Methodology for Determining an ICT Workforce Management Strategy Based on Complementarity of Investments and Sources of Relative Inefficiency

Sergey Samoilenko
Department of Management, Virginia Union University

Ojelanki Ngwenyama
Ted Rogers School of Management, Ryerson University

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Sergey Samoilenko* and Ojelanki Ngwenyama**

*Department of Management
VIRGINIA UNION UNIVERSITY
Richmond, VA, USA
& The Information Systems Research Institute
VIRGINIA COMMONWEALTH UNIVERSITY
Richmond, VA, USA
** The Institute of Innovation and Technology Management
Ted Rogers School of Management
RYERSON UNIVERSITY,
Toronto, Canada

ABSTRACT

Multiple factors mediate the relationship between investments in ICT and their macroeconomic outcomes. The amount and quality of the available workforce has been identified as one of the complementary to investments in ICT factors. Unlike the developed countries, developing and Transition Economies (TE) do not represent a homogenous group that allows for adapting and implementing strategies of the more successful counterparts. As a result, these economies face the task of formulating unique investment and workforce management strategies. In this study, we investigate the relationship between a subset of investments in ICT, namely, investments in Telecoms, and a full-time Telecom staff, and propose a methodology allowing for formulating a complementary to investments in ICT workforce management strategy. Adapting a framework of neoclassical growth accounting as the theoretical foundation of our inquiry, we propose a two-phase approach utilizing multivariate regression and data envelopment analysis. We argue that our methodology allows for formulating complementary to investments in Telecoms, empirically-justifiable and theoretically sound HR strategies. The illustrative example of the proposed methodology in action substantiates the argument.

KEYWORDS

HR strategy, Data Envelopment Analysis, Multivariate Regression, Transition Economies, Investments in Telecoms, Full-time Telecom staff

INTRODUCTION

An important problem for research on Information Technology for Development (IT4D) concerns unraveling the relationship between investments in Information and Communication Technologies (ICT) and macroeconomic outcomes (Avgerou, 1998; Colecchia & Schreyer, 2001, 2002; Lee & Khatri, 2003; Piatkowski, 2003a, 2003b; 2004; Pohjola, 2000; 2001; 2002; Morales-Gomez & Melesse, 1998; Kraemer & Dedrick, 2001). Evidence from studies on the impact of ICT on economic growth in context of developed countries demonstrates that such investments offer robust returns (OECD, 2005; Jorgenson, 2001; Jorgenson & Stiroh, 2000; Oliner & Sichel, 2002; Stiroh, 2002; Colecchia & Schreyer, 2001; van Ark et al., 2002; Daveri, 2002; Jalava & Pohjola, 2002). However, similar studies in the context of developing countries and Transition Economies (TE) identified significantly lower levels of returns (Dewan & Kraemer, 2000; Pohjola, 2001; Piatkowski, 2003a). In the hope of accelerating growth in developing and transition economies via ICT investments international developmental agencies have repeatedly asked for more research in this area (OECD, 2004; IMF, 2001). However, the context of developing countries and TEs differs from that of developed countries. Unlike a relatively homogenous environment of developed economies that allows for easier sharing of the successful strategies and best practices, developing and transition economies do not represent a homogenous group (Hoskisson et al., 2000; Arcelus & Arocena, 2000; Barro & Sala-i-Martin, 1995; Sala-i-Martin, 1996). The challenges faced by the latter are varied and do not easily allow for transplanting and implementing solution strategies from the developed context that have little in common with extant conditions.

Prior research has shown that an increase in ICT investments does not result in the proportional increase in revenues; instead, multiple internal and external factors mediate the relationship (Dewan & Kraemer, 2000; Piatkowski, 2002; Murakami, 1997; OECD, 2004). An emerging consensus among some IT4D researchers suggests that insufficient level of complementary investments is one of the reasons why the impact of investments in ICT does not manifest itself at the macroeconomic level (Kraemer and Dedrick 2001; Pohjola 2002). One example of the lack of complementary investments is represented by the scarcity of technological experts. It has been noted that a skilled and equipped workforce is more likely to result in higher rates of ICT-related innovation and increased productivity (OECD, 2004; van Ark, Frankema, & Duteweerd, 2004). Increased investments in ICT result in technological changes in work environment (Siegel, Waldman, & Youngdahl, 1997; Bresnahan, Brynjolfsson, & Hitt, 2002), as well as increased demand for highly skilled labor (Indjikian &Siegel, 2005). Consequently, a successful initiative of IT4D in the context of developing countries and TEs must be condition specific, with a clear focus on the development of technological and managerial skills of the ICT workforce. Indeed, current empirical findings provide evidence of a positive effect of complementarity of investments in ICT and investments in ICT–related workforce on the level of return on investments in ICT (Indjikian &Siegel, 2005).

