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The Impact of Information Technology on Productivity in Developing Countries

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Abstract

The information technology (IT) revolution has resulted in a digital divide evolving between nations that have the skills and capability to absorb these new technologies, and those without. Since developing countries have assumed that the adoption of IT may be their key engine of growth, they have exerted a lot of efforts in an attempt to overcome this digital gap. This study tests whether higher IT adoption results in higher total factor productivity (TFP) growth of developing countries or not, by conducting a panel data regression for 33 developing countries over the period 2002-2006. It also examines the relative importance of IT adoption in comparison to other technological aspects such as: Technology creation, technology transfer, and enhancing individuals' technological absorptive capacities through higher educational levels. The study concludes that IT adoption and higher educational attainment tend to relatively be the most significant factors affecting TFP growth in developing countries.

JEL classification

O33; O47

Keywords

Information Technology; Productivity; Digital Divide; Development

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I. INTRODUCTION

The information revolution promises to provide economic growth to those with access and ability to use these new technologies. This claim has provoked a considerable trend of research focusing upon the information technology (IT) sector investments, in an attempt to examine and quantify its contributions to economic growth and productivity. As expected in the case of any newly introduced technology, most of the research in this area has focused on the developed world; yet, with contradicting conclusions. A few earlier studies have claimed that IT may have had a negative contribution to productivity growth (such as: Roach 1986, 1987; Berndt & Morrison, 1995; Baily & Chakrabarti, 1998); namely, the productivity paradox. On the other hand, most of the more recent studies have reached a consensus that the production and/or usage of IT have become one of the main determinants of productivity growth in the developed world (such as: Oliner & Sichel, 2000; Jorgenson & Stiroh, 2000; Schreyer, 2000; Basu et al., 2003).

Even though the debate on the impact of IT on productivity growth has intensified within the studies tackling the developed world, a very limited number of studies have empirically examined the contribution of IT to the economic growth of developing countries. This can be justified by two factors: the limited availability and reliability of data for the developing countries, in contrast to that of the developed world, especially for recent technologies like IT. Another factor is that in addition to having investments in IT as a percentage of GDP very small in the developing world, the complementary investments in physical infrastructure and human resources tend to be much lower than those of the developed countries. This results in having the IT payoffs in the developing world less obvious in comparison to the developed world. Moreover, not only have the number of studies testing this hypothesis on the developing countries been very limited; but these few studies have also reached contradicting results.

Some of the cross-country studies which included both developed and developing countries in its samples (such as: Dewan & Kraemer, 2000; Pohjola, 2001; Kraemer & Dedrick, 2001; Plice & Kraemer, 2001; Lee et al., 2005) have agreed that, in contrast to the developed world, IT investment has not had a significant positive impact on the productivity and economic growth of the developing countries during the period of the 1980s and early 1990s. Even though these studies have used different methodologies, they reached nearly the same results. These studies consent that this conclusion is due to the fact that the developing countries have a low level of IT investment relative to GDP. In addition, developing countries lack complementary assets necessary in order to benefit from the payoffs of IT investments such as the needed infrastructure and the knowledge base which is essential to support the effective use of IT. In other words, even though some of these studies have shown that there is generally a positive correlation between economic growth, productivity and IT investment for the full set of countries in their samples; but, the results seemed less obvious for the subset which included only developing countries. On the other hand, other few cross-country studies (such as: Balimoune, 2002; Lee & Khatri, 2003; Chen & Dahlman, 2004) which have included only developing countries in their samples reached contradicting results. These studies have concluded that higher IT investments have resulted in higher economic growth in developing countries. It may be deduced, accordingly, that having a positive relationship between IT investments and growth has been recently more obvious for subsets that included only developed countries but there has been a clear disagreement among the studies tackling the impact of IT usage on the developing countries. This disagreement makes testing the hypothesis for developing countries yet to be interesting. Thus, the main motivation behind this study is to fill in the gap in the literature of developing countries.

Our study is an empirical study aiming at examining the impact of IT usage on the productivity growth in developing countries by testing the significance of the growth in Information and Communication Technology spending and the number of Internet users, as proxies to the magnitude of IT usage, on the growth of TFP[1]. Accordingly, we will start by computing the growth of TFP for 33 developing countries during the period of 2002-2006 using the neo-classical growth accounting techniques and then test for the significance of IT usage on the growth of TFP during the same period using a panel data regression analysis. The model will include other explanatory variables that reflect other aspects of technology; that is technology creation, transfer, and absorptive capacity and examine their significance on TFP. The main contribution of our study is that, to our knowledge, this is the only panel data model examining the relative importance of IT adoption in comparison to these other technology facets. Even though there are several studies that tackled each of these technological aspects individually; yet, none of them introduced these factors collectively to examine the importance of each aspect relative to the others. We believe that this comparison is particularly important in the case of the developing countries, which suffer from relatively limited resources and more pressing goals. Accordingly, choosing how to utilize these limited resources in an attempt to derive the highest utility and benefit for its peoples tends to be a critical issue which is worth seriously taking into account. Section II of this paper will introduce the methodology used; section III will present the data and variables used in estimation; and section IV will present the empirical results and section V is the conclusion.

[1] Many aspects of information technology such as the computers and the Internet, are nowadays used as a medium of communication (e.g. voice chats). Therefore, it may be difficult to strictly separate Information technologies from Communication technologies; and thus, we include ICT in total as our explanatory variable. As a result, IT and ICT may be used interchangeably.

