INFORMATION TECHNOLOGY AND ECONOMIC GROWTH: A CAUSAL ANALYSIS

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ABSTRACT

The pervasive role of Information and communication technology (ICT) in economic growth is well documented. It is today emerging as a necessary factor to develop a country's productive capacity across all sectors of the economy, linking the country with the global economy and ensuring competitiveness. Across the world, developing countries are seeking to improve their ICT investments and benefit from anticipated increases in economic activity, and a causal relationship between the two is often tacitly assumed. In this paper we examine if a causal relationship between ICT and economic growth (GDP) exists and at the secondary level, check for the causality between Foreign Direct Investment (FDI) and economic growth as well. This paper conducts an empirical analysis for 10 Latin American countries using time-series data (1975 – 2003). The results of the analysis support both the thesis of ICT led development and of the existence of a causal link between ICT and economic growth.

Keywords: Information Technology, Economic Growth, FDI and Causality
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INTRODUCTION

The relationship between information and communication technology (ICT) and economic growth (measured as GDP) is a question that continues to be of considerable theoretical and empirical interest. By investing in ICT , is it possible for developing countries to leapfrog stages of development rather than play catch-up with developed countries. Interpreting the importance of these activities towards economic growth lies at the heart of the current debate on investment in ICT and its effect on development and economic growth.

ICT offers a unique opportunity for developing countries to free themselves from historical and geographic disadvantages allowing trade and economic activities to be conducted as efficiently as in the developed world. An evolving and increasingly powerful ICT infrastructure has fundamentally changed the nature of global relationships, sources of competitive advantage and opportunities for economic and social development. Technologies such as the Internet, personal computers, broadband and wireless telephony have created an interconnected global network of individuals, firms and governments. For the developing world, a modern telecommunications infrastructure is not only essential for domestic economic growth, but also a prerequisite for participation in increasingly competitive world markets and for attracting the much-needed new investments.

While there is substantial evidence that new information technologies are in many ways transforming how modern economies operate, the impacts on productivity and economic growth have been much harder to detect. Although an increasing number of micro-economic studies have found a positive correlation between IT investment and various measures of economic performance across firms in industrial countries, macro-economic studies have been less supportive tending to find no correlation, or even negative correlation between IT investment and economy wide productivity (for a survey, see Brynjolfsson and Yang 1996).

Recent literature about the role of ICT on economic growth has been mixed. Among the country level studies, Kraemer and Dedrick (1994) found a significant relationship between IT investment and productivity growth with the data from 12 Asia Pacific countries. Dewan and Kraemer (1998) used a data set from 36 countries for the period 1985-1993 and showed that IT investment is positive for developed countries but not significant for developing countries. Matti Pohjola (2000, 2002) performed cross-country studies with the data from 39 and 42 countries covering the periods 1980-1995 and 1985-1999 respectively. The results confirmed Dewan and Kraemer (2000)'s conclusion that IT plays a significant role in economic growth in developed countries but no substantiated role in developing countries. However, single country studies, Kraemer and Tallon (1999) on Ireland; Oliner and Sichel (2000), and Jorgenson and Stirch (2000) on USA; Kraemer and Dedrick (2001)'s study of Singapore; and Joseph (2002) on India, showed that ICT contributed to economic growth.

The empirical growth literature that developed, regressed growth in real per capita GDP on its initial level and a wide variety of control variables of interest. Within this literature many papers have included various measures of technology or telecommunication related variables among these control variables. Many of these papers found significant positive correlations across countries between growth and technology related variables, controlling for other factors. These studies have been influential in reinforcing the consensus among many economists that "ICT promotes growth".

However, the mixed results from empirical work in the ICT literature is due mainly to the omission of a relevant mechanism through which openness or the re-structuring of an economy promotes growth. Liberalization, in particular, is expected to increase foreign direct investment (FDI). If a complementary relationship between FDI and ICT exists, then foreign investment or FDI may increase due to the existing ICT capacity within a country. FDI may also encourage greater ICT in intermediate inputs, especially between parent and affiliated producers as in the case of vertical trade as observed in developing countries where factor prices are lower such as India and China.