RESEARCH PROBLEM

Policy makers tasked with the responsibility of increasing the impact of IT4D programs face two distinct problems: (1) determining an appropriate ICT investment strategy and, (2) determining a complementary ICT workforce development and management strategy. While a methodology directed at identifying specific investment strategies in the context of TEs has been proposed (Samoilenko & Osei-Bryson, 2008), the question of how to determine a complementary workforce management strategy remains open. The broad research question of this investigation concerns the determining strategies for the requirements of high-technology human capital for IT4D initiatives in developing and transition economies. More specifically, we are interested in developing a methodology that policy makers would use in the process of the formulation of a workforce management strategy. The central logic of our approach is based on the assumption that the increases in the macro-economic impact of ICT investments can be achieved by two means. First, economies could follow the simplest route and achieve an improvement by increasing the level of investments in ICT technologies. Second, the increase of the level of macroeconomic impact of investments could be obtained by increasing the level of efficiency of conversion of investments into revenues. However, in order to achieve an efficiency of conversion of investments into revenues, corresponding changes in the level and/or a quality of a workforce will also be required. The question becomes, then, what are those required changes and how could they be reflected and taken into consideration by a workforce management strategy?

THE GENERAL APPROACH

We suggest that a policy maker promoting a strategy of increasing the level of macroeconomic outcomes from investments in Telecoms may benefit from resolving the following issues. First, it must be decided whether to pursue the path of increasing the size of the workforce or whether to follow the route of the increasing the level of productivity of a workforce. Clearly, while these two routes are not mutually exclusive, they are not likely to be implemented simultaneously.

It is reasonable to suggest that in the case of increasing the level of the workforce such increase could come from hiring full-time Telecom staff, or, conversely, from hiring contractors. In this research, we use the term 'contractor' to denote any non-full-time employee. Similarly, the strategy of increasing the productivity of the workforce could be based on impacting two factors. The first factor refers to improvements in the quality of the workforce itself (e.g., level of education, technical skills, 'know-how'), and the second factor refers to improvements in the quality of the technology utilized by the workforce (e.g., better infrastructure, faster networks, more powerful workstations, etc). Keeping the assumptions of this study in mind, the scope of our methodology is bounded by two broad questions, formulated as follows:

- Whether in the context of developing countries and TEs investments in Telecoms should be accompanied by hiring full-time Telecom staff or by hiring contractors?

- Whether in the context of developing countries and TEs improvements in the level of efficiency of conversion of investments in Telecoms into revenues should be accompanied by investments in a work-force development program or by investments in a better infrastructure?

For convenience of the reader we summarize the stated above in Table 1.

Table 1 Research questions representing the scope of the methodology

Strategy of Increasing the Level of Macroeconomic Impact of Investments in Telecoms by means of	Possible Implications for HR Strategy	Possible Implementation of HR Strategy
Increasing the Level of Investments	Increasing the Level/Quantity of Workforce	1. Increase in the level of Full-time staff 2. Increase in the level of contractors
Increasing the Level of Efficiency of Conversion Investments into Revenues	Increasing the Productivity of the Existing Level of Workforce	1. Increase in the quality/"know-how" of Full-time staff 2. Increase in the quality of technology utilized by Full-time staff

THE RESEARCH QUESTION

At this point, we outline two research questions that must be answered by the proposed methodology in more detail. The first question deals with the issue of determining an HR strategy that is complementary to the overall strategy of the increasing the level of revenues from investments in Telecoms. Based on the assumption of this study, the first question aims to determine whether a complementary HR strategy should be based on increasing the level of the full-time Telecom staff and can be stated as follows:

Whether in the context of TEs the level of full-time Telecom staff and the level of investments in Telecoms are complementary factors impacting the macroeconomic bottom line.

