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# CONVERGENCE AND PRODUCTIVE EFFICIENCY IN THE CONTEXT OF 18 TRANSITION ECONOMIES: EMPIRICAL INVESTIGATION USING DEA

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## ABSTRACT

One of the important to the filed of economic growth problems refers to the issue of convergence and catching-up of less developed and efficient countries with their more developed and efficient counterparts. In this study, we investigate convergence of two groups of Transition Economies (TE) in terms of the productive efficiency of utilization of investments in Telecoms and generation of revenues from Telecoms. We use Malmquist Index of input- and output-oriented Data Envelopment Analysis (DEA) to obtain values in changes in Total Factor Productivity (TFP) of 18 TEs over the period from 1993 to 2002. After comparison of the averaged values of Malmquist index for two groups, we were able to reject null hypotheses of no convergence.

## Keywords

Transition Economies, Investments in Telecoms, Productive efficiency, DEA, Malmquist Index

## INTRODUCTION

Multiple studies demonstrated that in the context of developed economies investments in *Information and Communication Technologies* (ICT) provide reliable stream of revenues and contribute to overall economic growth (Colecchia and Schreyer, 2002; Daveri, 2002; Jalava and Pohjola, 2002; Jorgenson, 2001; Jorgenson and Stiroh, 2000; OECD, 2005; Oliner and Sichel, 2002; Stiroh, 2002; van Ark, Melka, Mulder, Timmer, and Ypma, 2002). Scarce research in the context of the countries transitioning from centrally planned to a market economy, commonly referred to as *Transition Economies* (TE), yields an evidence of much lower levels of returns (Dewan and Kraemer, 2000; Pohjola, 2001; Piatkowski, 2003). The consensus of the research and development community is that more studies need to be conducted in the context of TE to justify investments in ICT by private sector or development agencies (OECD, 2004). In our previous inquiries (Samoilenko and Osei-Bryson, 2007; Samoilenko, 2008), we researched the relationship between *investments in Telecoms* (a subset of investments in ICT) and *revenues from Telecoms*. The investigations were conducted in the context of the 18 Transition Economies: Albania, Armenia, Azerbaijan, Belarus, Bulgaria, Czech Republic, Estonia, Hungary, Kazakhstan, Kyrgyzstan, Latvia, Lithuania, Moldova, Poland, Romania, Slovakia, Slovenia, and Ukraine. These countries started their transition in approximately the same time and classified by International Monetary Fund as belonging to the same group of *Transition economies in Europe and the former Soviet Union* (IMF, 2000). Looking at the archival data spanning a period from 1993 to 2002, we determined, by using *Cluster Analysis* (CA), that these 18 TEs are not homogenous in terms of levels of investments in Telecoms and revenues from Telecoms; results of CA yielded a two-cluster solution (Samoilenko and Osei-Bryson, 2007). Further, by using *Data Envelopment Analysis* (DEA), we determined that these two clusters of TEs differ in terms of the relative efficiency of the utilization of resources and relative efficiency of the production of revenues; we labeled a group with the higher averaged efficiency scores the *Leaders* and a group with lower scores the *Followers* (Samoilenko, 2008). We also established, by using *Decision Tree* (DT) analysis, that the *Leaders* differ from the *Followers* in some important areas, such as militarization of the economy, quality of human resources, and level of socio-technical development (Samoilenko, 2008). There seems to be a consensus that the level of investments in ICT should be above a certain threshold to manifest itself at the detectable macroeconomic level (Oliner and Sichel, 2000; Jorgenson, 2001; Jorgenson

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and Stiroh, 2000; Council of Economic Advisors, 2001). By using *Neural Networks* (NN) simulation, we demonstrated that the increase in the level of investments would not reduce the level of relative inefficiency of the *Followers*, for it is a result of inefficient processes of conversion of investments into revenues (Samoilenko and Osei-Bryson, under review). In this study, we build on our previous research and investigate the presence of conversion between the *Leaders* and the *Followers* in terms of the relative efficiency of utilization of investments in Telecoms and relative efficiency of production of revenues from Telecoms. Next, we provide a brief overview of the theoretical framework of this study, justification for our inquiry, as well as formal definition of the research problem.

