Linking Investments in Telecoms and Total Factor Productivity in Transition Economies

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LINKING INVESTMENTS IN TELECOMS & TOTAL FACTOR PRODUCTIVITY IN TRANSITION ECONOMIES

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Abstract

For several years researchers & practitioners have been concerned about the impact of investments in Information & Communication Technologies (ICT) on productivity. The research framework of neoclassical growth accounting is widely used in this area of research on IT & Productivity. While several studies have explored the relationship between investments in ICT and metrics such as GDP, the links between investments in ICT and Total Factor Productivity (TFP) have received less attention, particularly for Transition Economies. In this study is we propose & illustrate a methodology for investigating the relationship between investments in ICT and TFP that is consistent with the framework of neoclassical growth accounting.

Keywords: Investments in ICT, Economic Development, Total Factor Productivity, Transition Economies, Structural Equation Modeling, Cobb-Douglas Production Function; Translog Production Function
1 INTRODUCTION

The stream of research dedicated to investigating the relationship between investments in ICT and their macroeconomic outcomes is by now well-established (OECD, 2005a,b,c; IMF, 2001; Samoilenko & Osei-Bryson, 2008a,b). Not all settings, however, have received the equal attention of investigators, as the overwhelming majority of studies have been conducted in the context of developed countries (Lam & Lam, 2005; Madden & Savage, 1999; Dunne et al., 2000; Siegel, 1997). Resultantly, while the accumulated evidence of the positive impact of investments in ICT on the economies of developed countries is by now ample, the research concerning the effects of investments in ICT on Transition Economies (TE) is still scarce, which led to a call for conducting additional substantive research beyond the context of developed economies (OECD, 2004).

Although there are important differences between developed countries and TEs, the use of common theoretical frameworks allow investigators to explore the similar paths along which investments in ICT can impact the macroeconomic outcomes in both settings. For example, from the perspective of the research framework of neoclassical growth accounting that is widely used in Information Systems (IS) research (McGuckin & Stiroh, 1999; Brynjolfsson & Hitt, 1996), an increase in the macroeconomic bottom line (e.g., GDP) can come from two sources. The first source is represented by the “white-box” components, such as the available levels of capital (e.g., investments in ICT) and labor (e.g., ICT workforce). The origins of the “white-box” component are clear cut and transparent. The second source is reflected by Total Factor Productivity (TFP), a “black-box” component origin and composition of which is less clear.

The most straightforward way of improving a macroeconomic bottom line is clearly by increasing the contribution of such “white-box” components as the levels of available capital and labor. However, a contribution coming from a “black-box” component, TFP, is preferable because it represents the macroeconomic growth that is not accounted for by any “white-box” resource-intensive and potentially scarce components that are subject to a law of diminishing returns. Unfortunately, it is much easier to establish a link between investments in ICT and GDP (e.g., via revenues from ICT, for example), than between investments in ICT and TFP. Consequently, a scarcity of the scientific evidence is particularly noticeable in regard to establishing a link between investments in ICT and TFP.

The purpose of this study is twofold. First, we propose a methodology that is consistent with the assumptions of the framework of neoclassical growth accounting, and which is a complementary to the translog formulations of the production function. Second, we apply the proposed methodology to the context of TEs to test for the presence of the relationship between investments in ICT and TFP. We present our inquiry in the sequence of the following steps. First, we outline the research problem of our investigation in more detail and propose a methodological solution. Then, we provide an overview of the component technique supporting the proposed solution, as well as offer a justification for the chosen technique. Overview of the data used in our study will be presented next, followed by the results of the data analysis. Discussion of the results and a brief conclusion follow.