Consequently, we formulate the null hypothesis of the first research question as follows:

H01: *the level of a full-time Telecom staff is not complementary to the level of investments in Telecoms.*

If we able to reject H01, then we have an empirical evidence to suggest that an increase in the level of investments in Telecoms should be accompanied by the increase in the level of full-time Telecom staff. Alternatively, if we accept H01, then we are justified to suggest that any increase in the overall level of Telecom workforce should come from hiring contractors.

The second question deals with determining a complementary HR strategy directed at the improving the efficiency of the process of conversion of investments into revenues by full-time Telecom staff. According to the assumptions of this inquiry, an implementation can proceed along the routes of increasing the productivity of the current full-time workforce, or increasing the quality of the technology utilized by the current full-time workforce. We state the second research question as follows:

Whether in the context of TEs changes in efficiency of a full-time Telecom staff have a greater impact on the overall level of efficiency of conversion of investments in Telecoms into revenues than changes in technology.

Consequently, the null hypothesis of the second research question can be stated as follows:

H02: *given an overall change in efficiency of conversion of investments into revenues over a period of time, a contribution to the change associated with the efficiency of the full-time Telecom staff (EC) is greater than a contribution associated with the change in technology (TC).*

If, in the case of TC>EC, we able to reject H02, then we have an empirical evidence to suggest that workforce management strategy should consider implementing the program directed at the improvement of the quality of the full-time Telecom workforce. Conversely, in the case of TC<EC, we are justified to suggest that improvements in the efficiency should come from the introduction of better technology.

We present our inquiry as follows. First, we provide an overview of the framework of Neoclassical Growth Accounting and the theory of Complementarity, which serve as the theoretical foundation for our proposed methodology. The next section is dedicated to the overview of Multivariate Regression and Data Envelopment Analysis (DEA), the main data analytic tools employed to answer the research questions of this study. After an overview of the proposed methodology, we present the illustrative example that demonstrates our methodology in action. Brief conclusion follows.

THE THEORETICAL FRAMEWORK

The theoretical framework of our research is the neoclassical growth accounting model. This framework originated from the work of Solow (1957) and since then has been widely used by other researchers (Oliner and Sichel 2002). The objective of growth accounting is to decompose, using a neoclassical production function, the rate of growth of an economy into the contributions from the different inputs. A neoclassical production function relates output and inputs in the following manner:

$$\mathbf{Y} = \boldsymbol{f}\,(\mathbf{A}, \mathbf{K}, \mathbf{L})$$

where

Y = output (most often in the form of GDP),
A = the level of technology/ total factor productivity (TFP),
K = capital stock, and
L = quantity of labor/size of labor force.

Which, in the case of this study, becomes:

Y = GDP
A = TFP
K = investments in Telecoms
L = full-time Telecom staff.

Based on the function provided above, growth accounting uses a Cobb-Douglas production function:

$$\mathbf{Y = A * K^{\alpha} * L^{\beta}}$$

where

α and β are constants determined by technology.

In the case of constant returns to scale[1], $\alpha + \beta = 1$, thus, $\beta = 1 - \alpha$, which gives the following formulation:

$$\mathbf{Y = A * K^{\alpha} * L^{1-\alpha}}$$

Out of three inputs used by growth accounting, only capital *K* and labor *L* could be observed in the data, while TFP would serve as a residual (often referred to as *Solow's residual*) term capturing that contribution to *Y* (GDP), which is left unexplained by the inputs of capital and labor. In the case of this study, the neoclassical production function allows us to relate investments in Telecoms, full-time Telecom employees, and GDP in the following fashion:

GDP = f (TFP, investments in Telecoms, full-time Telecom employees)