## THEORETICAL FRAMEWORK, RESEARCH METHOD, AND DEFINITION OF THE RESEARCH PROBLEM

### Framework of Neoclassical Growth Accounting

In our investigation, we rely on a neoclassical framework of growth accounting, which originated from the work of Solow (1957). Previously, this analytical framework has been widely used to estimate contribution of ICT to economic growth in the context of developed and developing countries (Oliner and Sichel, 2000; Schreyer, 2000; Davery, 2000; Jorgenson and Stiroh, 2000; Whelan, 1999; Hernando and Nunez, 2002).

The objective of growth accounting is to decompose the rate of growth of an economy into the contributions from the different inputs. For every year, for each of the 18 TEs, neoclassical production function allows us to relate investments in Telecoms, number of full-time Telecom employees, and revenues from Telecoms in the following fashion:

***Revenues from Telecoms = f(TFP, investments in Telecoms, full-time Telecom employees),***

where TFP represent the level of technology/ total factor productivity.

It is important to note that only capital (*investments in Telecoms*) and labor (*full-time Telecom employees*) could be observed in the data, while TFP serves as a residual (a.k.a., *Solow's residual*) term capturing that contribution to macroeconomic bottom line (*revenues from Telecoms*), which is left unexplained by the inputs of capital and labor. Simplicity is one of the appeals of using the neoclassical growth accounting framework, for it uses only two factors to explain the growth rate of the output, the TFP growth, and the rate of increase in inputs. According to one of the assumptions of the growth accounting framework, the poor and wealthy economies must converge. While the reality reflects that the gap between poor and rich countries of the world is widening, we aim to test this assumption in the context of 18 TEs. Next, we present a brief overview of the research method used in this study.

### Data Envelopment Analysis and Malmquist Index

DEA is a non-parametric technique that uses methods of linear programming to determine relative efficiencies of the Decision Making Units (DMU). In the domain of DEA, a DMU is an entity, be it a person, a firm, or an economy that receives inputs and produces outputs. A *DEA model* ensures functional similarities of all DMUs in the sample by specifying the common set of inputs and outputs for each DMU in the sample. Usually, a definition of DEA model is under purview of the decision maker and is rarely supported by a theory. To ensure the rigor of our investigation, we use the framework of neoclassical growth accounting to help us define and justify the DEA model that was used in our previous and current inquiries. In order to calculate the score of the relative efficiency for each DMU in the sample, DEA collapses inputs and outputs into an abstract "meta input" and "meta output" and creates the ratio of the two for each DMU. The resultant score is then compared to the scores of other DMUs in the sample. The relatively efficient DMUs receive a score of "1" and constitute the *efficiency frontier* that envelops the DMUs in the sample. Depending on the orientation of the DEA model, the relatively inefficient DMUs receive the scores of less than "1" (in the case of the input-oriented model concerned with the minimization of inputs for achieving a given level of output), or greater than "1" (in the case of the output-oriented model concerned with the maximization of outputs for a given level of inputs). In addition to the orientation of a DEA model, a researcher is given a choice regarding the *return-to-scale*, where an investigator can choose among constant return-to-scale (CRS), variable return-to-scale (VRS), and decreasing or non-increasing return-to-scale (NIRS) models. In the case of our study, we use both input- and output-oriented DEA models. In both cases, whether we interested in a minimization of the level of investments, or a maximization of the levels of revenues, the use of DEA allows for producing the efficiency frontier consisting of the relatively efficient TEs. For the purposes of our study, we need to isolate yearly changes

in TFP, as values of investments and revenues change from year-to-year. This is accomplished by means of Malmquist index.

The framework of the neoclassical growth accounting posits that an economic growth is determined by two factors. The first factor, resource accumulation, could lead to high rates of growth, albeit, due to the law of diminishing return, only for a limited period of time. Thus, it is the growth in productivity that is assumed to allow for attaining of the sustained economic growth. The productivity is commonly referred to as Total Factor Productivity (TFP) and its growth can be measured by Malmquist index. Based on the idea of productivity index, originally suggested by Malmquist (1953), Caves, Christensen and Diewert (1982) defined the Malmquist index of TFP growth. Later, Färe, Grosskopf, Norris, and Zhang (1994) demonstrated that the Malmquist index could be constructed based on the results of DEA. Essentially, the approach is based on performing DEA analysis in two points in time; let us say  $t_1$  and  $t_2$ . Then, for a given DMU, the period of time ( $t_2-t_1$ ) could be represented as the distance between the data point at the time  $t_1$  and the data point at the time  $t_2$ . For each DMU in the sample, the distance between these data points would be reflective of the change in this DMU's TFP, which is represented by the Malmquist index. In the case of economic growth, we expect that the efficiency frontier for a given set of DMUs would change its position over time. Let us suppose that a DMU A have changed its position over the period of time ( $t_2 - t_1$ ). Such change is reflected by not only the new position of the DMU A, but also by the new position of the efficiency frontier itself. As a result, change in the position of each DMU in the sample could be perceived as consisting of the two components. The first component is the change in distance between a given DMU and the efficient frontier, which reflects the changes in efficiency (EC), and the second is the change in position of the efficient frontier itself, reflective of the technological change (TC) that took place over the period ( $t_2-t_1$ ).