II. FRAMEWORK AND METHODOLOGY

In testing for our hypothesis, our analysis is conducted on two phases: we will start by computing the growth of TFP for 33 developing countries during the period of 2002-2006 using the neo-classical growth accounting techniques and then test for the significance of IT spending on TFP during the same period using a panel data regression analysis.

1. Growth Accounting Framework

Growth accounting, which has been developed by Abramovitz (1956) and Solow (1957), remains to be a widely used technique to segregate growth between factor accumulation and productivity growth. We begin by applying the standard growth accounting framework: The production function of developing countries undertaken in our model relates the nation's GDP *(Y)* to the conventional inputs: Labor *(L)* and Capital Stock *(K)*. The function also contains a parameter $\left(A_t\right)$ which captures disembodied technological shifts over time. Since we are dealing with a panel data study covering 33 developing countries over the period 2002 till 2006, a production function of the form shown below will be assumed:

$$Y_{i,t} = A_t F\left(L_{i,t}, K_{i,t}\right) \qquad (1)$$

where: *i* indexes the country *i*, *for i = 1,2,…33*. and *t* indexes time t, for *t = 1,2,…5 (*country and time subscripts will be omitted hereafter for simplicity of illustration).

Assuming that the production functions takes a Cobb-Douglas form; in natural logarithms, the production function can be written as:

$$y = a + \alpha_1 l + \alpha_k k \qquad (2)$$

where lower case letters indicate that a variable has been transformed into a natural logarithm (e.g. $y = lnY$). Thus, the growth rate of output can be written as:

$$\dot{y} = \dot{a} + \alpha_l \dot{l} + \alpha_k \dot{k} \qquad (3)$$

where $\dot{a}$ is the TFP growth and the other terms are the growth rates of the inputs. ($\dot{x}$ indicates the first difference transformation).

Under the neo-classical assumptions of having perfectly competitive factor and product markets, the output elasticities of labor and capital (α_l and α_k) are equal to the ratio of the cost of the input to the value of the output (i.e. their shares in revenue).

$$\alpha_X = \frac{\lambda_X X}{PY} \qquad (4)$$

where λ_X is the unit cost of factor X and P is the output price (so PY is the revenue)

Growth in TFP (Solow Residual) is computed as the residual of growth in GDP after deducting the contributions of both labor and capital. TFP is estimated using the following equation:

$$\dot{a} = \dot{y} - \frac{rK}{PY}\dot{k} - \frac{wL}{PY}\dot{l} \qquad (5)$$

where: r, w and P are the real price of physical units of capital, labor, and output respectively.

2. Regression Analysis

After computing the TFP growth ($\dot{a}$); the second step is to estimate the elasticity of TFP to IT usage. Our regression will be having an array of independent variables each of which represents a certain aspect of technology. That is, the growth in ICT spending and the number of Internet users are indicators of information technology adoption (our main research interest), Research and Development (R&D) spending as an indicator of technology creation, Foreign Direct Investment (FDI) and Trade Openness as indicators of technology transfer, and Education represented in the Combined Gross Enrollment Ratio of all levels: primary, secondary, and tertiary as an indicator of the technology absorptive capacity. We hypothesize that technological advances reflected by the above mentioned explanatory variables is likely to influence the TFP growth of the developing countries.

The formulation of our model may be quite different from one formulated to study technology and growth of TFP of developed countries. This is because industrialized countries are already on or just below the World Technology Frontier; accordingly their main focus would be upon innovation through technology creation. On the other hand, the developing countries are still in the phase of trying to make use of the already existing technologies to catch up with the leaders. Accordingly, it would be expected that a model formulated for developed countries to include indicators of innovation capability, such as: R&D investment, patents, and intellectual property rights as their main aspects of technology rather than mere technology adoption and ensuring having the absorptive capacity needed.

In estimating our equations, panel data modeling will be used. In such models, it is crucial to properly account for cross-section heterogeneity unobserved by the researcher. The problem with such unobserved effects is that if they are correlated with any of the observed explanatory variables in the model, the least squares estimator of the parameter turns to be biased and inconsistent as a consequence of an omitted variable. In this case, the fixed effects estimators are used, and the model is formulated as shown in equation (6).

$$y_{it} = x'_{it}\beta + \alpha_i + \varepsilon_{it} \qquad (6)$$

where y_{it} is the dependent variable, x_{it} includes the *k* regressors (not including the constant term), α_i is the group or individual specific constant term, and ε_{it} is the white noise random error.

On the other hand, if the individual heterogeneity is assumed to be uncorrelated to the regressors included in the model, the random effects approach is more appropriate to be used. In this case the random effects framework will be as follows:

$$y_{it} = x'_{it}\beta + \alpha + u_i + \varepsilon_{it} \qquad (7)$$

Here u_i is specified as group specific random element[2]. The *Hausman (1978) specification test* which tests for the orthogonality of the unobserved effects and the regressors will be conducted to decide upon the more appropriate model to be used, fixed or random effects.

It is worth noting that in this study, we attempted to avoid some of the measurement problems faced by other studies testing the same hypothesis. For example, we may notice that most of the IT investments belong to the services sector. However, given that most of the measurement problems tend to be concentrated in this sector in specific in which most of the output is considered as intermediary elsewhere, we preferred to tackle the relationship between IT usage and productivity growth on the aggregate level rather than to concentrate exclusively on the services sector. This is because if IT truly raised the output of these intermediary industries in unmeasured ways, these pay-offs should appear in the output of final goods industries that appear in the aggregate GDP of nations.