Theory of Complementarity

Initially introduced in economics by Edgeworth (1881), the concept of *complementarity* refers to the notion that the increase in one factor could result in the increased benefit received from its complementary factors. Thus, if the two factors are more effective when taken jointly, rather than separately, we consider such factors complementary. However, even if the complementarity of the investments exists within a given production function, it could not be identified through the formulation offered by Cobb-Douglas production function. Complementarity of the investments could only be discerned if the formulation allows for the presence of the interaction term between the specified investments. By taking the logarithm of the standard Cobb-Douglas production function, the following formulation could be obtained:

$$\log Y = \log A + \alpha \log K + \beta \log L$$

Extension to the given above production function, called the Transcendental Logarithmic (*translog*) production function, takes the following form:

$$\log Y = \beta_0 + \beta_{1*}\log K + \beta_{2*}\log L + \beta_{3*}\log K^2 + \beta_{4*}\log L^2 + \beta_{5*}\log K * \log L + e$$

[1] If $\alpha + \beta > 1$, returns are increasing to scale, and if $\alpha + \beta < 1$, returns are decreasing to scale

The translog production function is more flexible than Cobb-Douglas function in the sense that it allows testing for the presence of the interactions between the variables, where the test for the presence of the interaction would involve testing of the following hypothesis:

H_0: β_5 is not statistically discernible from 0 at the given level of α

We are interested in investigating the following production function:

$$\mathbf{Y = f(A, K_{TC}, L_{TC}).}$$

This, in the translog formulation, becomes

$$\log Y = \beta_0 + \beta_1 * \log K_{TC} + \beta_2 * \log L_{TC} + \beta_3 * \log K_{TC}^2 + \beta_4 * \log L_{TC}^2 + \beta_5 * \log K_{TC} * \log L_{TC} + e.$$

By stating the null hypothesis **H_0: $\beta_5 = 0$,** we can test for the presence of interaction between the two variables, investments in Telecoms and full-time Telecom staff. Next, we offer a brief overview of Multivariate Regression (MR), the data analytic tools that we use in our study to determine the presence of the interaction effect.

OVERVIEW OF THE ANALYTICAL METHODS

In this research we use two primary data analytic methods, *Multivariate Regression (MR) and Data Envelopment Analysis (DEA).* MR is used in this investigation as we are interested in the interaction effect of the independent variables on the dependent variable. The DEA is used to determine the relative efficiency and to identify best practice among the countries of our analysis.

The Regression Analysis:

In this case, the general model of MR takes form of:

$$Y = a + b_1 * X_1 + b_2 * X_2 + b_3 * X_1 X_2 + \ldots + b_n * X_n + b_k * X_k + b_m * X_n * X_k + e$$

And the test for interaction amounts to testing the null hypothesis

H_0: $b_3 = 0$;

And in the case of $b_3 \neq 0$ we are able to reject the null hypothesis of no interaction between X_1 and X_2.

The interpretation of the interaction term in MR, however, is not as straightforward as the interpretation of the slope coefficient of an independent variable. For example, b_3 in the equation above reflects the relationship between Y and X_1 and X_2 when X_1 and X_2 increase *jointly*. Furthermore, b_3 in the equation above reflects conditional relationship between Y and X_1 and X_2, for the impact of X_1 on Y would depend on the level of X_2 and vice versa.

For the purposes of this research, we are interested only in testing the null hypothesis of no interaction between the investments in Telecoms and full-time Telecom staff. As a result, we are not going to inquire into such potentially affecting the interaction term issues as the presence of thresholds, level-dependent dynamic of the interacting variables, and so on.

The brief overview that we have provided in this section is not intended to reflect the true complexity of this topic. Consequently, any reader who is interested in the subject of interpreting the interactions in MR, would be well-served by referring to such sources as Jaccard et al. (1990), Aiken and West (1991), and Braumoeller (2004).

Data Envelopment Analysis

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 the case of our study, we use an output-oriented DEA model. 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. 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.

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 t1 and t2. Then, for a given DMU, the period of time (t2-t1) could be represented as the distance between the data point at the time t1 and the data point at the time t2. 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 (t2 –t1). 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 (t2-t1).

PROPOSED METHODOLOGY

To accomplish the goal of this investigation we propose a two-phase methodology consisting of MR and DEA. While each of the methods can provide valuable information to a decision maker, it is a synergy of the two that allow us to gain insight into the interplay between investments in Telecoms and the quantity and the quality of the workforce.