In developed countries there already exists an ICT capacity which causes inflow of FDI, while in developing countries ICT capacity must be built up to attract FDI. The inflow of FDI causes further increases in ICT investment and capacity. The rapid expansion in world FDI resulted from several factors including technical progress in telecommunication services and major currency realignment. Technical progress in telecommunication services facilitates international communications involving parent companies and their overseas affiliates, while major currency realignment has provided companies with the opportunities for making profits by undertaking FDI (Gholami, Tom Lee and Heshmati, 2003).

Along the same lines, Blomström, Globerman and Kokko (2000) argue that the beneficial impact of FDI is only enhanced in an environment characterized by an open trade and investment regime and macroeconomic stability. The contention that investment is correlated with economic growth is evidenced in the case of the South East Asian Tigers - the investment rates were the engine of growth for these countries (Srinivasan and Bhagwati, 1999).

The objective of this paper is to investigate if a causal relationship between ICT (using investment in telecommunication as a proxy) and economic growth (measured as output growth) in a sample of selected Latin American countries exists. This issue is analyzed using time series and panel data analysis tools of cointegration and error-correction models. If non-stationary time series variables are not co-integrated, then a high degree of correlation between the two variables does not mean a causal relationship between the variables. Time series methodology empowers us to recognize and avoid spurious results, which might happen using a simple OLS method. These techniques, as successfully applied in studies by Bahmani-Oskooee and Alse (1993), Addison and Heshmati (2003), and Gholami, Tom Lee and Heshmati (2003) demonstrate their econometric robustness and their ability to root out spurious relationships.

Our attempts to study the causal relationship between ICT and economic growth in Latin America adds to the expanding body of literature on this topic. Also the long time series for these variables we use in this study is quite unique.

The rest of the paper is organized as follows. Section 2 explains the empirical model and a description of the data sources. Section 3 contains the empirical results and comparison of our results with previous studies. Finally, Section 4 provides a discussion about the implication of the results and some conclusions.

MODEL AND DATA

The Model

This paper uses the cointegration and error-correction models, to test the causal relationship between ICT, and economic growth. Though ICT – economic growth is the main emphasis of the study, for a robust study on economic growth, the analysis has to be done in a multivariate setting including other variables. Therefore, FDI was included as an additional variable. We start by considering the three-variable vector autoregressive (VAR) model comprised of ICT, gross domestic product (GDP), and foreign direct investment (FDI), all expressed in natural logs. As shown in equation (1), all variables are systematically and endogenously considered at first.

$$\begin{bmatrix} ICT_t \\ GDP_t \\ FDI_t \end{bmatrix} = A_0 + A_1 \begin{bmatrix} ICT_{t-1} \\ GDP_{t-1} \\ FDI_{t-1} \end{bmatrix} + A_2 \begin{bmatrix} ICT_{t-2} \\ GDP_{t-2} \\ FDI_{t-2} \end{bmatrix} + \dots\dots\dots + A_s \begin{bmatrix} ICT_{t-s} \\ GDP_{t-s} \\ FDI_{t-s} \end{bmatrix} + \varepsilon_t \quad (1)$$

where A_0 is a vector of constant terms, A_i are all matrices of parameters (i = 1, 2, ….., s), and $\varepsilon_t \sim IN(0,1)$.

Testing for cointegration among the three variables, ICT, real GDP, and real FDI (expressed in logarithmic form), is accomplished in two steps. First, following Engle and Granger (1987), the time series properties of each variable are examined by unit root tests. In this step, it is tested whether ICT, GDP, and FDI are integrated of order zero, $\mathrm{I}(0)$, or in other words, that the three series are stationary. This is accomplished by performing the augmented Dickey-Fuller (ADF) test. The ADF test is based on the regression equation of the form

$$\Delta \ln X_t = \beta_0 + \theta_1 \ln X_{t-1} + \sum_{j=1}^{m} \beta_j \Delta \ln X_{t-j} + \varepsilon_t \qquad (2)$$

