5}, \quad (5)$$

where *E(Q)* denotes the expected value of the production.

4. Empirical Results

The stochastic frontier and data envelopment methods are applied to a sample of 25 transition economies over the period 1991-2000. Maximum-likelihood estimates of the parameters of the stochastic frontiers model defined by Equations (1) and (2) are estimated with FRONTIER 4.1 (Coelli, 1996).

Our analysis includes transition economies within the MEE countries (Albania; Bulgaria; Croatia; Czech Republic; Hungary; Macedonia, FRY; Poland, Romania, Slovak Republic, and Slovenia), the OFSU countries (Armenia, Azarbaijan, Belarus, Georgia, Kazakhstan, Kyrgyzstan, Moldova, Russian Federation, Tajikistan, Turkmenistan, Ukraina, and Uzbekistan), and Baltic countries (Estonia, Latvia, and Lithuania).

The preferred model in our study is the non-neutral translog model. Maximum-likelihood estimates for the parameters of the stochastic frontier production function for the transition economies were presented in Table 2.

<Table 2 here>

The table represents that most of the coefficients of the model are significant at 5 percent level of significance. Only insignificant parameter is β_{23}, which is the coefficient of [ln(labour) x time] interaction variable. As it is expected, the sign of the ln(labour) is positive. The coefficient of ln(capital) is however negative. The negative sign for capital suggests operation in Stage III of the production function in the capital input where there is considerable congestion in the use of this input (Coelli, Rao and Battase, 1998). In the case of transition economies, this possibility is not unlikely. These economies have surplus of gross capital and withdrawal of this capital from production doe not cause any output loss.

The estimates of the technical change parameters in Table 2 indicate a technical decline during the sample period. This will be discussed below along with productivity components. The inefficiency effects estimates (δ_i) suggests a mixture of both positive and negative effects all significant at 5 percent level**.**

The estimated variance parameter $\gamma = \sigma_u^2 / \ \sigma_s^2, \sigma_s^2 = \sigma_v^2 + \sigma_u^2$ was also found to be significant, and hence, we infer that technical inefficiency effects have significant impact on output (Wadud and White, 2000). The estimated value of σ_s^2 is also significant at 5 percent level of significance. This suggests that a conventional production function is not an adequate representation of the data. This result is also in line with Battese and Coelli (1995).

Several hypothesis tests were also conducted to find out whether the non-neutral translog stochastic frontier production model is appropriate. Table 3 presents the results of formal hypothesis tests. The null hypotheses test the assumptions imposed on the data through the model given in equations (1) and (2). All hypotheses are tested using the generalized likelihood-ratio statistic.

$$\lambda = -2\ln\left[L(H_0)/L(H_1)\right] \qquad (8)$$

where $L(H_0)$ and $L(H_1)$ are the values of the likelihood function of the frontier model under the null, H_0 , and alternative hypothesis H_1, respectively.

<Table 3 here>

For each hypothesis $L(H_1)$= -31.4040. All tests are performed at the 5 percent significance level. The first test in Table 3 suggests that the Cobb-Douglas production function is an adequate representation (all second order coefficients, β_{ij} , are zero). If the second null hypothesis, which specifies that there is no inefficiency effects, $\gamma = \delta_0 = \delta_1 = \ldots = \delta_7 = 0$, was to be accepted, then the model would be equivalent to the average response function and could be estimated by the ordinary least squares method. The third null hypothesis imposes Hicks-neutral technical change on the model. Test results suggest that Hicks-neutral technical change is not appropriate representation. The fourth hypothesis that there is no technical change is rejected. Thus, all of the null hypotheses above are rejected. These results, overall, suggest that the proposed non-neutral translog stochastic frontier model with inefficiency effect is an appropriate representation and should be estimated by maximum likelihood procedure.

Efficiency levels

Table 4 presents annual efficiency levels for transition economies over the period 1991-2000. Efficiency index lies between 0 and 1. One indicates full efficiency and 0 indicates full inefficiency for any country. The efficiency levels of countries are calculated by equation (3) based on the estimated stochastic frontier production function, which is expressed by equation with parameter values given in Table 1.

<Table 4 here>

According to annual averages of efficiency levels for all countries, which is given in the last column of Table 4, Slovenia, Turkmenistan, and Poland appear to be the most efficient countries, followed by Croatia and Hungary. On the other hand, Tajikistan, Ukraina, Russian Federation, and Uzbekistan appear to be the least efficient countries. Average efficiency level for 25 transition economies is 0.559 over the period 1991-2000.

Table 4 also presents the annual efficiency levels of MEE, OFSU, and Baltic countries. Efficiency levels of advanced reformers (Hungary, Poland, Slovenia, Czech Republic, Slovakia) and high intermediate reformers (Estonia, Lithuania, Latvia, Bulgaria, Albania, and

Romania), and slow reformers (Uzbekistan, Belarus, Ukraina, and Turkmenistan) and low intermediate reformers (Moldova, Kazakhstan, Kyrgyzstan, and Russian Federation) are also given in Table 4.