Moreover, in deflating the IT capital stock, hedonic price indexes have been used such that rapid technological and quality advances in IT equipment would be taken into consideration. Given that, hedonic prices are not available specifically for developing countries, we preferred to use the U.S. hedonic price deflator will be adopted. Since the U.S. is considered to be the leader in terms of IT innovation, and developing countries are merely recipients to the technological advances, we believe that hedonic prices of the U.S. economy would be a good indicator to the IT prices in the developing countries and hence it is used as a deflator to IT spending figures. In addition to the above, we tend to use the TFP growth as our dependent variable rather than other growth indicators such as GDP growth and GDP per labor, as we believe TFP may be a better indicator to economic efficiency improvements.

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[2] For a more detailed discussion on fixed and random effects estimation see Greene (2003, 301ff.)

III. DATA AND VARIABLES

Our analysis is based on 33 selected developing countries as shown in appendix II. Nominal as well as real figures are converted to international dollars using the World Bank PPP. Annual employment is used as a proxy to the labor input, the labor price by the annual wage in constant prices. The source of our employment and wages figures is the ILO database. For developing countries, the capital stock variable is not available; and therefore, it has to be estimated. Accordingly, the "Perpetual Inventory Method" (PIM) will be used to measure the capital stock for the developing countries undertaken in our study. The Perpetual Inventory Method (PIM) generates an estimate of the capital stock by accumulating past purchases of assets over their estimated service lives (OECD, 2001, p.43). The capital stock in period t is calculated as

$$K_t = I_t + (1-\delta)K_{t-1} \qquad (8)$$

where K is the capital stock, I is the value of gross fixed capital formation in constant prices and δ is the depreciation rate. Since we have no information on published data as to country-specific depreciation rates, so we assume the depreciation rate to be 10% as an attempt to capture the diversity of assets included in the gross fixed capital formation series (GFCF). In addition, it will be assumed to be constant across countries and overtime. The source of the GFCF series is the IFS database.

The unit cost of capital will be the interest rate (lending rate) plus the depreciation rate (assumed to be 10%) minus the price increase of capital goods (investment price index). The investment price index is published by the Penn World Tables until 2004. The years 2005 and 2006 are forecasted using the percentage rate of change in the GDP deflator. Multiplying the unit cost of capital by the capital stock figures derived using the PIM will be our estimate of the cost of capital.

R&D spending in our model is used as a proxy of technology creation. Although the developing countries may be far lagging behind the developed world in terms of R&D; yet, when discussing TFP, it is necessary to include R&D as one of our explanatory variables. R&D spending is expressed in 000 PPP$. The source of these figures is the UNESCO database.

Growth in ICT spending is our main interest, as it gives an indication to the magnitude of information technology adoption in developing countries. Data on ICT spending will be obtained from the Digital Planet Report (2006) issued by World Information Technology Services Alliance (WITSA) which is a consortium of information industry representatives from around the world. ICT spending will reflect spending on computer hardware, software, computer services, and communication in U.S. dollars on an annual basis. ICT spending includes expenditures by businesses, households, and government sectors. Figures for ICT spending will be deflated using the U.S. city average Consumer Price Index (CPI) for Information and Information Processing published by the U.S. Bureau of Labor Statistics. In order to take into account technology improvements and improvements in quality or functionality, a “hedonic” price should be used. Due to the unavailability of hedonic prices data for developing countries, we will use the U.S. CPI for IT equipment, as its prices in the U.S. (as the leader in the IT industry) are expected to be highly correlated to its prices in the developing world. Accordingly, the U.S. city average Consumer Price Index (CPI) for Information and Information Processing published by the U.S. Bureau of Labor Statistics has been used. The growth rate of ICT spending (ICTGR) will be our first explanatory variable denoting information technology adoption. Moreover, the number of internet users is another variable used as a proxy for IT adoption. The source of our figures on the number of Internet users is the International Telecommunication Union (ITU) estimates.

Educational Attainment is a proxy to the labor force's potential technological absorptive capacity. It will be reflected in the combined gross enrollment ratio, which includes: primary, secondary, and tertiary levels. Even though the combined gross enrollment ratio may be an indicator of the future absorptive capacity, not the current one; our argument is that the structure of the enrollment rates in the majority of the countries under study is rather stable. Thus, it may be also an indicator of the absorptive capacity of the current work force. The source of our data on educational attainment is the UNESCO database.

Foreign Direct Investment (FDI) is a direct form of technology transfer from developed to developing countries. The source of FDI figures is the UNCTAD database. The other variable reflecting technology transfer is trade openness which is a proxy for globalization and plays an important role in the indirect technology transfer from developed countries to developing countries; which in turn affects the growth of TFP. Trade openness is measured as the sum of exports and imports as a percentage of GDP. Figures of imports and exports are obtained from the IFS online database. Trade Openness (TO) will be our second explanatory variable for technology transfer. A summary of the descriptive statistics of the variables is shown in the appendix I.

IV. Empirical Results

Using the neoclassical growth accounting framework in computing the growth of TFP, our results indicated that (on average) capital growth share and TFP growth constitute the highest shares of economic growth. One of the arguments behind having low labor shares in incomes of developing countries is that there is a gap in the data quality for the developing countries in comparison to that of the developed countries. That is, low-income countries tend to have a large informal sector in which data is not available. In addition, many large family businesses exist in which labor income appears as profit. This in turn results in having low shares of income attributed to labor in developing countries in comparison to the developed world (Hulton & Isaksson, 2007).