where $\Delta X_t = X_t - X_{t-1}$ and X is the variable under consideration, m is the number of lags in the dependent variable (chosen so as to induce a white noise term), and ε_t is the stochastic error term. The null hypothesis that X_t contains a unit root (is non-stationary) amounts to testing the null hypothesis H_0: $\theta_1 = 0$. The null hypothesis is rejected if θ_1 takes a negative value and is statistically different from zero, in which case the series is considered stationary. In addition to this test, we also performed an augmented Dickey-Fuller (ADF) test including a trend in equation (2). This second test is based on the regression equation with the inclusion of a constant and a trend of the form

$$\Delta \ln X_t = \varphi_0 + \varphi_1 t + \theta_2 \ln X_{t-1} + \sum_{j=1}^{m} \varphi_j \Delta \ln X_{t-j} + \varsigma_t \qquad (3)$$

The null hypothesis that X_t contains a unit root (is non-stationary) amounts to testing the null hypothesis H_0: $\theta_2 = 0$. The null hypothesis is rejected if θ_2 takes a negative value and is statistically different from zero, in which case the series is considered stationary. To distinguish these two tests, the unit-root test results are reported as ADF_1 and ADF_2 in Table 1.

When the variables are found to be both integrated of degree $\mathrm{I}(1)$, and cointegrated, then either unidirectional or bi-directional Granger causality must exist in at least the $\mathrm{I}(0)$ variables. If the variables are cointegrated then there must exist an error-correction representation that may take the following form:

$$\Delta \ln ICT_t = \phi_0 + g\delta_{t-1} + \sum_{i=1}^{k} \phi_{1i} \Delta \ln ICT_{t-i} + \sum_{i=1}^{k} \phi_{2i} \Delta \ln GDP_{t-i} + \sum_{i=1}^{k} \phi_{3i} \Delta \ln FDI_{t-i} + \varepsilon_{2t} \qquad (4)$$

$$\Delta \ln GDP_t = \pi_0 + h\rho_{t-1} + \sum_{i=1}^{k} \pi_{1i} \Delta \ln GDP_{t-i} + \sum_{i=1}^{k} \pi_{2i} \Delta \ln ICT_{t-i} + \sum_{i=1}^{k} \pi_{3i} \Delta \ln FDI_{t-i} + \varepsilon_{3t} \qquad (5)$$

Where δ_{t-1} and ρ_{t-1} are the error-correction terms. If the series are cointegrated, then the error-correction models given in equations (4) and (5) are valid and the coefficients g and h are expected to capture the adjustments of $\Delta \ln \mathrm{ICT}_t$

and $\Delta \ln \text{GDP}_t$ towards long-run equilibrium, while $\Delta \ln \text{ICT}_{t-i}$, $\Delta \ln \text{GDP}_{t-i}$ and $\Delta \ln \text{FDI}_{t-i}$ are expected to capture the short-run dynamics of the model.

TABLE 1
AUGMENTED DICKEY-FULLER UNIT ROOT TEST

	$\ln \text{ICT}$		$\ln \text{GDP}$		$\ln \text{FDI}$	
Country	ADF_1	ADF_2	ADF_1	ADF_2	ADF_1	ADF_2
Brazil	-2.0726	-2.3096	-0.2413	-0.6036	-1.9116	-1.8470
Colombia	-1.0940	-2.3007	-0.1819	-1.7525	-1.4735	-1.2808
Costa Rica	-1.6019	-0.7665	-1.4219	-1.4804	-1.5224	-1.9317
Ecuador	-1.5369	-1.3862	-1.3667	-2.0801	-0.4682	-2.0610
El Salvador	-0.9139	-1.8692	-1.5079	-0.5552	-1.0941	-1.9572
Mexico	-2.0875	-1.4585	-1.5512	-1.1975	-1.2287	-1.4776
Paraguay	-1.2067	-1.4568	-0.1029	-1.8537	-1.4270	-1.6117
Peru	-1.3709	-1.3123	-1.3989	-1.8646	-1.5553	-2.1746
Uruguay	-1.9864	-2.0243	-1.3981	-1.9518	-1.8828	-2.2247
Venezuela	-0.7169	-2.2031	0.8396	-1.8485	-1.9263	-1.9886