2 RESEARCH PROBLEM OF THE STUDY AND THE PROPOSED METHODOLOGICAL SOLUTION

A neoclassical production function relates output and inputs in the following manner

\[ Y = f(A, K, L) \]

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.
Previous investigations established that in order for investments in ICT to impact the economic bottom line, the level of investments must be above a certain threshold, and also that such investments must be complemented by other factors, notably, investments in human resources (OECD, 2004). If such complementarity of the investments exists, then the relevant growth accounting production function must allow for the presence of the interaction term between the specified inputs. Thus, investigators usually turn their attention to the transcendental logarithmic (translog) production function that offers an opportunity for exploring interactions. This function is expressed as:

$$\log Y = \beta_0 + \beta_1 \log K + \beta_2 \log L + \beta_3 \log K^2 + \beta_4 \log L^2 + \beta_5 \log K \log L + \xi$$

Of three inputs used by our growth accounting model, only capital $K$ and labor $L$ can be observed in the data, while $A$ (representing TFP) would appear as a residual $\xi$ (often referred to as Solow’s residual) term that captures the contribution to $Y$ (GDP that is left unexplained by the inputs of capital and labor. Thus, $A$ would have to be computationally derived.

One of the methods for obtaining the values of TFP involves performing Data Envelopment Analysis (DEA) of the time-series data and calculating values of Malmquist Index (MI). MI is an index number, formed as a ratio of distance functions (Caves et al., 1982), allowing for a comparison of productivity of a given economy, or multiple economies, over the period of time. DEA is a widely used in the field of IS for evaluating productivity and performance (e.g., Khouja, 1995; Shao & Lin 2001), and the approach of obtaining the values of TFP via MI is also well-established in IS research (Chen & Zhu, 2004; DaBler et al., 2002; Samoilenko & Osei-Bryson, 2008a,b). For an overview of the theory behind the computations in DEA we would like to direct the interested reader to Dula (2002).

It might appear that if we want to test the presence of the relationship between investments in ICT and TFP, then we can perform a simple regression analysis using the following equation:

$$P = \beta_0 + \beta_6 K + \gamma$$

Where $P = TFP$, and $K = Investments in ICT$.

And the null hypothesis corresponding to this formulation could be stated as follows:

$$H_0: for a given sample of TEs there exists no statistically discernible relationship between the capital investments in ICT and Total Factor Productivity,$$

And expressed as

$$H_0: \beta_6 is not statistically discernible from 0 at the given significance level \alpha$$

However, there are two reasons why such approach should not be accepted. First, from the perspective of the theoretical framework, TFP is exogenous to the Solow’s production function, and, as such, it cannot be directly explained by the variables endogenous to the function such as labor or capital. Second, from the perspective of statistics, a one of the fundamental assumptions of the regression analysis is that an error term $\xi$ (which in equation (1) represents TFP) is not correlated with the independent variables $K$ and $L$. If we attempt a regression analysis of an independent variable $K$ against the error term $\xi$ (that represents TFP and which in (2) becomes $P$), then we do so in violation of the fundamental assumption which implies that the results of such data analysis would be invalid.

To solve this problem of endogeneity we suggest the following approach. Let us suppose that the relationship between the investments in ICT and TFP is indirect, mediated by some latent variables, which we name “ICT Capitalization” and “Productivity.” The justification for this hypothesized indirect relationship is as follows. First, previous investigations demonstrated that investments in ICT can facilitate macro-economic growth in developed countries (OECD, 2005a; Jorgenson, 2001; Jorgenson and Daveri, 2002; Jalava & Pohjola, 2002), and there is no obvious reason why TEs could not similarly benefit from investments in ICT. Second, the relationship must be indirect, or, rather, must not be direct, in order to ensure the consistency of the model with the framework of neoclassical growth accounting.
Simply put, our hypothesized relationship is a vehicle of reconciliation of the existing empirical evidence with the established theory.

For the purposes of this study we can offer the following operational definitions for these latent variables. We define *ICT Capitalization* as a *fiscal state of ICT reflecting relationships between ICT-related investments, revenues, and labor in reference to the overall state of the economy*, and *Productivity* as *an annual change in macro-economic bottom line that is not directly associated with the changes in investments in labor*. Then the relationship between investments in ICT and TFP, mediated by the latent variables, could be depicted by Figure 1 below.