Phase 1: Using MR to Determine the Presence of Complementarity

The purpose of the first phase is to determine the presence of complementarity between the level of investments in Telecoms and the level of the full-time Telecom staff. In order to do so, we utilize the following formulation of the Translog function

$$\log Y = \\ = \beta_0 + \beta_1 * \log K_{TC} + \beta_2 * \log L_{TC} + \beta_3 * \log K_{TC}^2 + \beta_4 * \log L_{TC}^2 + \beta_5 * \log K_{TC} * \log L_{TC} + e$$

Consequently, the test for the presence of the interaction involves testing of the following hypothesis:

H0: β_5 is not statistically discernible from 0 at the given level of α

If the interaction term between investments in Telecoms and full-time Telecom staff is significant (i.e., we reject the null hypothesis of $\beta_5 = 0$), then we have a reason to assume that such investments are complementary. Furthermore, if the direction of the interaction effect is positive (i.e., "$+\beta_5$ "), then we have a reason to suggest that complementary investments in Telecoms and full-time Telecom labor have a combined positive effect on the macroeconomic outcome. This implies that in the case of the increase in the level of investments in Telecoms a complementary HR strategy should be directed at the increase in the level of the full-time Telecom labor. If, however, the direction of the interaction effect is negative (i.e., "$-\beta_5$ "), then the increase in the level of full-time Telecom labor would, actually, be detrimental to the overall macroeconomic impact from the increasing in the level of investments in Telecoms. We summarize the possible outcomes and implications of the first phase of our methodology in Table 2 below.

Table 2 Summary of Results and Implications of Phase 1

Results of the first phase	Implication for Complementarity	Implications for HR strategy
Null hypothesis accepted	No complementarity between Investments in Telecoms and full-time Telecom staff	There is no empirical justification for hiring full-time Telecom staff An increase in the level of current workforce should come from hiring contractors
Null hypothesis rejected, Interaction effect is positive	Combined effect of Investments in Telecoms and full-time Telecom staff is positive	There is an empirical justification for hiring full-time Telecom staff HR strategy should be directed at the increase in the level of full-time Telecom staff
Null hypothesis rejected, Interaction effect is negative	Combined effect of Investments in Telecoms and full-time Telecom staff is negative	There is no empirical justification for hiring additional full-time Telecom staff HR strategy should be directed at the increase in the level of efficiency of the current full-time Telecom staff

Phase 2: Using DEA to Determine the Sources of Relative Inefficiency

The second phase of our methodology deals with the issue of determining an appropriate route of increasing the level of efficiency of the conversion of investments in ICT into revenues. In order to do so, we perform DEA and calculate the values of Malmquist index (MI) for DMUs in our sample. Keeping in mind that MI can be decomposed into two components, TC (change associated with changes in technology) and EC (change associated with changes in efficiency), we can determine which component contributes more to the overall change in efficiency of DMUs in the sample. We summarize the possible outcomes and implications of the first phase of our methodology in Table 3 below.

Table 3 Summary of Results and Implications of Phase 2

Results of the second phase	Interpretation of the results	Implications for HR strategy
TC> EC	Greater part of the change in efficiency comes from the changes associated with technology; efficiency of the full-time staff is lagging behind	HR strategy should consider introducing development programs for the full-time staff
EC>TC	Greater part of the change in efficiency comes from the changes associated with efficiency of the full-time staff; technology- associated change is lagging behind	HR strategy should consider increasing the quality of the technology used by full-time staff

We present our methodology in a summarized form in Table 4 below.

Table 4 A Summary of the Proposed Two-Phase Methodology

<table>
<tr><th>Research Question # 1</th><th>Results, Phase1</th><th>Implication for HR</th><th>Research Question # 2</th><th>Results, Phase 2</th><th>Implication for HR</th></tr>
<tr><td rowspan="3">Determining the existence of complementarity between the levels of full-time Telecom staff and annual investments in Telecoms</td><td>No interaction effect</td><td>Hire contractors</td><td rowspan="3">Determining the relative contributions of changes in technology and changes in efficiency to the process of conversion of investments into revenues</td><td>TC> EC</td><td>Increase the quality of the current workforce</td></tr>
<tr><td>Interaction effect positive</td><td>Hire full-time workers</td><td rowspan="2">EC>TC</td><td rowspan="2">Increase the quality of technology</td></tr>
<tr><td>Interaction effect negative</td><td>Improve efficiency of full-time workers</td></tr>
</table>