First Difference

	$\Delta \ln \text{ICT}$		$\Delta \ln \text{GDP}$		$\Delta \ln \text{FDI}$	
Country	ADF_1	ADF_2	ADF_1	ADF_2	ADF_1	ADF_2
Brazil	-3.4777**	-3.3211*	-3.1214**	-3.8671**	-4.7550***	-4.8044***
Colombia	-3.2270**	-3.2754*	-3.4500**	-3.3352*	-4.1992***	-4.9146***
Costa Rica	-2.8095*	-3.4158*	-4.0108***	-4.1758**	-4.2528***	-4.8156***
Ecuador	-3.4797**	-3.4859*	-3.6399**	-3.5999*	-3.9630***	-3.9434**
El Salvador	-3.8592***	-3.9255**	-2.7175*	-3.4314*	-4.9083***	-5.0767***
Mexico	-2.7984*	-3.4905*	-2.8358*	-3.5424*	-3.1157**	-3.3152*
Paraguay	-4.6685***	-4.6761***	-2.7095*	-3.3767*	-3.5412**	-3.4358*
Peru	-4.5908***	-4.4392***	-4.2503***	-4.1459**	-4.0363***	-4.0042**
Uruguay	-5.0824***	-5.2838***	-2.7154*	-3.2963*	-3.9787***	-3.8851**
Venezuela	-4.4901***	-4.5626***	-3.0166**	-3.2826*	-4.8772***	-4.9677***

Notes:

ADF_1 tests H_0: $\theta_1 = 0$ in $$\Delta \ln X_t = \beta_0 + \theta_1 \ln X_{t-1} + \sum_{j=1}^{m} \beta_j \Delta \ln X_{t-j} + \varepsilon_t \qquad (6)$$

ADF_2 tests H_0: $\theta_2 = 0$ in $$\Delta \ln X_t = \varphi_0 + \varphi_1 t + \theta_2 \ln X_{t-1} + \sum_{j=1}^{m} \varphi_j \Delta \ln X_{t-j} + \varsigma_t \qquad (7)$$

*, **, and *** denote statistical significance at the 10% 5%, and 1% levels, respectively. The critical values of ADF_1 statistics are -3.72, -2.98, and -2.63 at 1%, 5%, and 10% levels of significance respectively. The critical values of ADF_2 statistics are -4.37, -3.60, and -3.23 at 1%, 5%, and 10% levels of significance respectively.

DATA

Annual data for the period 1975-2003 are used for estimation. Investment in telecommunications is taken as a proxy for ICT. The data on investment in telecommunications are from International Telecommunication Union's *World Telecommunication Indicators Database*. Data on inward FDI and gross domestic product (GDP) for the selected Latin American countries are from several issues of the UNCTAD, *World Investment Report* and from International Monetary Fund's *International Financial Statistics Yearbook*, respectively. The ten Latin countries included in this study are Brazil, Colombia, Costa Rica, Ecuador, El Salvador, Mexico, Paraguay, Peru, Uruguay and Venezuela. The choice of countries reflects the span of data availability and those that are important recipients of FDI. Two larger economies in Latin America, namely Chile and Argentina, were excluded due to the non-availability of data on ICT. Nominal figures of inward FDI, ICT, and GDP were deflated by the GDP deflator (1990=100) for each country to express them in real terms. The GDP deflator was collected from the International Monetary Fund's *International Financial Statistics Yearbook*.

EMPIRICAL RESULTS

The cointegrating properties of the variables involved are examined and the empirical results are discussed in this section. Table 1 presents the results of unit root tests obtained using the augmented Dickey-Fuller test. The results support the presence of unit roots in all of the series for all countries. This is confirmed by the fact that the null hypothesis that the series are non-stationary is not rejected at the levels for all variables. However, the null hypothesis is rejected in favor of the alternative hypothesis that the series are stationary when the first difference of the variables is taken. Thus, their first differences are found to be stationary and hence, are all integrated of order one; in all cases, the null hypothesis that the series has unit roots cannot be rejected. The tests of unit roots support the unit root hypothesis at the 1%, 5% or 10% levels of significance for all data series.