![Figure 1: Proposed Mediated Relationship between Investments in ICT and TFP](image)

**Figure 1: Proposed Mediated Relationship between Investments in ICT and TFP**

We propose this model not with the purpose of describing, as close as possible, the process of how investments in ICT contribute to the unexplained growth in the form of TFP. Rather, the purpose of our model is to serve as a vehicle of understanding whether or not the mentioned above process indeed takes place. Based on the suggested above approach the null hypothesis of this study can be formulated as follows:

\[ H_0: \text{There exists no statistically significant relationship between the constructs ICT Capitalization and Productivity} \]

Consequently, the comprehensive methodology that will allow relating investments in ICT to GDP and TFP within the framework of neoclassical growth accounting can be depicted within the sequence of three steps, described in Table 1 and illustrated in Figure 2 below. In the current study we concentrate on Step 3 of the proposed methodology. The approach that we chose to test the hypothesized relationship is Structural Equation Modeling (SEM) as implemented in the Partial Least Squares (PLS) method (e.g. Chin, 1995; Chin, 1998; Geffen & Straub, 2005; Chin & Hubona, 2006). For an overview on the PLS we would like to direct the interested reader to Geffen & Straub (2005), Gefen, Straub, & Boudreau (2000) & Chin & Hubona, (2006).

<table>
<thead>
<tr>
<th>Step</th>
<th>Technique</th>
<th>Purpose</th>
<th>Outcome</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step 1</td>
<td>Data Envelopment Analysis</td>
<td>Obtain the values of Malmquist Index (MI)</td>
<td>Values of TFP</td>
</tr>
<tr>
<td>Step 2</td>
<td>Multivariate Regression Analysis</td>
<td>Test the presence of the relationship between capital Investments in ICT, ICT Labor, and GDP</td>
<td>Strength of the relationship between the “white-box” independent variables and the dependent variable</td>
</tr>
<tr>
<td>Step 3</td>
<td>Structural Equation Modeling</td>
<td>Test the presence of the indirect/mediated relationship between Investments in ICT and TFP</td>
<td>Strength of the indirect/mediated relationship between the “white-box” independent variable and the “black-box” error term</td>
</tr>
</tbody>
</table>

*Table 1: Steps of the Proposed Comprehensive Methodology*
3 OVERVIEW OF THE DATA

In this investigation we utilize a time-series data set that on 18 TEs spanning the period from 1993 to 2002 was used in previous studies (Samoilenko, 2008). The data were obtained from the World Development Indicators database (web.worldbank.org/WEBSITE/EXTERNAL/DATASTATISTICS), and the Yearbook of Statistics (2004) (www.itu.int/ITU-D/ict/publications) of International Telecommunication Union (ITU)(www.itu.int). This sample of 18 TEs can be represented in terms of two clusters (see Table A1): the more efficient group was labeled the Leaders and the less efficient group the Followers (Samoilenko & Osei-Bryson, 2007). Consequently, in order to account for the heterogeneity of the sample, we can expand our original research question as follows:

- \( H_1: \) There exists no statistically significant relationship between the constructs ICT Capitalization and Productivity for the 18 Transition Economies of the sample
- \( H_2: \) There exists no statistically significant relationship between the constructs ICT Capitalization and Productivity for the Leaders subset of the 18 Transition Economies of the sample
- \( H_3: \) There exists no statistically significant relationship between the constructs ICT Capitalization and Productivity for the Followers subset of the 18 Transition Economies of the sample

In order to reduce the bias associated with the heterogeneity of the sample we needed to represent all 18 TEs in such way, that difference in geographical size, population, economic wealth, and so on would be countered. Thus, our research model, reflecting two latent variables, is represented by four measures described in Table 2 below.
<table>
<thead>
<tr>
<th>Measure</th>
<th>Source variables</th>
<th>Representation</th>
<th>Latent Construct</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Factor Productivity</td>
<td><em>Malmquist Index</em> (MI)</td>
<td>Annual Change in Productivity</td>
<td>Productivity</td>
</tr>
<tr>
<td>RatioGDPtoInvestment</td>
<td>1. GDP per capita (in current US$)</td>
<td>Ratio of GDP per capita to Annual Telecom Investment per capita</td>
<td>ICT Capitalization</td>
</tr>
<tr>
<td></td>
<td>2. Annual Telecom Investment per capita (in current US$)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>RatioProductivity</td>
<td>1. Annual Total Revenue from Telecoms (% of GDP)</td>
<td>Ratio of annual Total revenue from Telecoms to Annual investments in Telecoms</td>
<td>ICT Capitalization</td>
</tr>
<tr>
<td></td>
<td>2. Annual Investments in Telecoms (% of GDP)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>RatioStafftoInvestment</td>
<td>1. Full-time Telecom Staff</td>
<td>Ratio of Full-time telecom staff to the Annual investment in telecoms</td>
<td>ICT Capitalization</td>
</tr>
<tr>
<td></td>
<td>2. Annual investment in telecoms (in current US$)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Table 2: Measures of the Research Model**