ILLUSTRATIVE EXAMPLE

In our illustrative example we look at18 transition economies over two consecutive periods of time, first, from 1993 to 1997, and then from 1998 to 2002. These TEs, namely, Albania, Armenia, Azerbaijan, Belarus, Bulgaria, Czech Republic, Estonia, Hungary, Kazakhstan, Kyrgyzstan, Latvia, Lithuania, Moldova, Poland, Romania, Slovakia, Slovenia, and Ukraine, are classified as *Transition economies in Europe and the former Soviet Union* by IMF (2000). The data for our illustrative example came from the *World Development Indicators* database (web.worldbank.org/WBSITE/EXTERNAL/DATASTATISTICS) and the *Yearbook of Statistics* (2004) (www.itu.int/ITU-D/ict/publications*),* an annual publication of *International Telecommunication Union (ITU)(* www.itu.int*)*. In our previous inquiries we determined, that these 18 TEs are not homogenous in terms of levels of *investments in Telecoms* and *revenues from Telecoms*; results of cluster analysis (CA) yielded a two-cluster solution (Samoilenko and Osei-Bryson 2007). Further, by using 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 and Osei-Bryson 2007). The membership of each cluster is provided in Table 5.

Table 5 Membership of the 2-cluster solution

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

Keeping in mind the circumstances outlined earlier in the paper, we cannot expect that the strategy of the *Leaders* could be adopted by the *Followers*. Furthermore, it is not even clear what strategy should the *Leaders* follow in order to increase their level of revenues from investments in Telecoms. Consequently, given the context of the illustrative example, we would like to determine:

- Whether in the context of the *Leaders* and the *Followers* investments in Telecoms should be accompanied by hiring full-time Telecom staff or by hiring contractors?

- Whether in the context of the *Leaders* and the *Followers* improvements in the level of efficiency of conversion of investments in Telecoms into revenues should be accompanied by investments in a work-force development program or by investments in a better infrastructure?

Considering the context of the illustrative example, we re-state the research questions as follows. First question aims to determine *whether in the context of 18 TEs the level of full-time Telecom staff and the level of investments in Telecoms are complementary factors.*

Consequently, we formulate the corresponding null hypotheses as follows:

H01: *During the period from 1992 to 1997, the Leaders' subset of 18 TEs did not exhibit a statistically significant interaction effect between the level of a full-time Telecom staff and the level of investments in Telecoms*
H02: *During the period from 1992 to 1997, the Followers' subset of 18 TEs did not exhibit a statistically significant interaction effect between the level of a full-time Telecom staff and the level of investments in Telecoms*
H03: *During the period from 1998 to 2002, the Leaders' subset of 18 TEs did not exhibit a statistically significant interaction effect between the level of a full-time Telecom staff and the level of investments in Telecoms*
H04: *During the period from 1998 to 2002, the Followers' subset of 18 TEs did not exhibit a statistically significant interaction effect between the level of a full-time Telecom staff and the level of investments in Telecoms*

Similarly, we re-state the second research question as follows:

Whether in the context of 18 TEs changes in efficiency of a full-time Telecom staff have a greater impact on the overall level of efficiency of conversion of investments in Telecoms into revenues than changes in technology.
Correspondingly, the null hypotheses of the second research question are formulated as follows:

H05: *During the period from 1992 to 1997, the Leaders' subset of 18 TEs had a greater contribution to the change in productivity associated with the efficiency of the full-time Telecom staff (EC), than a contribution associated with the change in technology (TC).*
H06: *During the period from 1992 to 1997, the Followers' subset of 18 TEs had a greater contribution to the change in productivity associated with the efficiency of the full-time Telecom staff (EC), than a contribution associated with the change in technology (TC).*

H07: *During the period from 1998 to 2002, the Leaders' subset of 18 TEs had a greater contribution to the change in productivity associated with the efficiency of the full-time Telecom staff (EC), than a contribution associated with the change in technology (TC).*
H08: *During the period from 1998 to 2002, the Followers' subset of 18 TEs had a greater contribution to the change in productivity associated with the efficiency of the full-time Telecom staff (EC), than a contribution associated with the change in technology (TC).*

RESULTS OF THE DATA ANALYSIS

Phase 1

We used SAS *Enterprise Miner* to perform the data analysis of the first phase of our methodology, the results of which are presented in Table 6. Following three variables were used in MR analysis:

1. GDP(in current US $)
2. Annual telecom investment(% of GDP)
3. Full-time telecommunication staff(% of total labor force).