The annual average efficiency level of MEE countries is 0.733, of FSU countries is 0.408, of Baltic countries is 0.582, of advanced and high intermediate reformers is 0.684, and of slow and low intermediate reformers is 0.429. That is, MEE countries seem to be the most efficient, followed by advanced and high intermediate reformers. Most surprisingly, these advanced and high intermediate reformers belong to MEE region. The OFSU countries seem to be the least efficient, followed by slow and low intermediate reformers. Most of these slow and low intermediate reformers belong to OFSU countries.

Efficiency changes

The average annual changes in the efficiency of countries over time are presented in Table 5. We calculated these efficiency changes by using equation (4). Growth in efficiency change is an indicator of a country's performance in adapting the global technology, and therefore represents the catch-up factor (Rao and Coelli, 1998b). Growth in efficiency also indicates a more efficient use of existing technology over time.

<Table 5 here>

The results of average efficiency change (or catch-up) in transition economies suggest that there is a mixture of increasing and decreasing efficiency levels for the whole period (see the last column in Table 5). For example, the first group of economies, (with average technical efficiency growth about 11.87 percent), consisting of Albania, Uzbekistan, and Armenia, have average rates of growth of 13.6, 12.0, and 10 percents in technical efficiency level over the period 1991-2000, respectively. The second group of economies (with average technical efficiency growth about 3.55 percent) consists of Belarus, Bulgaria, Estonia, Georgia, Kazakhstan, Kyrgyzstan, Latvia, Macedonia, Romania, Russian Federation, Slovak Republic, Tajikistan, and Turkmenistan. The third group of economies, (with average technical efficiency growth of -1.46 percent), consists of Croatia, Czech Republic, Hungary, Lithuania, Moldova, Poland, Slovenia, and Ukraina. On the other hand, Azerbaijan experienced no efficiency change over the period 1991-2000.

These results show that the poorest countries have the highest technical efficiency growth. On the other hand, the rich countries have the lowest (negative, indeed) technical efficiency growth. This clearly is an indicator of convergence.

As the table shows, the average annual technical efficiency change ranges from -0.006 to 0.136 in the transition economies. The average growth in the mean technical efficiency is 2.8 percent over the period 1991-2000.

The average technical efficiency growths (or catch-up) in MEE, OFSU, Baltic countries are 2.0, 3.7, and 2.1 percents, respectively. The OFSU countries have a higher average efficiency growth rate (or catch-up) than that of others. On the other hand, the average technical efficiency growth in the advanced and high intermediate reformers and the slow and low reformers are 2.0 and 3.5 percents, respectively. We see that the later ones have grown faster than the former ones, in respect to efficiency growth over the period 1991-2000.

Technical changes

The annual average technical changes of countries over time are presented in Table 6. The technical change index between any two adjacent periods *s* and *t* was calculated directly from the estimated parameters of stochastic frontier production function by taking a partial derivative of output with respect to time (t). Then, we calculated technical change for each country and given period by using equation (5).

<Table 6 here>

Table 6 shows that average technical change in transition economies, (with average technical change about –19 percent), is negative over the period 1991-2000. That is, there is no technological progress, but over the whole period there has been technological decline.

The average annual technical change ranges from –15 percent to –22.3 percent in the transition economies. While the Russian Federation exhibits the highest technical decline, (with average technical change about –22.3 percent), Georgia exhibits the least technical decline, (with average technical change about –15.0 percent).

The average annual technical changes in MEE, OFSU, Baltic countries are –19.4, -18.8, and –18.6 percents, respectively. On the other hand, the average annual technical changes in the advanced and high intermediate reformers and the slow and low reformers are -19.3 and –19.5 percents, respectively. Therefore, these countries or transition economies have suffered severe decreases in technical levels over the period 1991-2000.

Total factor productivity changes

Productivity and its growth are important because it determines the real standard of living that a country can achieved for its citizens. There is a simple link between productivity growth and the standard of living. Total factor productivity (TFP) growth is the sum of efficiency change component and technical change component (see, Nishimizu and Page, 1982).These two changes constitute the TFP change index. On the other hand, the decomposition of total factor productivity change into technical efficiency change and technical change makes it possible to understand whether the countries have improved their productivity levels simply through a more efficient use of existing technology or through technical progress. Furthermore, these two components make up for the overall productivity growth. Table 7 provides the average annual TFP productivity growth.

<Table 7 here>

As can be seen from tis table, the TFP growth rates have declined due to huge negative technical changes and slightly increasing efficiency changes. This decline during the whole period is most likely a consequence of the technical decline in transition economies. Overall, we observe that the average annual technical efficiency change growth is 2.8 percent, but the average annual technical change decline is 19 percent. The sum of these two changes is –16.2 percent (see Table 7). That is, the average annual TFP has declined 16.2 percent over the period 1991-2000. These results suggest that technical efficiency change or catch-up is overcompensated by the negative effect of the decline in technical change.