Our results, moreover, emphasize the fact that the relative importance of growth in TFP in comparison to conventional factor accumulation differs among countries according to their economic characteristics. In other words, the capital share in economic growth tends to be highest in oil countries such as: Algeria, Iran, Venezuela, Kuwait, Bolivia and Ecuador. On the other hand, in most of the emerging economies, such as:

Argentina, Indonesia, Pakistan, Poland, Singapore, and South Africa, growth in TFP constitutes more than 60% of output per capita growth. After estimating the TFP growth; the elasticity of TFP to different aspects of technology including: technology creation, adoption, transfer, and absorptive capacity have been estimated. By conducting the Hausmann specification test, the null hypothesis of orthogonality is rejected for the 8 regressions conducted. Accordingly, the OLS fixed effects model is preferred to the GLS random effects one; as it will be more consistent.

One of the determinants of technology creation is R&D spending. Table (1) (Panel F) shows that RDGR, which represents growth in R&D spending, took the expected positive sign for its coefficients; yet, not significant at (10% significance level)[3]. It is worth noting that several studies (such as: Ahn (2001); Baldwin et al. (1995); McGuckin et al. (1998)) argued that it is not investment in R&D that counts, but the usage of new technologies is what affects productivity. In other words, innovations have a greater impact on users of the technology rather than the producers (Isaksson, 2007). In fact, R&D spending as a percentage of GDP in the developing countries under study is very low[4]; according to the UNESCO estimates, on average it never exceeded 0.36% of GDP for the period 2000 till 2005[5]. Moreover, in some cases the relationship between R&D spending and productivity may be more complex than just a static linear relationship between both variables as assumed in our model. That is, there may be a time lag between R&D spending and technological improvements or even a non-linear relationship between both variables (Lang, 2009). Hence, our model results indicate that in the short-run developing countries would be better off investing in learning how to have the ability and competence to adopt new technologies rather than trying to create them through devoting more resources to R&D.

The results of the fixed effects regressions reported in Table (1) indicate that the growth of spending on ICT has always been significant in explaining variations in the growth of TFP. That is, growth in ICT spending has been the most robust to the addition of explanatory variables. The results show that there is an increasing relationship between both variables, but at a diminishing rate, since the coefficient of (ICTGR^2) turned out to be negative. This implies that the latecomers in using the information technologies have the potential to leapfrog and boost their productivities at a higher rate than the first movers. Adding another explanatory variable, namely the number of Internet users, to the base regression (Table: (1), Panel A) reaffirmed the fact that IT usage is considered to be an important determinant of TFP growth; as our results indicated that as the number of Internet users increases by one user every 100 persons, TFP grows by 0.15%. Moreover, by observing the R-squared of the same equation, we may see that IT usage reflected in both, growth of ICT spending and number of Internet users explains around 49% of the growth in TFP.

As for the combined gross enrolment ratio; unsurprisingly, it appears from Table (1): panel C that it as well is an important factor in explaining variations in TFP.

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[3] R&D spending and R&D spending as a percentage of GDP turned out to be insignificant as well.

[4] South Korea, Singapore and China are an exception as R&D spending as a % of GDP reached 2.99%, 2.36% and 1.34% in 2005.

[5] The highest were South Africa, India, and Morocco with averages of 0.8%, 0.69%, and 0.69% respectively; while, the lowest was for Honduras, Ecuador, and Indonesia with averages of 0.05%, 0.06%, and 0.06% respectively.

However, when variables, educational attainment and the number of internet users are included together, one of them changes to be insignificant as shown in panel E. This may be explained by the high correlation between both variables. This may be an expected result since one of the most important determinants of the Internet usage is the level of education. Accordingly, as more people are educated, more of them use the Internet. When multicollinearity between two explanatory variables is present, the estimated coefficients may be unstable in their degree of significance and the t-statistics usually fall; however, the OLS estimates remain unbiased (Greene, 2003). In fact, the correlation coefficient between both variables appeared to be significantly high (0.95). This shows that a strong correlation exists between both variables, which justifies the instability of the significance of both variables when they are both included together as explanatory variables in the same regression.

Results of our model shown in Table (1), Panel G, indicate that the relationship between FDI, TO and growth of TFP for the developing countries under study is insignificant. Some arguments revert this to the fact that many of the host developing countries lack the minimum threshold of human capital needed in order to adapt and absorb new technologies; and as a result, productivity does not significantly increase (Borensztein et al. (1998)). Another argument is that this may be due to the technological gap between the Multinational Enterprises affiliates and the domestic firms in the host countries and therefore developing countries do not benefit from the positive spillovers of FDI (Meyer, 2004). Our results also indicate that trade openness has not a significant factor explaining change in TFP. This may contradict with many other studies which emphasize the importance of trade to increase the productivity of developing countries. Yet, this is not the main focus of our research; and hence, we believe that if other indicators for the intensity of trade have been used, results may have been more affirmative.

According to the Akaike Information Criterion (AIC), the best models that suffice to make statistical inferences are Panels C and E (Table (1)). This is because they are the models with the lowest values of AIC. It is worth noting that AIC penalizes the loss of degrees of freedom as the model is expanded more harshly than that by the adjusted R-squared. Accordingly, generically it is more preferred to be used in comparison to the adjusted R-squared (Greene, 2003). Meaning that, our results indicate that technology adoption and the technological absorptive capacity, where ICT spending, Internet usage and education are used as proxies, are the most important factors affecting growth of TFP. Our results may coincide with other studies like: Cohen & Soto (2001); Hanushek and Kimko (2000) which have also proved in their international cross sectional studies that education has a positive effect on economic growth and productivity. On the other hand, our results still contradict with other studies like: Dewan & Kraemer (2000); Pohjola (2001), which argue that IT spending turned out to be insignificant in explaining growth in developing countries. Our results may be different from the previously mentioned studies due to the fact that we are examining a different period of study. The previously mentioned studies examined the period of the 80's and the early 90's. We are using more recent data covering a period in which developing countries started to pay more attention to the ICT sector in terms of access and promoting skills of its users.