Having confirmed the existence of unit roots for all the data series, the next step is to check the results of Johansen-Juselius cointegration tests presented in Table 2. Both the Trace test and the Maximum Eigenvalues test reject the null hypothesis of zero cointegrating vectors in eight of the ten cases. Thus, the Johansen-Juselius cointegration test provides evidence for the existence of one cointegration vector implying that the three variables are cointegrated in eight of the ten cases. Thus, the results of Johansen-Juselius cointegration test imply a long-run association between ICT, real GDP, and inward FDI for these eight countries. Therefore, equations (3) and (4) have been estimated for these eight countries including the error-correction terms. In cases of El Salvador and Peru, there is no long-run association between the three variables and, therefore, equations (3) and (4) were estimated excluding the error-correction terms.

The empirical results of the estimated error-correction models are presented in Table 3. Beyond the analysis of the long-run relationship among the three variables in the system for each country, the short-run dynamics is also explored performing multivariate Granger causality tests for the vector error-correction model. The F-statistics and probability (in parentheses) for the Granger causality tests are presented in columns 2-4 in Table 3. It also includes the t-statistics for error-correction terms for each of the three equations. For each variable in the system, at least one channel of Granger causality is active, either in the short-run through the joint tests of the lagged-differences or in the long run through statistically significant error-correction term.

TABLE 2
JOHANSEN MULTIVARIATE COINTEGRATION TESTS

Trace Test

Trace Test			
Country	Null Hypothesis		
	$r = 0$	$r \leq 1$	$r \leq 2$
Brazil	37.22***	10.67	0.22
Colombia	32.57**	14.47	0.71
Costa Rica	40.80***	14.25	2.15
Ecuador	33.93**	5.20	0.10
El Salvador	24.16	8.22	2.52
Mexico	41.75***	13.26	2.33
Paraguay	44.73***	15.21	0.04
Peru	28.46	9.08	0.19
Uruguay	36.38***	15.31	2.65
Venezuela	38.77***	15.20	0.05
Maximum Eigenvalues Test			
Country	Null Hypothesis		
	$r = 0$	$r = 1$	$r = 2$
Brazil	26.55**	10.45	0.22
Colombia	18.10**	13.76	0.71
Costa Rica	26.55**	12.10	2.15
Ecuador	28.73**	5.10	0.10
El Salvador	15.94	5.70	2.52
Mexico	28.49**	10.93	2.33
Paraguay	29.52**	15.17	0.04
Peru	19.38	8.89	0.19
Uruguay	21.07**	12.66	2.65
Venezuela	23.57**	15.15	0.05

Cointegration Equations Normalized on $\ln GDP_t$

Country	Constant	$\ln \text{ICT}_t$	$\ln \text{FDI}_t$	Log Likelihood
Brazil	13.3261	0.3896*** (4.14)	0.3781*** (8.04)	35.82
Colombia	1.8901	1.6358*** (4.56)	0.3131 (1.05)	18.42
Costa Rica	2.0405	0.4868 (0.49)	4.5512 (1.21)	24.39
Ecuador	9.0862	0.0688* (1.91)	0.1681*** (7.64)	41.77
El Salvador	-	-	-	-
Mexico	5.4409	1.8782*** (5.74)	0.7652** (2.16)	22.21
Paraguay	2.7540	1.1585*** (17.0)	0.2287** (2.82)	20.21
Peru	-	-	-	-
Uruguay	3.6767	0.9946*** (23.6)	0.3287*** (17.3)	27.63
Venezuela	1.9828	1.5392*** (20.8)	0.0309 (0.26)	29.31

Note: The test statistic is the Johansen trace test statistic for testing the null of no-cointegration (r = 0), where r indicates the number of cointegrating vectors. Asymptotic critical values for the trace test statistic are: 27.07 (10%), 29.80 (5%), 35.46 (1%). Asymptotic critical values for the maximum eigenvalue test statistic are: 12.78 (10%), 21.13 (5%), 28.08 (1%). *, **, and *** denote statistical significance at the 10% 5%, and 1% levels, respectively. Figures in parentheses are t-statistics.