However, some countries have steady increase in TFP in some years. For example, in 1995 and 1996 Georgia experienced positive TFP changes, which are 1.2 and 6.3 percents, respectively. Tajikistan has experienced TFP growth for last three years, which are 2.0, 0.5, and 4.8 percents . Turkmenistan experienced TFP growth, which are 1.6 and 5.5 percents in 1988 and 1999, respectively. In 2000, Armenia, Azerbaijan, Kazakhstan, Russian Federation, Ukraina, and Uzbekistan experienced positive TFP changes, which are 0.2, 3.9, 3.7, 1.7, 0.5, and 1.1 percents, respectively. For the above countries, the TFP growth is due to efficiency change or catch-up.

Sources of inefficiency

There are various reasons for the efficiency and technical change differentials among transition economies. Socio-economic, demographic, regional, and environmental factors are among them. These reasons incorporate country-specific factors. However, providing a full account of efficiency differentials requires the collection of all relevant data and a careful examination of various reasons for each country. Therefore, in this study we consider a set of inefficiency effects variables, namely, natural resources, income distribution as measured by the Gini coefficient, urbanization rate, liberalization index, time period under Soviet Union, degree and level of reforms, and population of the countries. These factors should explain part, but not all, of productivity growth over time and across different countries. A full understanding of these differences and their effect on productivity growth in transition economies is still an open research problem in economics.

Inefficiency effects are modeled as expressed in equation (2) and the parameters of the model are estimated simultaneously along with the other parameters of the stochastic frontier model defined in Equation (1).

The sign of the coefficients for the natural resources, urbanization, liberalization, and advanced and high intermediate reformers variables were estimated to be negative and significant at the 5 percent level of significance, indicating that a country that has rich natural resources, high urbanization rate, high liberalization index, and is an advanced or high intermediate reformers has also a higher technical efficiency. On the other hand, the sign of coefficients for the Gini index, time period under Soviet Union, and population of the country variables were estimated to be positive and significant at the 5 percent significance level, showing that a country has a long time period under communist regime, unequal income distribution, large population has also a lesser technical efficiency level.

Confirmatory Analysis

In order evaluate robustness of our results we will estimate technical efficiency, technical change, and TFP indexes for the same dataset using the DEA. We use the variable returns to scale (VRS) oriented DEA. The estimates of technical efficiency of each country for any given period in the output oriented DEA with VRS will be higher or equal to that in the output oriented DEA with constant returns to scale (CRS) as the DEA with VRS is more flexible than the DEA with CRS (Wadud and White, 2000). The DEA with CRS gave similar results. The estimation results for DEA with CRS are not reported for brevity.

According to VRS DEA efficiency results given Table 8, Georgia, Turkmenistan, and Slovenia are the fully efficient countries that determine the production frontier, (with average annual technical efficiency levels equal to 1).

<Table 8 here>

These are followed by Croatia, Hungary, Poland, Macedonia, and Albania, with average annual technical efficiency levels of 0.903, 0.828, 0.872, 0.805, and 0.711, respectively. On the other hand, Tajikistan, Ukraina, Uzbekistan, Moldova, Azerbaijan, and Russian Federation appear to be the least efficient countries, with average annual technical efficiency levels of 0.213, 0.254, 0.259, 0.273, 0.386, and 0.389, respectively. Average efficiency level for 25 transition economies is 0.605 over the period 1991-2000. These results perfectly confirm the SFA results.

The average efficiency change, technical change, and total factor productivity change of countries over time are presented in Table 9.

<Table 9 here>

The average results of efficiency change (or catch-up) in economies suggest that there is a mixture of increasing and decreasing efficiency levels for the whole period. The average annual technical efficiency change is 3.7 percent over the period 1991-2000. This rate is slightly higher than that of the SFA, which is 2.8 percent.

The average annual technical change suggests that there is a decline in technical levels of countries, (with average decline about 19.2 percent) over the period 1991-2000. This rate is 19 percent in the SFA, so DEA gives almost the same result as SFA.

As can be seen in Table 9, TFP growth rates have declined due to huge negative average annual technical change (–19.2 percent) and slight increase in the efficiency change (3.7 percent). This decline during the whole period is most likely a consequence of the negative technical change in transition economies. That is, the average annual TFP has declined by 16.2 percent over the period 1991-2000. This a net decline of 16.2 percent in TFP over the sample period. This result exactly matches the result obtained by the SFA, which is 16.2 percent.

Since two quite different approaches, namely DEA and SFA, give similar results this implies that the measures of efficiency and explanation of relative efficiency in terms of natural resources, Gini index, urbanization, liberalization index, time period under Soviet Union, degree and level of reforms, and population are robust and can be used as a basis of policy recommendations (Wadud and White, 2000).

5. Conclusions

In this paper, we attempted to assess the performance of the transition economies using two popular methods, namely stochastic frontier production analysis and data envelopment analysis. Our aim in using two methods was to compare the results of them and investigate their appropriateness for our data. In doing so, we estimated level of technical efficiency for each country, and then calculated technical efficiency change or catch-up, technical change, and the total factor productivity growth. Results of statistical tests led us to accept a non-neutral translog stochastic frontier production function. The technical inefficiency effects were examined as a function of various factors. In the period covered, for all transition economies, we found a decline in the technical change, but a mixture increase and decrease in efficiency change, indicating catch-up and convergence among transition economies. These two changes led TFP change or decline due to huge decline in technical change in all transition countries over the period 1991-2000.