We assume that if we can demonstrate the presence of a statistically significant relationship between the constructs *ICT Capitalization* and *Productivity*, then we would be able to infer the presence of the indirect relationship between the investments in ICT and TFP. However, this can only be done if we demonstrate that the measures that we use to represent our constructs are valid and reliable. We present the results of our data analysis in the next section.

4  RESULTS OF THE DATA ANALYSIS

4.1 Preliminary Data Analysis

First, we used SPSS package to conduct an exploratory Principal Component Analysis (PCA) in order to determine whether the measures we chose to represent our constructs *ICT Capitalization* and *Productivity* demonstrate a specific pattern of loadings, align in the same direction, and load together on the same principal component. There are two latent constructs in our research model; therefore, we requested two components to be extracted.

We also requested the results of the Kaiser-Meyer-Olkin (KMO) test of sampling adequacy and Bartlett’s test of sphericity to be included in the output as these two measures are commonly used to determine whether or not a data set could be successfully analyzed using factor analysis. In order for our data set to pass these two tests, KMO value must be above 0.5, and Bartlett’s test value must be less than 0.05 (Bollen & Long, 1993). Results of the analysis produced the values of KMO of 0.661, and the value of Bartlett’s test of 0.000; thus we conclude that our data set passed the two tests and is suitable for PCA.

Next, we performed 2-component PCA, choosing only values above 0.7 to be displayed. We also requested the most common rotation option, varimax, in order to obtain an easy to interpret solution, where each of our measures would be maximally associated with a single construct. Obtained values for *RatioProductivity*, *RatioGDPtoInvestment*, and *RatioStafftoInvestment* were, respectively, 0.909, 0.972, and 0.922; thus, the chosen measures can be reliably used for representing the construct *ICT Capitalization*. Next, we present the results of PLS analysis.

4.2 PLS Analysis: Steps, Procedures, and Results

4.2.1 Assessment of the Measurement Model

We evaluate the adequacy of our measurement model using the following three criteria: the reliability of the individual measures and their constructs; the convergent validity of the measures representing each
construct; and the discriminant validity of the measures (Hulland, 1999). A commonly accepted test of the reliability of the individual items consists of assessment of the loadings of the measures on their construct, where the loadings of 0.7 and higher are considered to be acceptable. We present the results of the assessment of the measurement model in terms of the reliability of the individual items and their constructs in Table 3 below. Our results demonstrate that the measures of the internal consistency (“Composite Reliability” column) are higher than suggested by baseline of 0.7 (Nunnaly, 1978), and the variance shared by each construct and the construct’ measures (“AVE” column) is significantly higher than the cutoff value of 0.5 (Rivard & Huff, 1988). Thus, our research model passed the reliability assessment test.

<table>
<thead>
<tr>
<th>Construct/Measure</th>
<th>Composite Reliability</th>
<th>AVE</th>
<th>Squared Root of AVE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Productivity</td>
<td>1.000</td>
<td>1.000</td>
<td>1.000</td>
</tr>
<tr>
<td>ICT Capitalization</td>
<td>0.968</td>
<td>0.909</td>
<td>0.9534</td>
</tr>
</tbody>
</table>

*Table 3: Assessment of the Reliability of the Constructs*

We examined the reliability of the individual measures next. The values of the loadings of the measures provided in Table 4 indicate that our research model also passed the second test of the individual items reliability assessment. Individual loadings of the all items are greater than 0.8, which indicates that the measures and the construct share the significant amount of variance.