TABLE 3
RESULTS OF ERROR CORRECTION MODELS

Dep. Variable	Source of causation ΔICT	ΔGDP	ΔFDI	EC_{t-1} (t-value)	Causal inference
Brazil					
ΔICT	-	10.677*** (0.001)	6.628*** (0.006)	-0.1418 (-1.574)	$GDP \xrightarrow{SR} ICT$; $FDI \xrightarrow{SR} ICT$
ΔGDP	9.301*** (0.001)	-	5.835*** (0.006)	-0.0412 (-1.784)	$ICT \xrightarrow{SR} GDP$; $FDI \xrightarrow{SR} GDP$
ΔFDI	3.890** (0.027)	16.139*** (0.000)	-	-0.2662* (-1.976)	$ICT \xrightarrow{SR} FDI$; $GDP \xrightarrow{SR} FDI$ $ICT, GDP \xrightarrow{LR} FDI$
Colombia					
ΔICT	-	2.041 (0.147)	1.492 (0.260)	-1.2442* (-1.910)	$GDP, FDI \xrightarrow{LR} ICT$
ΔGDP	2.213* (0.097)	-	1.414 (0.286)	-0.0494** (-2.693)	$ICT \xrightarrow{SR} GDP$ $ICT, FDI \xrightarrow{LR} GDP$
ΔFDI	1.193 (0.357)	3.489** (0.045)	-	-0.3501*** (-3.673)	$GDP \xrightarrow{SR} FDI$ $ICT, GDP \xrightarrow{LR} FDI$
Costa Rica					
ΔICT	-	4.918** (0.011)	3.176* (0.073)	-0.0253 (-1.384)	$GDP \xrightarrow{SR} ICT$; $FDI \xrightarrow{SR} ICT$
ΔGDP	8.324*** (0.005)	-	3.484** (0.047)	-0.0552*** (-3.403)	$ICT \xrightarrow{SR} GDP$; $FDI \xrightarrow{SR} GDP$ $ICT, FDI \xrightarrow{LR} GDP$

Dep. Variable	Source of causation ΔICT	ΔGDP	ΔFDI	EC_{t-1} (t-value)	Causal inference
ΔFDI	2.602 (0.105)	8.321*** (0.004)	-	-0.0770** (-2.231)	$GDP \xrightarrow{SR} FDI$ $ICT, GDP \xrightarrow{LR} FDI$
Ecuador					
ΔICT	-	5.254** (0.013)	4.056** (0.023)	-0.2562 (-0.416)	$GDP \xrightarrow{SR} ICT$; $FDI \xrightarrow{SR} ICT$
ΔGDP	2.244 (0.120)	-	2.605* (0.096)	-0.5469*** (-3.355)	$FDI \xrightarrow{SR} GDP$ $ICT, FDI \xrightarrow{LR} GDP$
ΔFDI	1.676 (0.115)	2.831* (0.065)	-	-1.6318* (-1.961)	$GDP \xrightarrow{SR} FDI$ $ICT, GDP \xrightarrow{LR} FDI$
El Salvador					
ΔICT	-	1.864* (0.082)	3.357** (0.037)	-	$GDP \xrightarrow{SR} ICT$; $FDI \xrightarrow{SR} ICT$
ΔGDP	6.633*** (0.005)	-	5.422** (0.019)	-	$ICT \xrightarrow{SR} GDP$; $FDI \xrightarrow{SR} GDP$
ΔFDI	2.485* (0.099)	1.854 (0.191)	-	-	$ICT \xrightarrow{SR} FDI$
Mexico					
ΔICT	-	11.645*** (0.000)	7.728*** (0.006)	-0.0117 (-0.634)	$GDP \xrightarrow{SR} ICT$; $FDI \xrightarrow{SR} ICT$
ΔGDP	12.219*** (0.001)	-	5.999*** (0.010)	-0.0176 (-1.058)	$ICT \xrightarrow{SR} GDP$; $FDI \xrightarrow{SR} GDP$
ΔFDI	5.558*** (0.007)	15.620*** (0.000)	-	-0.0050 (-0.176)	$ICT \xrightarrow{SR} FDI$; $GDP \xrightarrow{SR} FDI$
Paraguay					
Dep. Variable	Source of causation ΔICT	ΔGDP	ΔFDI	EC_{t-1} (t-value)	Causal inference