Accordingly, it may be understood that countries which are investing more in the ICT sector are starting to reap its returns.

The interesting fact is that as we re-estimated the previous models having the growth of labor productivity as the dependent variable instead of the growth of TFP, the same results, in terms of significance, have been achieved. That is, ICT spending, Internet usage and education turned out to be the most significant in explaining the growth of labor productivity. In fact, our results indicate that each 1% increase in ICT spending is associated with more than 0.2% increase in labor productivity growth, which is slightly less than its impact on TFP growth.

As for the country specific intercepts, given that IT adoption is our main concern in this study, Figure (1) shows the intercepts corresponding to Panel B, where only ICT spending and Internet usage are taken into consideration. The intercepts in this case reflect growth of TFP when there is no growth in ICT spending and no Internet usage. It may be inferred that most of the countries tend to have negative TFP growth; yet, the countries most affected by the absence of the Internet and ICT growth are: South Korea, Malaysia, Singapore, Chile, and Hong Kong. These countries already proved to have established a well-built ICT sector in terms of ICT infrastructure and a high e-readiness rank. On the other hand, countries least affected are: Venezuela, Pakistan, and Egypt which indicates that these countries may be relying more heavily on factors other than IT in their productivity growth; such as: investments in human capital or physical public infrastructure.

Since the relationship between growth of ICT spending and TFP growth is increasing at a decreasing rate, we will attempt to compute the optimal level of growth in ICT spending that is needed to maximize the rate of growth of TFP. According to panel (C):

$$TFP = 0.3185ICTGR - 0.6985ICTGR\hat{}2 + 0.0025EDU \qquad (9)$$

$$\frac{\partial TFP}{\partial ICTGR} = 0.3185 - 2(0.6985)ICTGR \qquad (10)$$

As we equate Equation (10) to zero, our estimates show that the optimal level for ICTGR is 0.228. That is, in order to maximize TFP growth, ICT spending of the countries understudy should grow by almost 23% per annum on average. On the other hand, according to the database ICT spending grows only be 13.23% per annum on average. In other words, according to the results of our study, the rate of growth of ICT spending should at least double to reach the optimal level to maximize productivity.

Table (1): Fixed Effects Estimation Results[6]

Dependent Variable: "TFPGR" Independent Variables:	*Panel A*	*Panel B*	*Panel C*	*Panel D*	*Panel E*
ICTGR	0.3576** (0.0543)	0.3664** (0.0548)	0.3185** (0.0547)	0.3525** (0.0509)	0.3430** (0.0548)
ICTGR^2	-0.7753** (0.1738)	-0.7777** (0.1804)	-0.6985** (0.1792)	-0.7394** (0.1739)	-0.7805** (0.1802)
EDU			0.0025* (0.0015)		0.0015 (0.0017)
INT		0.0015** (0.0006)			0.0009 (0.0008)
TO				0.0266 (0.0208)	
RDGR					
FDIGR					
R-squared	0.4578	0.4907	0.5369	0.4822	0.5591
Adjusted R-squared	0.3139	0.3446	0.3779	0.3324	0.3983
SE of regression	0.0295	0.0289	0.0271	0.0291	0.0265
F-Statistic	108.1**	58.8**	57.4**	56.3**	40.6**
Akaike Information Criterion (AIC)	-2.7366	-2.7352	-2.7437	-2.7266	-2.7464