We also tried to investigate the reasons of this hierarchy of the transition economies concerning efficiency. As the inefficiency effects, the roles of natural resources, urbanization rate, liberalization, the level and degree of reforms, time period under communist regime, income distribution, and population size of countries were considered. Estimation results suggest that small countries are more efficient than large countries. The urbanization rate implies that countries could reap the benefit of urbanization effects and metropolitan externalities, i.e. infrastructure, technology, information network, availability of qualified labor, etc., in these countries.

Examining the question of catch-up and convergence, we find countries are well below the frontier over the period 1991-2000. But, according to DEA, Georgia, Slovenia, and Turkmenistan determine the frontier. That is, these countries are on the frontier, the others are below the frontier.

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Tables

Table 1. Growth of Output in Transition Economies

Country	Average annual % growth 1990-2000	Country	Average annual % growth 1990-2000
Albania	3.3	Latvia	-3.4
Armenia	-1.9	Lithuania	-3.1
Azerbaijan	-6.3	Macedonia, FYR	-0.8
Belarus	-1.6	Moldova	-9.7
Bulgaria	-2.1	Poland	4.6
Croatia	0.6	Romania	-0.7
Czech Republic	0.9	Russian Federation	-4.8
Estonia	-0.5	Slovak Republic	2.1
Georgia	-13	Slovenia	2.7
Hungary	1.5	Tajikistan	-10.4
Kazakhstan	-4.1	Turkmenistan	-4.8
Kyrgyzstan	-4.1	Ukraina	-9.3
		Uzbekistan	-0.5
Average growth rate			-1.92

Source: World Development Indicators, 2002.

Table 2. Stochastic Production Frontier Estimation Results

Variable	Parameter	Coefficients	*t*-ratios
Constant	β_o	32.3318	10.1293*
ln(capital)	β_1	-1.9857	-5.0438*
ln(labour)	β_2	0.8073	2.5115*
$[\ln(\text{capital})]^2$	β_{11}	0.1802	9.5555 *
$[\ln(\text{labour})]^2$	β_{22}	0.1090	4.6383*
ln(capital)xln(labour)	β_{12}	0.0975	6.9368*
ln(capital)x(Year)	β_{13}	-0.0118	-1.7640**
ln(labour)x(Year)	β_{23}	0.0050	0.5898
Year	β_3	-0.2275	-2.3512*
$(\text{Year})^2$	β_{33}	0.0215	11.3868*
Inefficiency Effects			
Constant	δ_0	-6.5859	-7.0951*
Natural Resources	δ_1	-0.3827	-9.0735*
Income Distribution	δ_2	0.0283	6.3736*
Urbanization	δ_3	-0.0022	-1.1135**
Liberalization	δ_4	-0.6650	-5.2798*
Time P.Under USSR	δ_5	0.8612	4.4173*
ln(population)	δ_6	0.2244	7.4755*
Advanced & High Int. Ref.	δ_7	-0.0022	-2.4249*
Variance Parameters			
σ_s^2		0.1225	8.9677*
γ		0.9999	45524.026*
Log-likelihood		-31.4040	

*significant at 5percent level and **significant at 10percent level.

Table 3. Hypothesis Tests

Null Hypotheses	Log-likelihood[a]	Test Statistic	Critical value[b]	Decision
Cobb-Douglas production function All $\beta_{ij}=0$	-116.073	169.338	10.371	Reject H_0
No inefficiency $\gamma=\delta_0=\delta_1=\ldots=\delta_7=0$ [c]	-135.869	208.934	16.274	Reject H_0
Hicks-neutral technical change $\beta_{12}=\beta_{13}=0$	-41.826	20.844	5.138	Reject H_0
No technical change $\beta_3=\beta_{33}=\beta_{13}=\beta_{23}=0$	-97.712	132.612	10.371	Reject H_0

(a) Log-likelihood value under null hypothesis,

(b) Critical value of the test statistic at the 5 percent level of significance,

(c) If the null hypothesis of no technical inefficiency effects in the model, is true, then the generalized likelihood-ratio statistic is asymptotically distributed as a mixture of chi-square distributions (Table 1, Kodde and Palm, 1986).