For the detailed overview and justification of the variables of this translog model, we direct the reader to Samoilenko and Osei-Bryson (2008).
The interaction term is given in the form as it appeared in the actual model (column "Term in the model"). The column "Estimate" provides a value of the parameter estimate for the β an interaction term. The column labeled "p-value" provides a 2-tailed p-value used in testing of our null hypothesis that β = 0. We test the hypothesis at 95% confidence level, or, as it is commonly expressed, at a level of α = 0.05. As a result, a coefficient having a p-value of 0.05 or less would be considered statistically significant, which would allow us to reject the null hypothesis at the level of α = 0.05.

Table 6 Results of the Multivariate Regression

Cluster/Period	Term in the model	Estimate (value of β)	p-value	Adjusted R^2
The "Followers" 1993-1997 60 data points	ANNU_EL1*FULL_2KW Log (Annual Telecom Investment)*Log(Full-time Telecom Staff)	1.0876	0.2699	0.9922
The "Leaders" 1993-1997 30 data points	ANNU_EL1*FULL_2KW Log (Annual Telecom Investment)*Log(Full-time Telecom Staff)	-18.066	0.0416	0.9927
The "Followers" 1998-2002 51data points	ANNU_EL1*FULL_2KW Log (Annual Telecom Investment)*Log(Full-time Telecom Staff)	-3.2261	0.2296	0.9870
The "Leaders" 1998-2002 39 data points	ANNU_EL1*FULL_2KW Log (Annual Telecom Investment)*Log(Full-time Telecom Staff)	53.6891	<.0001	0.9184

Based on the results Phase 1, we accept H01, H02, H03, and reject H04.

Phase 2

To perform DEA we used the software application "OnFront," version 2.02, produced by Lund Corporation (www.emq.com). The variables used to perform DEA are listed in Table 7. For justification of the variables constituting our DEA model we direct our reader to Samoilenko (2008). Results of DEA are summarized in Table 8.

Table 7 List of Variables for DEA Models

Role	Subset of Variables
Input	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
Output	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

Table 8 Values of Malmquist index and EC and TC components

Time Period	Criterion for comparison	"*Leaders*" cluster	"*Followers*" cluster	Difference %
First 5-years (1993-1997)	Malmquist Index (MI)	**1.18**	**1.21**	**-2.39%**
	MI, TC	**1.08**	**1.11**	**-2.57%**
	MI, EC	**1.14**	**1.15**	**-0.41%**
Second 5-years (1998-2002)	Malmquist Index (MI)	**1.159**	**1.159**	**-0.03%**
	MI, TC	**1.106**	**1.103**	**0.29%**
	MI, EC	**1.058**	**1.056**	**0.14%**

Results of Phase 2 provide us with sufficient evidence to accept H05, H06, and to reject H07, and H08.

The summary of the results of the data analysis is provided in Table 9 below.

Table 9 Summary of the results of the data analysis

Cluster	**Analyzed Period**	**H01:** *the level of a full-time Telecom staff is not complementary to the level of investments in Telecoms.*	**H02:** *a contribution to the change associated with the efficiency of the full-time Telecom staff (EC) is greater than a contribution associated with the change in technology (TC).*
"*Leaders*"	1993-1997	Accept H01	Accept H05
"*Followers*"	1993-1997	Accept H02	Accept H06
"*Leaders*"	1998-2002	Accept H03	Reject H07
"*Followers*"	1998-2002	Reject H04	Reject H08

INTERPRETATIONS OF THE RESULTS

Phase 1

The Leaders, 1993-1997

Results of the data analysis conducted in Phase 1 suggest that for the *Leaders,* the level of full-time Telecom staff is a complementary factor to investments in Telecoms. However, the direction of the effect is negative. This may be interpreted as the *Leaders*, at that time, having a level of the full-time Telecom staff that was too high. This interpretation suggests that additional investments in Telecoms should have not been accompanied by the increase in the level of the full-time Telecom staff. During that period, the *Leaders* would have benefited from reducing its current level of the full-time Telecom staff. It is also reasonable to suggest, that the negative direction of the interaction could have been reversed by increasing the level of the efficiency of the full-time Telecom staff.