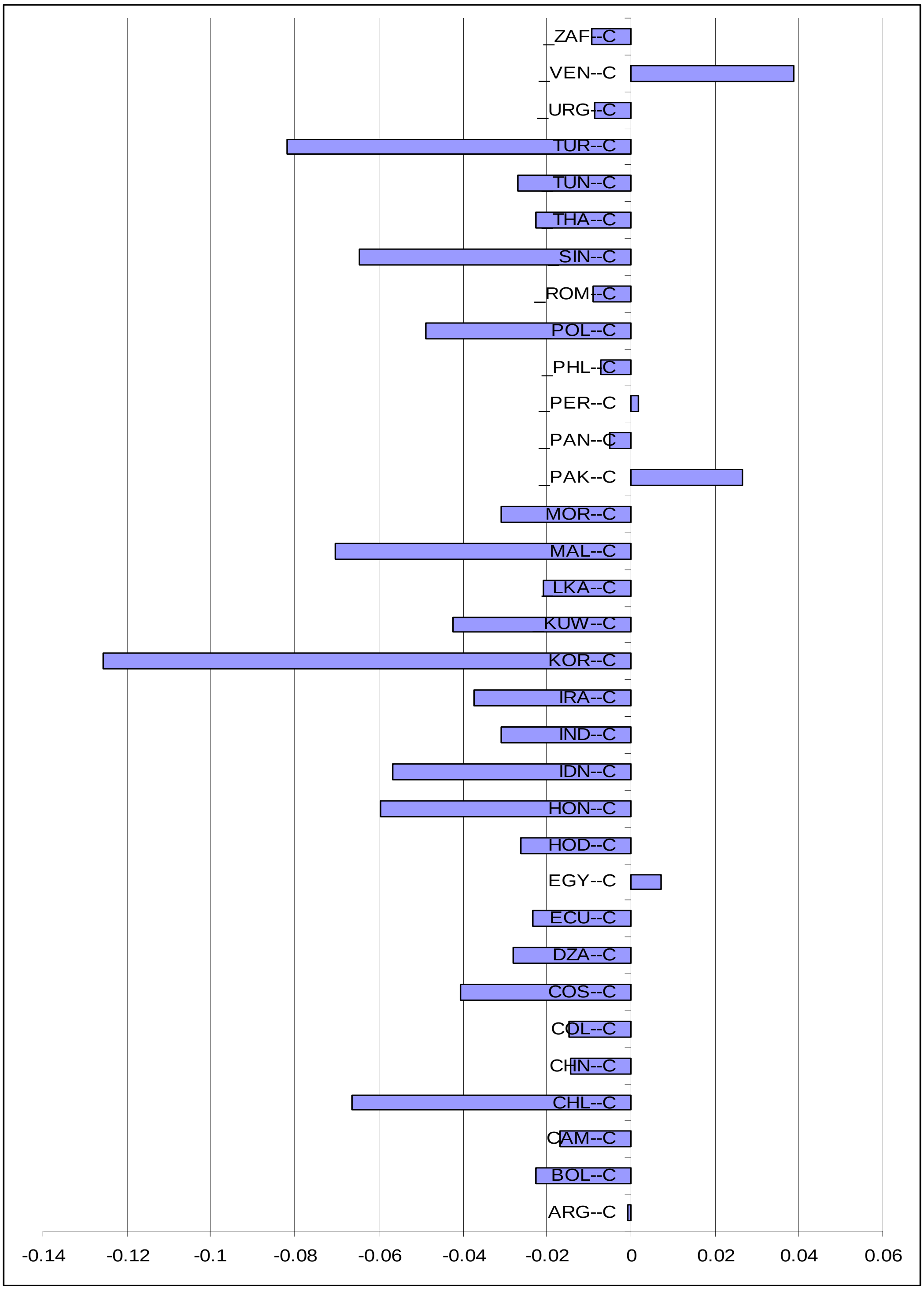
6 Figures in ( ) and show the values of standard errors.
*, ** show the level of significance at 10% and 5%, respectively.

Table (1): (continued): Fixed Effects Estimation Results[7]

Dependent Variable: "TFPGR" Independent Variables:	*Panel F*	*Panel G*	*Panel H*
ICTGR	0.6509** (0.1182)	0.3597** (0.0580)	0.6998** (0.1309)
ICTGR^2	-1.3122** (0.3069)	-0.6898** (0.1918)	-1.4609** (0.3443)
EDU			0.0032 (0.0035)
INT			-0.0010 (0.0014)
TO			-0.0546 (0.0692)
RDGR	0.0089 (0.0274)		0.00412 (0.02976)
FDIGR		-0.0016 (0.0024)	0.00488 (0.0050)
R-squared	0.6581	0.4519	0.7229
Adjusted R-squared	0.4226	0.2776	0.4458
SE of regression	0.0279	0.0307	0.0294
F-Statistic	43.3**	45.4**	13.9**
Akaike Information Criterion (AIC)	-2.5088	-2.6561	-2.3562

[7] Figures in ( ) show the values of standard errors.
*, ** show the level of significance at 10% and 5%, respectively.

Figure (1): Intercepts of countries under study when there is no growth in ICT spending and no Internet Usage



Source: Based on the Author's Calculations

V. Conclusion

Even though IT diffusion has been proven to have significant spillovers on the world economy, these benefits have not appeared to be evenly distributed among countries. In fact, effective usage of IT equipment requires many other complementary investments including factors like human capital and the provision of a reliable telecommunication infrastructure which many of the developing countries still lack. As such, there is a global fear that poor countries would be left behind by the information revolution. Pessimistic views claim that developing countries are trapped in a vicious endless cycle where low per capita income leads to low levels of ICT diffusion. This will negatively affect their competitiveness, which in turn directs us back to the initial stage of low per capita income and growth. Nevertheless, there is a counter-argument that states that although it is a fact that economic growth creates opportunities for technological innovations; yet, the process can also be reversed. In other words, investments in technology can equip people with better tools that enhance their productivity and in turn enhance the growth process of the developing countries. Our study supports the latter more optimistic argument.

Results of our model show that technology adoption and enhancing the individual's technological absorptive capacity are the most important short-run aspects of technology that positively affect the growth of TFP in developing countries. This is reflected in having the growth in IT spending, the Internet usage, in addition to having a higher level of educational attainment as the most significant explanatory variables affecting TFP growth. Another important conclusion is that the average ICT spending in developing countries is less than the optimal level. In fact, it grows by only 50 percent of its optimal rate; which in turn results in less than maximized growth of TFP. This proposition reflects that developing countries have ample space for productive IT investment to take advantage of the substantial potential returns. However, it is worth noting that "successful use of IT requires much more than mere installation and application of systematised knowledge. It also requires the application of implied knowledge regarding the organisation and management of the technology and its application to the contextual environment in which it is to be used" (Davidson et al., 2000). In other words, spending on new technologies is not only what matters, but knowing how to make the best use out of these technologies to achieve personal and organizational objectives is what matters most.