Table 4. Efficiency Levels for Transition Countries (SFA)

Country&Year	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	Mean
Albania	0.217	0.280	0.373	0.447	0.520	0.605	0.584	0.631	0.654	0.650	0.496
Armenia	0.237	0.193	0.226	0.281	0.349	0.412	0.456	0.505	0.521	0.529	0.371
Azerbaijan	0.476	0.352	0.354	0.320	0.319	0.347	0.371	0.407	0.429	0.451	0.383
Belarus	0.457	0.379	0.364	0.365	0.377	0.431	0.510	0.564	0.585	0.595	0.463
Bulgaria	0.502	0.486	0.548	0.664	0.755	0.774	0.775	0.813	0.808	0.806	0.693
Croatia	0.951	0.787	0.732	0.802	0.916	0.980	1.000	0.981	0.921	0.878	0.895
Czech Republic	0.785	0.663	0.651	0.656	0.674	0.683	0.663	0.633	0.601	0.568	0.658
Estonia	0.438	0.366	0.379	0.416	0.478	0.527	0.587	0.607	0.587	0.585	0.497
Georgia	0.444	0.555	0.464	0.341	0.424	0.530	0.596	0.579	0.596	0.566	0.510
Hungary	0.926	0.874	0.853	0.868	0.883	0.880	0.886	0.865	0.824	0.768	0.863
Kazakhstan	0.394	0.337	0.363	0.349	0.372	0.431	0.487	0.511	0.533	0.571	0.435
Kyrgyzstan	0.458	0.422	0.436	0.427	0.453	0.525	0.603	0.640	0.656	0.661	0.528
Latvia	0.534	0.387	0.429	0.527	0.585	0.656	0.742	0.756	0.737	0.736	0.609
Lithuania	0.764	0.625	0.544	0.559	0.609	0.660	0.694	0.695	0.633	0.613	0.640
Macedonia, FYR	0.525	0.535	0.556	0.618	0.652	0.696	0.728	0.752	0.767	0.758	0.659
Moldova	0.359	0.228	0.236	0.198	0.232	0.250	0.281	0.278	0.275	0.276	0.261
Poland	0.848	0.816	0.847	0.914	0.971	1.000	1.000	0.959	0.899	0.824	0.908
Romania	0.447	0.391	0.417	0.472	0.552	0.612	0.601	0.586	0.569	0.550	0.520
Russian Federation	0.283	0.215	0.213	0.218	0.241	0.266	0.298	0.309	0.340	0.366	0.275
Slovak Republic	0.637	0.618	0.599	0.674	0.733	0.756	0.779	0.760	0.725	0.676	0.696
Slovenia	1.000	0.871	0.888	0.940	0.961	0.986	1.000	0.977	0.928	0.862	0.941
Tajikistan	0.223	0.188	0.187	0.175	0.183	0.176	0.200	0.227	0.243	0.259	0.206
Turkmenistan	0.840	0.930	1.000	0.944	0.883	0.874	0.802	0.899	0.999	0.977	0.915
Ukraina	0.320	0.250	0.233	0.214	0.224	0.235	0.255	0.270	0.278	0.292	0.257
Uzbekistan	0.155	0.189	0.214	0.238	0.273	0.305	0.346	0.386	0.411	0.425	0.294
General Mean	0.529	0.478	0.484	0.505	0.545	0.584	0.610	0.624	0.621	0.610	0.559
MEE Countries	0.684	0.632	0.646	0.706	0.762	0.797	0.801	0.796	0.770	0.734	0.733
OFSU Countries	0.387	0.353	0.358	0.339	0.361	0.399	0.434	0.465	0.489	0.497	0.408
Baltic Countries	0.579	0.459	0.451	0.501	0.557	0.614	0.674	0.686	0.652	0.645	0.582
Advanced & High Intermediate Reform.	0.645	0.580	0.593	0.649	0.702	0.740	0.755	0.753	0.724	0.694	0.684
Slow & Low Interm. Reformers	0.408	0.369	0.383	0.369	0.382	0.415	0.448	0.482	0.510	0.520	0.429

Table 5. Efficiency Change for Transition Countries (SFA)