The Leaders, 1998-2002

Statistically significant interaction effect between the level of full-time Telecom staff and investments in Telecoms demonstrate that this complementarity still holds true for the *Leaders* during the period from 1997 to 2002. The direction of the interaction, however, is positive. Consequently, the results of MR suggest that the increase in the level of investments in Telecoms should have been accompanied by the increase in the level of full-time Telecom staff. What is the significance of the change in the direction of the interaction effect? It is reasonable to suggest that there is a certain 'optimal level' of full-time Telecom staff that is required for a given level of investments in Telecoms to contribute maximally to the increase in GDP. If this is the case, then there exists a 'golden middle' of the investment-to-staff ratio. For example, it could be that up to the certain level of investments in Telecoms the number of the full-time staff must grow rapidly, while after that point only increase in productivity of the full-time Telecom staff could provide increased contribution of the investments in Telecoms to the macroeconomic growth.

The Followers, 1993-1997 & 1998-2002

In the case of the *Followers*, however, the results of Phase 1 provide no evidence of complementarity of the investments in Telecoms and the level of full-time Telecom staff for the period from 1993 to 1997, as well as for the period from 1998-2002. Consequently, the evidence suggests that the increase in the level of investments in Telecoms should not have been accompanied by the increase in the level of full-time Telecom staff.

Phase 2

1993-1997

The results of DEA display a similarity between the sources of inefficiency of the Leaders and Followers. For the period from 1993 to 1997, for both groups the greater part of the changes in productivity came from changes in efficiency (EC). It is reasonable to suggest, that at that period of time both groups could have benefited the most from investments in the better technology utilized by the workforce.

1998-2002

For the period from 1998-2002, however, the situation changes, and both groups have a greater part of changes in productivity coming from changes in technology (TC). This may suggest that the Telecom workforce does not utilize the available technology to its full extent and, therefore, the both groups could benefit from investing in the full-time workforce development programs. Interpretation of the data analysis, in a summarized form, is presented in Table 10.

Table 10 Interpretation of the Results

Cluster	**Analyzed Period**	**HR Strategy based on Analyzed Period**
"*Leaders*"	1993-1997	Hire contractors and Improve the level of efficiency of the current full-time workforce Improve efficiency by investing in better technology
"*Followers*"	1993-1997	Hire contractors Improve efficiency by investing in better technology
"*Leaders*"	1998-2002	Hire full-time workers, Improve efficiency by investing in full-time workforce development programs
"*Followers*"	1998-2002	Hire contractors, Improve efficiency by investing in a higher quality contractors

CONCLUSION

At this point, to our knowledge, there is no methodology allowing for formulating complementary to investments in Telecoms HR strategies. In this paper, we proposed a theoretically sound, empirically-driven, two-phase methodology allowing for formulating human capital management strategies that are intended to complement investments in Telecoms. We would like to identify some strengths of the proposed approach. First, our methodology is grounded in the accepted and widely used theoretical framework of neoclassical growth accounting. Second, our solution relies on such established data analytic methods as multivariate regression and data envelopment analysis. Third, our methodology allows for formulating strategies that are supported by historical data. Fourth, our solution allows for formulating HR strategies that explicitly take into consideration the level of investments in Telecoms. Fifth, our methodology takes explicitly into consideration the sources of relative inefficiency of a given economy. Finally, the proposed approach allows for forecasting of the demand for the full-time workforce.

However, the proposed solution is not without its weaknesses. First, our approach does not allow for taking into consideration the unusual events, such as a sudden spike or a fall in the level of investments. Second, being based on historical data, our approach assumes presence of trend in the levels of investments and workforce. Third, the proposed methodology assumes availability of the workforce. Nevertheless, we hope that contributions of our study outweigh its limitations.

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