<table>
<thead>
<tr>
<th>Variable/Measure</th>
<th>Loading</th>
<th>Communality</th>
</tr>
</thead>
<tbody>
<tr>
<td>Malmquist Index (MI)</td>
<td>1.0000</td>
<td>1.0000</td>
</tr>
<tr>
<td>RatioGDPtoInvestment</td>
<td>0.9910</td>
<td>0.9822</td>
</tr>
<tr>
<td>RatioProductivity</td>
<td>0.9591</td>
<td>0.9199</td>
</tr>
<tr>
<td>RatioStafftoInvestment</td>
<td>0.9082</td>
<td>0.8249</td>
</tr>
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</table>

*Table 4: Assessment of the Reliability of the Measures*

Convergent validity of the measures is assessed through the evaluation of the measure of internal consistency (Fornell & Larcker, 1981), with values above 0.7 being acceptable (Nunnaly, 1978). The process of evaluation involves assessment of the loadings of the measures on their own constructs, where it is expected that the measures representing a construct would exhibit high loadings on that construct (high convergent validity), and low loadings on the all other constructs in the model (discriminant validity). We also look at the magnitude and significance of the t-values for the loadings of each of the individual items. Our results displayed in Table 5 demonstrate that all t-values for all measures of ICT Capitalization are significant, which indicates that the model passed the test of the convergent validity.

<table>
<thead>
<tr>
<th>Measure</th>
<th>T-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>RatioGDPtoInvestment</td>
<td>206.0844</td>
</tr>
<tr>
<td>RatioProductivity</td>
<td>31.5843</td>
</tr>
<tr>
<td>RatioStafftoInvestment</td>
<td>21.9873</td>
</tr>
</tbody>
</table>

*Table 5: Assessment of Convergent validity*

The test of discriminant validity involves assessing the loadings of the measures on their own constructs, in comparison to the other constructs present in the model, where each measure must load high on its own construct and low on other constructs. To obtain the values of the loadings we followed a method outlined by Chin and Hubona (2006), which is as accurate as and more efficient than the one offered by Gefen and Straub (2005). Results provided in Table 6 demonstrate that that all measures load highly on their own construct; thus, our model passed the test of discriminant validity.
One of the suggested ways (e.g., Fornell & Larcker, 1981) of determining discriminant validity in PLS is by assessing the average variance that is shared by a construct and the construct’s measures. This measure is provided by PLS-Graph output as Average Variance Extracted (AVE). The commonly accepted practice is to substitute diagonal elements of the correlation matrix that includes the correlations between the model’s constructs with the squared root of AVE. The adequacy of the discriminant validity is demonstrated if the diagonal elements of the matrix, represented by squared roots of AVE, are greater than the off-diagonal elements (Hulland, 1999). The results of the final test of convergent and discriminant validity of our research model are presented in Table 7.

The results of the assessment provided above allow us to conclude that our research model successfully passed the last test of convergent and discriminant validity, and we can proceed further with the assessment of the structural model.

### 4.2.2. PLS Analysis: Assessment of the Structural Model

The process of the assessment of the structural model involves testing the significance of the hypothesized relationships between specified in the research model constructs. By running PLS-Graph analysis we observe the path coefficients between the constructs in the model. The significance of the path coefficients is evaluated by running a bootstrapping procedure, which yields T-values for each path; the significance level of the path is established using 2-tailed t-distribution table. The result of the assessment of the structural model is presented below.

### 5 DISCUSSION OF THE RESULTS

Results of the data analysis demonstrate that while for the Leaders group there is a statistically significant relationship between the constructs Productivity and ICT Capitalization, for the Followers group this relationship does not exist. Let us place the findings of this study within the broader context of the previous investigations, which determined that:

- The Leaders have higher averaged levels of investments and revenues from Telecoms, as well as the higher averaged level of GDP, than the Followers (Samoilenko & Osei-Bryson, 2007)
The Leaders have higher levels of economic development and of accumulated ICT capital, as well as a higher level of socio-technical development than the Followers (Samoilenko, 2008).