#### Justification and Formal Definition of the Research Problem

Multiple studies inquired into the issue of convergence and catching-up of less developed and efficient countries with their more efficient and developed counterparts (for a review, see Barro and Sala-i-Martin, 1995; Quah, 1996; Sala-i-Martin, 1996; de la Fuente, 1997), thus demonstrating the importance of this problem to the field of economic growth (Durlauf, 1996). Although the issue of productivity convergence can be investigated by using various methodologies, the use of Malmquist index for this purpose is well-established (Färe et al., 1994; Färe, Grosskopf, and Roos, 1998; Coelli, Rao, and Battese, 1998).

For the purposes of this study, we define the term *convergence* as the tendency of TEs to become more similar in terms of the growth of productivity, as it is measured by Malmquist index. In this investigation, we only concerned with  $\beta$ -convergence (Arcellus and Arocena, 2000; Sala-i-Martin, 1996; Bernard and Jones, 1996; Cornwell and Wachter, 1998) associated with the tendency of less efficient economies to grow faster than their more efficient counterparts did. Consequently, if the average value of Malmquist index of the *Followers* is greater than the average value of the *Leaders*, we consider that the *Followers* are converging with the *Leaders*. Following are the null hypotheses associated with the research question of this study:

H01: *Based on the input-oriented DEA model, averaged value of Malmquist index of the Leaders' subset of 18 TEs, calculated over the period from 1993 to 2002, is greater than the averaged value of Malmquist index of the Followers' subset of 18 TEs, calculated over the period from 1993 to 2002*

H02: *Based on the output-oriented DEA model, averaged value of Malmquist index of the Leaders' subset of 18 TEs, calculated over the period from 1993 to 2002, is greater than the averaged value of Malmquist index of the Followers' subset of 18 TEs, calculated over the period from 1993 to 2002*

If the value of the averaged Malmquist index of the Followers turns out to be greater than that of the Leaders, we reject H01 and H02 of this study and state that the two groups of TEs are converging in terms of the growth in productivity. We present a necessarily brief summary of our previous findings next.

#### PREVIOUS FINDINGS

In our previous inquiry (Samoilenko and Osei-Bryson, 2007) we used Cluster Analysis (CA) to determine that a 10-year data set on 18 TEs, spanning a period from 1993 to 2002, is not homogenous in terms of the investments in and revenues from Telecoms. As a result, we were able to come up with a solution that partitions our sample into two clusters. The membership of each cluster is provided in Table 1. Once the results of CA were obtained, data set was partitioned into two subsets and input- and output-oriented DEA

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was conducted to calculate the scores of the averaged relative efficiency for each cluster. We list the variables constituting the DEA model in Table 2.

**Table 1 Membership of the 2-cluster solution**

Cluster 1 ( <i>Followers</i> )		Cluster 2 ( <i>Leaders</i> )
Albania (1993-2002);	Armenia (1993-2002)	Bulgaria (2002); Czech Rep (1993-2002)
Azerbaijan (1993-2002);	Belarus (1993-2002)	Estonia (1994-2002); Hungary (1993-2002)
Bulgaria (1993-2001);	Estonia (1993)	Latvia (1994, 1995, 1997-2002);
Kazakhstan (1993-2002);	Kyrgyzstan (1993-2002)	Lithuania (1999-2002)
Latvia (1993, 1996);	Lithuania (1993-1998)	Poland (1993-2002)
Moldova (1993-2002);	Romania (1993-2002)	Slovenia (1993-2002)
Slovakia (1993,1994, 1999);	Ukraine (1993-2002)	Slovakia(1995-1998, 2000-2002)

For justification of the variables used to specify DEA model, as well as for overview of the theoretical framework used in the study, see (Samoilenko, 2008).