Country&Year	1992	1993	1994	1995	1996	1997	1998	1999	2000	Mean
Albania	1,292	1,333	1,198	1,163	1,163	0,966	1,081	1,036	0,994	1,136
Armenia	0,814	1,170	1,243	1,242	1,179	1,108	1,108	1,031	1,015	1,101
Azerbaijan	0,740	1,007	0,905	0,995	1,087	1,070	1,098	1,053	1,051	1,000
Belarus	0,830	0,961	1,000	1,033	1,144	1,183	1,105	1,038	1,017	1,035
Bulgaria	0,968	1,127	1,213	1,136	1,025	1,001	1,050	0,993	0,998	1,057
Croatia	0,827	0,930	1,096	1,143	1,070	1,020	0,981	0,939	0,953	0,995
Czech Republic	0,844	0,982	1,009	1,027	1,013	0,970	0,956	0,950	0,945	0,966
Estonia	0,835	1,036	1,100	1,148	1,103	1,113	1,034	0,967	0,997	1,037
Georgia	1,251	0,835	0,735	1,245	1,248	1,124	0,973	1,028	0,950	1,043
Hungary	0,944	0,976	1,018	1,017	0,997	1,006	0,976	0,954	0,931	0,980
Kazakhstan	0,857	1,076	0,961	1,065	1,160	1,129	1,050	1,044	1,070	1,046
Kyrgyzstan	0,922	1,034	0,979	1,060	1,159	1,150	1,061	1,025	1,007	1,044
Latvia	0,725	1,107	1,230	1,110	1,121	1,131	1,018	0,975	0,999	1,046
Lithuania	0,818	0,871	1,026	1,090	1,083	1,051	1,002	0,910	0,968	0,980
Macedonia, FYR	1,019	1,040	1,110	1,055	1,067	1,047	1,032	1,020	0,988	1,042
Moldova	0,637	1,034	0,840	1,167	1,080	1,122	0,989	0,992	1,003	0,985
Poland	0,962	1,038	1,079	1,062	1,030	1,000	0,960	0,937	0,917	0,998
Romania	0,874	1,065	1,132	1,170	1,108	0,982	0,976	0,970	0,967	1,027
Russian Federation	0,757	0,995	1,019	1,109	1,104	1,118	1,038	1,101	1,075	1,035
Slovak Republic	0,971	0,968	1,126	1,086	1,032	1,031	0,975	0,954	0,933	1,008
Slovenia	0,871	1,020	1,058	1,022	1,026	1,014	0,978	0,950	0,929	0,985
Tajikistan	0,843	0,993	0,939	1,042	0,966	1,135	1,136	1,068	1,066	1,021
Turkmenistan	1,107	1,075	0,945	0,935	0,991	0,918	1,121	1,112	0,978	1,020
Ukraina	0,781	0,933	0,915	1,047	1,051	1,086	1,056	1,032	1,048	0,994
Uzbekistan	1,220	1,134	1,111	1,147	1,118	1,132	1,115	1,066	1,035	1,120
General Mean	0,908	1,030	1,040	1,093	1,085	1,064	1,035	1,006	0,993	1,028
MEE Countries	0,957	1,048	1,104	1,088	1,053	1,004	0,996	0,970	0,955	1,020
OFSU Countries	0,897	1,020	0,966	1,091	1,107	1,106	1,071	1,049	1,026	1,037
Baltic Countries	0,793	1,005	1,119	1,116	1,102	1,098	1,018	0,951	0,988	1,021
Advanced & High Intermediate Reform.	0,918	1,048	1,108	1,094	1,064	1,024	1,000	0,963	0,962	1,020
Slow & Low Interm. Reformers	0,889	1,030	0,971	1,070	1,101	1,105	1,067	1,051	1,029	1,035

Table 6. Technical Change for Transition Countries (SFA)

Country&Year	1992	1993	1994	1995	1996	1997	1998	1999	2000	Mean
Albania	0,687	0,722	0,757	0,793	0,832	0,872	0,913	0,954	0,995	0,836
Armenia	0,652	0,695	0,736	0,778	0,819	0,861	0,903	0,945	0,987	0,820
Azerbaijan	0,668	0,704	0,743	0,783	0,824	0,864	0,905	0,946	0,988	0,825
Belarus	0,636	0,674	0,713	0,755	0,797	0,838	0,880	0,922	0,964	0,798
Bulgaria	0,653	0,690	0,731	0,772	0,813	0,855	0,897	0,938	0,980	0,814
Croatia	0,649	0,685	0,724	0,763	0,804	0,844	0,884	0,925	0,967	0,805
Czech Republic	0,637	0,674	0,712	0,752	0,791	0,832	0,873	0,915	0,956	0,794
Estonia	0,649	0,687	0,727	0,768	0,809	0,849	0,890	0,932	0,974	0,809
Georgia	0,703	0,734	0,773	0,813	0,852	0,888	0,924	0,962	1,003	0,850
Hungary	0,641	0,678	0,717	0,756	0,796	0,836	0,877	0,918	0,959	0,798
Kazakhstan	0,638	0,676	0,716	0,757	0,799	0,842	0,884	0,926	0,969	0,801
Kyrgyzstan	0,661	0,699	0,740	0,781	0,822	0,863	0,905	0,947	0,989	0,823
Latvia	0,652	0,692	0,734	0,775	0,816	0,857	0,898	0,939	0,981	0,816
Lithuania	0,660	0,696	0,734	0,774	0,814	0,854	0,895	0,936	0,977	0,815
Macedonia, FYR	0,659	0,696	0,736	0,776	0,816	0,857	0,898	0,940	0,982	0,818
Moldova	0,652	0,688	0,728	0,769	0,812	0,854	0,896	0,939	0,981	0,813
Poland	0,638	0,675	0,714	0,753	0,793	0,833	0,874	0,914	0,955	0,794
Romania	0,641	0,678	0,717	0,758	0,799	0,840	0,882	0,924	0,966	0,801
Russian Federation	0,612	0,651	0,692	0,734	0,776	0,818	0,861	0,903	0,946	0,777
Slovak Republic	0,646	0,684	0,723	0,762	0,802	0,842	0,883	0,924	0,966	0,804
Slovenia	0,646	0,682	0,720	0,760	0,799	0,840	0,881	0,922	0,963	0,801
Tajikistan	0,647	0,687	0,728	0,770	0,812	0,855	0,898	0,941	0,984	0,813
Turkmenistan	0,668	0,706	0,746	0,785	0,824	0,865	0,907	0,949	0,989	0,827
Ukraina	0,627	0,665	0,705	0,747	0,790	0,832	0,875	0,917	0,960	0,791
Uzbekistan	0,641	0,682	0,723	0,765	0,807	0,849	0,891	0,934	0,977	0,808
General Mean	0,651	0,688	0,728	0,768	0,809	0,850	0,891	0,933	0,974	0,810
MEE Countries	0,650	0,686	0,725	0,764	0,805	0,845	0,886	0,927	0,969	0,806
OFSU Countries	0,650	0,688	0,729	0,770	0,811	0,852	0,894	0,936	0,978	0,812
Baltic Countries	0,654	0,692	0,732	0,772	0,813	0,854	0,894	0,936	0,977	0,814
Advanced & High Intermediate Reform.	0,650	0,687	0,726	0,766	0,806	0,847	0,887	0,929	0,970	0,807
Slow & Low Interm. Reformers	0,642	0,680	0,721	0,762	0,803	0,845	0,887	0,930	0,972	0,805