Despite the fact that income is one of the most important determinants of IT diffusion, we believe that this factor may not necessarily hinder the diffusion of IT in the developing countries, as governments of developing countries still have the chance to benefit from many relatively low cost opportunities that enable them to provide IT access to their people. One of the opportunities developing countries have is leapfrogging over successive generations of technologies to reach the newest versions without having to pass through all the previous stages (Davidson et al., 2000). Moreover, latecomer advantages enable developing countries to benefit from the rapidly decreasing prices of IT equipment resulting from technological innovations and R&D conducted by the developed world. An example of leapfrogging is when the developing countries use wireless communication technologies rather than having to pass through the stage of having a well-developed wire-line infrastructure. Thus, more recent technologies may result in the need for cheaper infrastructures. Also, using open source software which is provided for free on the Internet, in addition to importing used or low-specification computers are all considered low cost options that developing countries may benefit from (James, 2003). It may be noticed that most of the solutions proposed involve integrated efforts exerted by both, the developing countries (as technology adopters) and the developed countries (as technology innovators). Yet, given that the higher the rate of diffusion of the Internet and IT usage, the higher the benefits derived by all the technology users; this implies that the process of technology transfer to developing countries tends not only to benefit the technology recipients, but also benefits the technology innovators; that is, the developed countries.

In addition to the above, our results indicate that enhancing the individuals' capacities to absorb new technologies are considered as necessary or even a pre-requisite to being able to effectively use such new technologies. This cannot be fulfilled without having a better quality of the educational system in the IT-adopting nations. Moreover, integrating IT equipment in educational systems not only increases the skills of individuals using such new technologies; but in addition, introducing these technologies at an early age will enable individuals of surpassing the motivational and cultural obstacles that hinder the diffusion of IT. However, the introduction of these technologies in schools should be complemented with training programs in on how to use these tools effectively in order to ensure a better educational system and a society more oriented to being "knowledge-based". Hence, since developing countries suffer from skill deficiencies in the workforce. It has been suggested that this deficiency may be overcome either by letting the state-run educational institutions provide courses of training and skill development or by providing incentives to firms to engage in such training themselves either by reducing their taxes or providing subsidies (Indjikian & Siegel, 2005). Hence, education is one of the most critical factors that must be taken into consideration by policy makers in an attempt to achieve positive spillovers on productivity and growth of developing countries.

Our study, like any other, has its own limitations. For example, we were not able to use a more dynamic approach in modeling, as a long time series of data is not easily and consistently available for developing countries for a relatively new technology such as computers. Another limitation worth taking into account is that our indicators of IT remain to be limited to its material access in terms of access to computers and its networks (i.e. the Internet). However, we did not approach the dimension of how efficient and meaningful the usage of IT and the Internet is; and how this affects productivity of developing countries. This could be an area for further empirical research.

List of References

Abramovitz, M. (1986). Catching Up, Forging Ahead, and Falling behind. *The Journal of Economic History, 46 (2)*, 385-406.

Ahn, S. (2001). Firm Dynamics and Productivity Growth: A Review of Micro Evidence from OECD Countries. *Economics Department Working Papers No. 297*, Paris: OECD.

Baily, M., & Chakrabarti, A. (1988) Electronics and White-Collar Productivity. In *Innovation and the Productivity Crisis.* Washington D.C.: The Brookings Institution.

Balimoune, M. (2002).The New Economy and Developing Countries: Assessing the Role of ICT Diffusion. *Paper presented at the WIDER Conference on The New Economy in Development*, 10-11 May, Helsinki: UNU/WIDER.

Basu, S., Fernald, J., Oulton, N., & Srinivasan, S. (2003). The Case of the Missing Productivity Growth: Or, Does Information Technology Explain Why Productivity Accelerated in the United States but not the United Kingdom? *NBER Working Paper No. 10010*.

Berndt, E. R., & Morrison, C. J. (1995). High-tech Capital Formation and Economic Performance in U.S. Manufacturing Industries: An Exploratory Analysis. *Journal of Econometrics, 65*, 9-43.

Borensztein, E., De Gregio, J., & Lee, J. (1998). How does foreign direct investment affect economic growth? *Journal of International Economics, 45*, 115–135.

Chen, D., H., & Dahlman, C., J. (2004) Knowledge and Development: A Cross-Section Approach. *World Bank Policy Research Working Paper 3366*.

Cohen, D., & Soto, M. (2001) .Growth and Human Capital: Good Data, Good Results. *CEPR Working Paper*, No. 3100, Centre for Economic Policy Research, London.

Davidson, R., Vogel, D., Harris, R., & Jones, N. (2000). Technology Leapfrogging in Developing Countries – An Inevitable Luxury? *The Electronic Journal on Information Systems in Developing Countries, 1*(5), pp. 1-10.

Dewan, S., & Kraemer, K. (2000). Information technology and productivity: Preliminary evidence from country-level data. *Management Science, 46* (4), 548–562.

Greene, W. H. (2003). *Econometric Analysis* (5th Ed.). Englewood Cliffs, New Jersey: Prentice-Hall.

Hanushek, E. A., & Kimko, D. D. (2000), Schooling, Labour Force Quality, and the Growth of Nations, *American Economic Review*, *90*, 1184-1208.

Hausmann, J. (1978). Specification Tests in Econometrics. *Econometrica*, 46, 1251-1271.

Hulton, C. R., & Isaksson, A. (2007). Why Development Levels Differ: The Sources of Differential Economic Growth in a Panel of High and Low Income Countries. *NBER Working Paper No 13469*, Cambridge, MA: NBER.