The Leaders have a positive effect of complementarity of investments in Telecoms and investments in Telecoms on macroeconomic bottom line, while the Followers have a negative effect (Samoilenko & Osei-Bryson, 2008a).

The Leaders have a higher level of relative efficiency of utilization of investments and a higher level of efficiency of the production of revenues from Telecoms than the Followers (Samoilenko & Osei-Bryson, 2008b).

While it appears to be clear what determines the higher level of revenues from Telecoms and a greater impact of investments in Telecoms on macroeconomic bottom line in the case of the Leaders vs. the Followers, the previous studies did not shed any light on the relationship between investments in Telecoms and TFP. This investigation, however, demonstrates that the differences between the Leaders and the Followers extend to the existence of the relationship between investments in Telecoms and TFP also.

In order to understand the underlying factors that are possibly responsible for the difference between two subgroups of the sample, we can compare the Leaders and the Followers in terms of the averaged values of the indicators that were used to represent the latent constructs in the current investigation; the results are summarized in Table 9 below.

<table>
<thead>
<tr>
<th>Measure</th>
<th>The Leaders (Average Value)</th>
<th>The Followers (Average Value)</th>
<th>Magnitude of the Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Malmquist Index (MI)</td>
<td>1.23</td>
<td>1.20</td>
<td>0.98</td>
</tr>
<tr>
<td>RatioGDPtoInvestment</td>
<td>100.41</td>
<td>732.86</td>
<td>7.30</td>
</tr>
<tr>
<td>RatioProductivity</td>
<td>3.04</td>
<td>10.70</td>
<td>3.52</td>
</tr>
<tr>
<td>RatioStafftoInvestment</td>
<td>0.06</td>
<td>1.94</td>
<td>34.09</td>
</tr>
</tbody>
</table>

Table 9: Comparison of the Leaders and the Followers

The results of the comparison of the measures of the constructs suggest that the Leaders and the Followers do not significantly differ in terms of the corresponding averaged values of the measure MI, representing annual productivity growth reflected by the construct Productivity. However, the two groups do significantly differ in terms of the values of the measures (i.e. RatioGDPtoInvestment, RatioProductivity, RatioStafftoInvestment) representing the construct ICT Capitalization. These differences could be interpreted as follows:

- The Leaders invest in Telecoms in excess of seven times more per capita than the Followers,
- The Leaders generate three and a half times more revenues from Telecoms from the same level of investments than the Followers,
- The Leaders employ thirty four times less full-time Telecom workers to handle the same level of investments than the Followers.

In summary, the Leaders invest more per capita in Telecoms, with a greater efficiency and effectiveness, while using less full-time Telecom workers in comparison to the Followers. Based on the insights offered by this study, it is reasonable to suggest that in order for the Followers to establish the link between investments in ICT and growth in productivity, they should develop and pursue policies that concentrate on bringing the levels of values of the three measures used in this study closer to the levels of the Leaders. The impact of the changes could be investigated based on the simulation approach suggested earlier by Samoilenko and Osei-Bryson (2008a).
6 CONCLUSION

In this study we presented a new methodology for testing the relationship between investments in ICT and TFP that is consistent with the framework of neoclassical growth accounting. To adequately & appropriately address the complicating issue of endogeneity that arises, our methodology involves the use of multiple methods: Data Envelopment Analysis, Multivariate Regression Analysis, and Structural Equation Modeling. Given the fact that insufficient attention has be given in IT & Productivity research to developing and transition economies, we applied this methodology to 18 transition economies (TEs). Specifically we explored the hypothesis that for a given sample of TEs there exists no statistically discernible relationship between the capital investments in ICT and Total Factor Productivity. Major contributions of this research are the new methodology and the results that followed from its application to TEs.

References


four Recent Studies, Strategic Management Journal, 20(2), 195-204.


Appendix

<table>
<thead>
<tr>
<th>The Followers</th>
<th>The Leaders</th>
</tr>
</thead>
</table>

Table A1 18 Transition Economies: the Leaders and the Followers