Table 7. Total Factor Productivity Change for Transition Countries (SFA)

Country&Year	1992	1993	1994	1995	1996	1997	1998	1999	2000	Mean
Albania	0,979	1,056	0,955	0,956	0,995	0,839	0,994	0,991	0,989	0,972
Armenia	0,466	0,865	0,979	1,020	0,999	0,969	1,010	0,976	1,002	0,921
Azerbaijan	0,407	0,710	0,647	0,778	0,911	0,934	1,003	0,999	1,040	0,825
Belarus	0,466	0,634	0,714	0,788	0,941	1,022	0,985	0,960	0,982	0,832
Bulgaria	0,621	0,817	0,944	0,908	0,838	0,856	0,947	0,931	0,978	0,871
Croatia	0,477	0,615	0,819	0,906	0,874	0,864	0,865	0,864	0,920	0,800
Czech Republic	0,481	0,655	0,721	0,779	0,804	0,802	0,829	0,864	0,901	0,760
Estonia	0,484	0,723	0,827	0,915	0,911	0,963	0,924	0,899	0,971	0,846
Georgia	0,955	0,569	0,508	1,058	1,100	1,012	0,897	0,991	0,953	0,893
Hungary	0,585	0,655	0,734	0,773	0,793	0,843	0,853	0,871	0,890	0,778
Kazakhstan	0,495	0,752	0,677	0,822	0,959	0,971	0,934	0,970	1,039	0,847
Kyrgyzstan	0,583	0,733	0,719	0,841	0,981	1,013	0,966	0,972	0,996	0,867
Latvia	0,378	0,799	0,964	0,885	0,937	0,988	0,917	0,915	0,979	0,862
Lithuania	0,478	0,567	0,760	0,864	0,897	0,906	0,897	0,846	0,945	0,796
Macedonia, FYR	0,678	0,736	0,846	0,831	0,884	0,904	0,931	0,960	0,970	0,860
Moldova	0,289	0,722	0,568	0,937	0,892	0,976	0,885	0,930	0,984	0,798
Poland	0,600	0,713	0,793	0,815	0,823	0,833	0,833	0,851	0,872	0,793
Romania	0,515	0,743	0,850	0,928	0,907	0,823	0,858	0,894	0,933	0,828
Russian Federation	0,370	0,646	0,711	0,843	0,880	0,936	0,899	1,004	1,021	0,812
Slovak Republic	0,617	0,652	0,849	0,849	0,834	0,873	0,858	0,878	0,899	0,812
Slovenia	0,517	0,702	0,779	0,782	0,826	0,854	0,858	0,871	0,891	0,787
Tajikistan	0,489	0,679	0,667	0,812	0,778	0,990	1,034	1,009	1,049	0,834
Turkmenistan	0,776	0,781	0,691	0,720	0,815	0,783	1,028	1,061	0,967	0,847
Ukraina	0,408	0,598	0,620	0,795	0,841	0,918	0,931	0,949	1,007	0,785
Uzbekistan	0,861	0,816	0,834	0,912	0,925	0,981	1,006	1,000	1,011	0,927
General Mean	0,559	0,718	0,767	0,861	0,894	0,914	0,926	0,938	0,968	0,838
MEE Countries	0,607	0,734	0,829	0,853	0,858	0,849	0,883	0,898	0,924	0,826
OFSU Countries	0,547	0,709	0,695	0,860	0,918	0,959	0,965	0,985	1,004	0,849
Baltic Countries	0,446	0,696	0,850	0,888	0,915	0,952	0,912	0,887	0,965	0,835
Advanced & High Intermediate Reform	0,569	0,735	0,834	0,859	0,870	0,871	0,888	0,892	0,932	0,828
Slow & Low Interm. Reformers	0,531	0,710	0,692	0,832	0,904	0,950	0,954	0,981	1,001	0,839

Table 8. Efficiency Levels for Transition Countries, (DEA)