Dep. Variable	Source of causation ΔICT	ΔGDP	ΔFDI	EC_{t-1} (t-value)	Causal inference
ΔICT	-	6.960*** (0.008)	3.807** (0.039)	-0.1666** (-2.137)	$GDP \xrightarrow{SR} ICT$; $FDI \xrightarrow{SR} ICT$ $GDP, FDI \xrightarrow{LR} ICT$
ΔGDP	4.564** (0.019)	-	9.987*** (0.002)	-0.0439*** (-3.002)	$ICT \xrightarrow{SR} GDP$; $FDI \xrightarrow{SR} GDP$ $ICT, FDI \xrightarrow{LR} GDP$
ΔFDI	1.859 (0.188)	2.652 (0.114)	-	-0.8118** (-2.615)	$ICT, GDP \xrightarrow{LR} FDI$
Peru					
Dep. Variable	Source of causation ΔICT	ΔGDP	ΔFDI	EC_{t-1} (t-value)	Causal inference
ΔICT	-	3.350* (0.064)	7.940*** (0.004)	-	$GDP \xrightarrow{SR} ICT$; $FDI \xrightarrow{SR} ICT$
ΔGDP	1.328 (0.307)	-	0.617 (0.554)	-	
ΔFDI	4.617** (0.013)	1.871 (0.180)	-	-	$ICT \xrightarrow{SR} FDI$
Uruguay					
Dep. Variable	Source of causation ΔICT	ΔGDP	ΔFDI	EC_{t-1} (t-value)	Causal inference
ΔICT	-	6.878*** (0.005)	16.487*** (0.000)	-0.0987* (-1.870)	$GDP \xrightarrow{SR} ICT$; $FDI \xrightarrow{SR} ICT$ $GDP, FDI \xrightarrow{LR} ICT$
ΔGDP	5.286** (0.016)	-	4.882** (0.041)	-0.0708** (-2.241)	$ICT \xrightarrow{SR} GDP$; $FDI \xrightarrow{SR} GDP$ $ICT, FDI \xrightarrow{LR} GDP$
ΔFDI	5.700** (0.011)	9.749*** (0.001)	-	-0.7723*** (-3.520)	$ICT \xrightarrow{SR} FDI$; $GDP \xrightarrow{SR} FDI$ $ICT, GDP \xrightarrow{LR} FDI$
Venezuela					
Dep. Variable	Source of causation ΔICT	ΔGDP	ΔFDI	EC_{t-1} (t-value)	Causal inference
ΔICT	-	31.519*** (0.000)	1.153 (0.339)	-0.0296 (-0.714)	$GDP \xrightarrow{SR} ICT$

ΔGDP	13.788*** (0.000)	-	2.823* (0.080)	-0.0643* (-1.913)	$ICT \xrightarrow{SR} GDP$; $FDI \xrightarrow{SR} GDP$ $ICT, FDI \xrightarrow{LR} GDP$
ΔFDI	4.373** (0.026)	4.565** (0.017)	-	-0.6488*** (-4.274)	$ICT \xrightarrow{SR} FDI$; $GDP \xrightarrow{SR} FDI$ $ICT, GDP \xrightarrow{LR} FDI$

Notes:
EC denotes the error-correction term. *, ** and *** indicate the statistical significance at the 10%, 5% and 1% levels of significance respectively. The critical t-values at the 10%, 5% and 1% levels of significance, respectively, are 2.94, 2.13, and 1.75. Figures in parentheses are p-values. The symbols "$\xrightarrow{SR}$" and "$\xrightarrow{LR}$" represent unidirectional causality in the short run and long run respectively.

The first interesting observation from our results is that seven out of ten countries- Brazil, Costa Rica, El Salvador, Mexico, Paraguay, Uruguay and Venezuela - show evidence of bi-directional causality for ICT and economic growth. These finding are quite unique to empirical literature but consistent with the theory on ICT and growth.