**Table 2 List of Variables for DEA Models**

Input Variables of the DEA Model	Output Variables of the DEA Model
GDP per capita (in current US \$), Full-time telecommunication staff(% of total labor force), Annual telecom investment per telecom worker, Annual telecom investment(% of GDP in current US \$), Annual telecom investment per capita, Annual telecom investment per worker	Total telecom services revenue per telecom worker, Total telecom services revenue(% of GDP in current US \$), Total telecom services revenue per worker, Total telecom services revenue per capita

According to the results of DEA, one of the clusters has a higher level of averaged relative efficiency scores than the other cluster. Subsequently, we call the first group the *Leaders* and the second group the *Followers*. Results of DEA presented in Table 3.

**Table 3 Comparison of the Leaders and Followers in Terms of the Averaged Levels of Relative Efficiency**

DEA Model	Criterion for comparison, return-to-scale	<i>Leaders</i> cluster	<i>Followers</i> cluster	Difference	Difference, %
Input-Oriented	Avg. efficiency score, CRS	0.89	0.79	0.10	12.54%
Input-Oriented	Avg. efficiency score, VRS	0.95	0.88	0.07	7.48%
Input-Oriented	Avg. efficiency score, NIRS	0.89	0.80	0.09	11.63%
Output-Oriented	Avg. efficiency score, CRS	1.21	1.44	0.22	15.58%
Output-Oriented	Avg. efficiency score, VRS	1.18	1.30	0.12	8.88%
Output-Oriented	Avg. efficiency score, NIRS	1.21	1.38	0.18	12.78%

## RESULTS OF DATA ANALYSIS

To perform DEA, we used the software application “OnFront,” version 2.02, produced by Lund Corporation ([www.emq.com](http://www.emq.com)). We obtained the values of Malmquist index (MI), as well as its components TC (technology change) and EC (change in efficiency), for both input- and output-oriented DEA models under assumption of constant returns to scale (CRS). Values of greater than “1” indicate an increase, less than “1” indicate a decrease, and equal to “1” indicate no change in productivity (MI), technology (TC), and efficiency (EC). Results of the analysis (scores are rounded to two decimal points) presented in Table 4 below.

**Table 4 Comparison of the Leaders and Followers in Terms of the Averaged Levels of Productivity Growth**

DEA Model	Criterion for comparison	<i>Leaders</i>	<i>Followers</i>	Difference	Difference, %
Input-Oriented	Malmquist Index	1.18	1.18	0	-0.13%
Input-Oriented	Malmquist Index, TC	1.13	1.11	0.02	1.52%
Input-Oriented	Malmquist Index, EC	1.04	1.07	-0.03	-2.11%
Output-Oriented	Malmquist Index	1.17	1.2	-0.02	-1.79%
Output-Oriented	Malmquist Index, TC	1.1	1.14	-0.04	-3.83%
Output-Oriented	Malmquist Index, EC	1.09	1.08	0.02	1.45%

Based on the results of the data analysis we have a reason to reject null hypotheses of this study and state that we obtained the evidence of conversion of the *Leaders* and *Followers* subsets of 18 TEs in terms of the efficiency of utilization of inputs and efficiency of the production of revenues.

## DISCUSSION AND CONCLUSION

Purpose of our inquiry was to determine whether the group of less efficient TEs, the *Followers*, was converging in terms of the growth in productive efficiency with the group of the more efficient TEs, the *Leaders*, over the period from 1993 to 2002. Based on the results of the data analysis we obtained an evidence of convergence and catching-up of these two groups of TEs. One of the contributions of our study is that we corroborated one of the assumptions of the neoclassical framework of growth accounting in the context of TEs. Another contribution is associated with the determining the source of the conversion. For example, in the case of conversion in terms of efficiency of utilization of investments, the *Followers* increase their level of efficiency at the higher rate than the *Leaders*, however, the *Followers* are behind in terms of the change in technology. This may mean that while the *Followers* improve their level of efficiency of utilization of investments, they are still lacking in terms of the level of capital investments allowing for utilization of the latest technology and building economies of scale. In terms of the efficiency of the production of revenues from Telecoms, the picture is quite different. While the *Followers* are ahead in terms of benefiting from the level of technology, they are failing to utilize it as effectively as the *Leaders* do. Consequently, practical contributions of our investigation refer to the identification of some of the paths by which the Followers could further affect their growth in productivity.

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