Country&Year	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	Mean
Albania	0.346	0.496	0.606	0.664	0.777	0.858	0.869	0.845	0.794	0.852	0.711
Armenia	0.231	0.211	0.237	0.302	0.392	0.466	0.548	0.564	0.545	0.564	0.406
Azerbaijan	0.482	0.336	0.308	0.293	0.346	0.377	0.431	0.415	0.402	0.474	0.386
Belarus	0.356	0.364	0.356	0.349	0.362	0.410	0.484	0.543	0.575	0.619	0.442
Bulgaria	0.433	0.439	0.488	0.611	0.732	0.757	0.806	0.794	0.750	0.772	0.658
Croatia	0.908	0.819	0.751	0.807	0.927	0.973	0.978	0.972	0.941	0.955	0.903
Czech Republic	0.618	0.633	0.635	0.632	0.655	0.660	0.641	0.630	0.627	0.636	0.637
Estonia	0.465	0.446	0.453	0.480	0.546	0.588	0.642	0.670	0.667	0.707	0.566
Georgia	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Hungary	0.751	0.829	0.820	0.828	0.850	0.840	0.843	0.843	0.838	0.840	0.828
Kazakhstan	0.304	0.313	0.338	0.325	0.352	0.406	0.463	0.484	0.501	0.560	0.405
Kyrgyzstan	0.502	0.452	0.447	0.456	0.511	0.597	0.739	0.712	0.668	0.714	0.580
Latvia	0.553	0.440	0.478	0.594	0.676	0.752	0.864	0.850	0.815	0.850	0.687
Lithuania	0.824	0.665	0.566	0.592	0.663	0.710	0.751	0.731	0.657	0.666	0.683
Macedonia, FYR	0.666	0.697	0.694	0.762	0.805	0.840	0.879	0.889	0.897	0.925	0.805
Moldova	0.358	0.240	0.244	0.204	0.244	0.263	0.304	0.293	0.282	0.293	0.273
Poland	0.617	0.698	0.754	0.847	0.943	0.985	1.000	0.986	0.954	0.940	0.872
Romania	0.338	0.343	0.372	0.429	0.518	0.575	0.574	0.556	0.535	0.542	0.478
Russian Federation	0.376	0.340	0.304	0.304	0.339	0.370	0.410	0.429	0.478	0.539	0.389
Slovak Republic	0.567	0.623	0.598	0.664	0.725	0.735	0.751	0.741	0.727	0.722	0.685
Slovenia	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Tajikistan	0.203	0.199	0.194	0.181	0.192	0.186	0.220	0.240	0.244	0.266	0.213
Turkmenistan	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Ukraina	0.244	0.248	0.239	0.217	0.230	0.239	0.260	0.274	0.281	0.306	0.254
Uzbekistan	0.119	0.164	0.183	0.208	0.248	0.279	0.335	0.348	0.345	0.358	0.259
General Mean	0.530	0.520	0.523	0.550	0.601	0.635	0.672	0.672	0.661	0.684	0.605
MEE Countries	0.624	0.658	0.672	0.724	0.793	0.822	0.834	0.826	0.806	0.818	0.758
OFSU Countries	0.431	0.406	0.404	0.403	0.435	0.466	0.516	0.525	0.527	0.558	0.467
Baltic Countries	0.614	0.517	0.499	0.555	0.628	0.683	0.752	0.750	0.713	0.741	0.645
Advanced & High Intermediate Reform.	0.592	0.601	0.615	0.667	0.735	0.769	0.795	0.786	0.760	0.775	0.710
Slow & Low Interm. Reformers	0.407	0.390	0.389	0.383	0.411	0.446	0.499	0.510	0.516	0.549	0.450

Table 9. Total Factor Productivity Growth Components for Transition Countries over the period 1991-2000, (DEA).

Country	Eeffch[a]	Techch[b]	Tfpch[c]
Albania	1.105	0.750	0.829
Armenia	1.105	0.821	0.907
Azerbaijan	0.998	0.785	0.783
Belarus	1.063	0.819	0.871
Bulgaria	1.066	0.829	0.884
Croatia	1.006	0.802	0.807
Czech Republic	1.003	0.815	0.818
Estonia	1.048	0.810	0.848
Georgia	1.000	0.625	0.625
Hungary	1.013	0.801	0.811
Kazakhstan	1.070	0.811	0.868
Kyrgyzstan	1.040	0.830	0.863
Latvia	1.049	0.809	0.849
Lithuania	0.977	0.821	0.801
Macedonia, FYR	1.037	0.812	0.843
Moldova	0.978	0.817	0.799
Poland	1.048	0.808	0.847
Romania	1.054	0.812	0.855
Russian Federation	1.041	0.861	0.896
Slovak Republic	1.027	0.801	0.823
Slovenia	1.000	0.903	0.903
Tajikistan	1.031	0.813	0.838
Turkmenistan	1.000	0.806	0.806
Ukraina	1.025	0.814	0.835
Uzbekistan	1.131	0.821	0.929
General Mean	1.037	0.808	0.838
MEE Countries	1.036	0.813	0.842
OFSU Countries	1.040	0.802	0.835
Baltic Countries	1.025	0.813	0.833
Advanced & High Interm. Reform.	1.035	0.814	0.843
Slow & Low Intermediate Reformers	1.044	0.822	0.858

(a) Technical efficiency change
(b) Technical change
(c) Total factor productivity change