Indjikian, R., & Siegel, D. (2005). The Impact of Investment in IT on Economic Performance: Implications for Developing Countries. *World Development, 33* (5), pp. 681-700.

Isaksson, A. (2007). Determinants of TFP: A Literature Review. *United Nations Industrial Development Organization (UNIDO), Research and Statistics Branch.*

ITU. (2008). *World Telecommunications Indicators: Database*.

James, J. (2003). Free Software and The Digital Divide: Opportunities and Constraints for Developing Countries. *Journal of Information Science, 29*(1), pp. 25-33.

Jorgenson, D., & Stiroh, K. (2000). Raising the Speed Limit: U.S. Economic Growth in the Information Age. *Brookings Papers on Economic Activity, 2000* (1), 125 – 235.

Kraemer, K. L., & Dedrick, J. (2001). Information Technology and Economic Development: Results and Policy Implications of Cross-Country Studies. In: M. Pohjola (ed.), *Information Technology, Productivity and Economic Growth*. Oxford: Oxford University Press.

Lang, G. (2009). Measuring the Returns of R&D: An Empirical Study of the German Manufacturing Sector over 45 years. *Research Policy, vol. 38 , pp. 1438-1445.*

Lee, S. T., Gholami, R., & Tong, T. Y. (2005). Time series analysis in the assessment of ICT impact at the aggregate level – lessons and implications for the new economy. *Information & Management, 42,* 1009-1022.

Lee, I. H., & Khatri, Y. (2003). Information Technology and Productivity Growth in Asia, *IMF Working Paper*, WP/03/15, 2003, Washington D.C.

McGuckin, R.H., Streitwieser, M., & Doms, M. (1998), Advanced Technology Usage and Productivity Growth, *Economic of Innovation and New Technology*, 7, 1-26.

Meyer, K. E. (2004). Perspectives on multinational enterprises in emerging economies. *Journal of International Business Studies,* 21, 235-253.

OECD. (2001). Measuring Capital, OECD Manual: Measurement of Capital Stocks, Consumption of Fixed Capital and Capital Services. *OECD Publishing*.

Oliner, S., & Sichel, D. (2000). The Resurgence of Growth in the Late 1990s: Is the Information Technology the Story? *The Journal of Economic Perspectives*, *14* (4), 3-22.

Plice, R. K., & Kraemer, K. L. (2001). Measuring Payoffs from Information-Technology Investments: New Evidence from Sector-Level Data on Developed and Developing Countries. *Center for Research on Information Technology and Organizations*, Working Paper.

Pohjola, M. (2001). Information Technology and Economic Growth: A Cross-Country Analysis. in M. Pohjola (ed.), *Information Technology, Productivity and Economic Growth*. Oxford: Oxford University Press.

Roach, S. (1986). Macrorealities of the Information Economy. In Landau, R. & Rosenberg, N. (Eds.). *The Positive Sum Strategy*, Washington, D.C.: National Academy Press.

Roach, S. (1987). America's Technology dilemma: A Profile of the Information Economy. *Morgan Stanely Special Economic Study.*

Schreyer, P. (2000). The Contribution of Information and Communication Technology to Output Growth: A Study of the G7 Countries. *OECD Science, Technology and Industry Working Papers*, 2000/2, OECD Publishing.

Solow, R. (1957). Technical Change and the Aggregate Production Function. *Review of Economics and Statistics*, *39*, 312-320

UN (United Nations). (2008). *The Global Information Society: A Statistical View*. Chile.

WITSA (World Information Technology and Services Alliance). (2006). *Digital Planet Report 2006*, Washington D.C. http://www.witsa.org/

Appendix I

Descriptive Statistics of the Data

	Mean	*Median*	*Standard Deviation*	*Maximum Value*	*Minimum Value*
GDP Growth Rates	0.0585	0.0553	0.0438	0.2620	-0.1169
Labor Growth Rates	0.0184	0.0165	0.0322	0.2377	-0.1470
Capital Stock Growth Rates	0.0419	0.0338	0.0553	0.3624	-0.0723
TFP Growth Rates	0.0249	0.0214	0.0356	0.2262	-0.1042
R&D Growth Rates	0.0878	0.0859	0.1625	0.5305	-0.5307
ICT Spending Growth Rates	0.1323	0.1271	0.1000	0.4445	-0.5039
Combined Gross Enrollment Ratios	73.9025	73.9341	11.8654	97.2302	36.0503
No. of Internet Users	15.3144	9.2500	15.4261	71.1000	0.4000
FDI Growth Rates	0.0189	0.0094	0.0298	0.1610	-0.0092
Trade Openness	0.9417	0.6900	0.8619	4.7400	0.2900

Appendix II

List of Countries undertaken in study

Argentina (ARG)

Bolivia (BOL)

Cameroon (CAM)

Chile (CHL)

China (CHN)

Colombia (COL)

Costa Rica (COS)

Algeria (DZA)

Ecuador (ECU)

Egypt (EGY)

Honduras (HOD)

Hong Kong (HON)

India (IND)

Indonesia (IDN)

Iran (IRA)

Jamaica (JAM)

Korea (KOR)

Kuwait (KUW)

Malaysia (MAL)

Morocco (MOR)

Panama (PAN)

Pakistan (PAK)

Peru (PER)

Philippines (PHL)

Poland (POL)

Romania (ROM)

Singapore (SIN)

Sri Lanka (SRI)

Thailand (THA)

Tunisia (TUN)

Uruguay (URG)

Venezuela (VEN)

South Africa (ZAF)