The second observation is that nine of the ten countries showed causality running from growth to ICT. While Ecuador and Peru have causality running from growth to ICT only, Brazil, Costa Rica, El Salvador, Mexico, Paraguay, Uruguay and Venezuela show causality from ICT and economic growth running both ways. The lack of ICT led growth in both Ecuador and Peru could be due to factors such as weak backward linkages, weak linkage between FDI and industrialization, lack of positive spillover effect of openness, low levels of human capital. Despite the robust expansion of ICT in recent years, econometric analysis does not support the view that ICT is an engine of economic growth for these two countries.

A third important observation of this study is that more than three fourths of the countries studied show evidence for ICT-led growth. In addition to the seven countries that show two-way causality, Colombia alone has causality running from ICT to growth, implying that eight out of ten countries show evidence for ICT-led growth.

The results of this study find evidence to support the claim that ICT enhances economic growth in this region. In all of the countries considered, there is some evidence of either ICT-led growth or growth-led ICT Granger causality in the short-run. Summary of our findings are presented in Table 4.

TABLE 4
COMPARATIVE EVALUATION OF MAJOR FINDINGS

Causation	*Brazil*	*Colombia*	*Costa Rica*	*Ecuador*	*El Salvador*	*Mexico*	*Paraguay*	*Peru*	*Uruguay*	*Venezuela*
$ICT \Leftrightarrow GD$	√		√		√	√	√		√	√
$ICT \Rightarrow GDI$	√	√	√		√	√	√		√	√
$GDP \Rightarrow IC$	√		√	√	√	√	√	√	√	√
$FDI \Leftrightarrow GD$	√		√	√		√			√	√
$FDI \Rightarrow GD$	√		√	√	√	√			√	√
$GDP \Rightarrow FD$	√	√	√	√		√	√	√	√	√
$ICT \Leftrightarrow FDI$	√				√	√		√	√	
$ICT \Rightarrow FDI$	√				√	√		√	√	√
$FDI \Rightarrow IC$	√		√	√	√	√	√	√	√	

Notes:

√ denotes the presence of causality and blank spaces indicate no evidence of causality.

While the findings of our study are decidedly different from those of studies by Dewan and Kraemer (1998; 2000), Matti Pohjola (2000; 2002), and Addison and Heshmati (2003), they are however more consistent with theory. Our analysis shows mixed results with regard to a complementary relationship between Growth, FDI and ICT. However, since the coverage of countries and time span varies from study to study no direct comparison can be made.

In general, the differences in outcomes of these studies could be due to a number of reasons including different time periods, different sample intervals, and different methodologies. However, only one of these studies shares some procedural aspects to our study (see Bahmani-Oskooe and Alse (1993)). Also there is considerable heterogeneity across developing countries with regard to the impact of ICT and other conditioning variables on economic growth; however, traditional panel estimators have often imposed homogeneity assumptions across countries for statistical convenience.

SUMMARY AND CONCLUSIONS

The cointegration and error-correction modeling techniques used in this paper indicate that there is two-way causality between ICT and economic growth in two thirds of the countries considered, and ICT-led growth in eight out of ten cases considered. However, there is strong evidence of association between these variables in all cases. The central question concerning this paper, whether there exists a causal relationship between ICT and economic growth was found to be true except for three countries. The results for three Latin American countries have been mixed, indicating that the reasons for the differing historical levels of development between these nations arise from some other source that needs to be further explored.

The emergence of ICT and liberalization process in the 1990's has increased not just ICT alone, but FDI flows as well. This is particularly true in the Latin American region, a major recipient of FDI in the developing world. Therefore, due to the increasing importance of FDI, which has facilitated technology and productivity spillovers, has brought the issue of ICT to the forefront. Also at a time when the countries of the hemisphere are set to integrate into a regional block under the Free Trade Area of the Americas (FTAA) understanding the causal relationships between ICT and growth especially those that have been the main recipient countries of FDI in the hemisphere makes this study interesting. It is all the more important to understand the realities of the digital divide that exists between these countries that needs to be addressed if integration is to succeed.

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