INFORMATION TECHNOLOGY, FDI AND ECONOMIC GROWTH: AN INDIA CASE STUDY

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ABSTRACT

This paper investigates the relationship between investments in information and communication technology (ICT) and Foreign Direct Investment (FDI) with reference to its implications on economic growth of India. ICT is a necessary factor to develop a country's productive capacity in all sectors of the economy; it links a country with the global economy and ensures competitiveness. Unlike in developed countries where there already exists a built up ICT capacity which causes inflow of FDI, in developing countries like India, ICT capacity must be built up by attracting FDI. 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. This paper conducts an empirical analysis of India using time-series data (1970 – 2005), to see if there is empirical evidence that supports this assumption.

INTRODUCTION

The success of India's software industry has captured the imagination of both Indians and the world. A poor country ranked 104 in the Human Development Index has achieved prominence and global competitiveness in a leading edge sector – Information and Communication Technologies (ICT). ICT can potentially be used in every sector of the economy. The true impact of ICT on growth and productivity continues to be a matter of debate, even in the United States, which has been the leader and largest adopter of ICT. There is no doubt that the ICT sector has been a dynamic one in many developed countries, and in a developing country like India it has stood out in the guise of software exports, despite the country's relatively low level of income and development. In this paper we examine if ICT can contribute to India's economic development in a broader, more fundamental way. What are the potential mechanisms by which ICT can accelerate India's growth? The broader question is can one sector of the economy fuel sustained economic growth.

The Indian industry exported software and services worth 25 million dollars in 1985. By 2000-01, this figure had grown to $6.4 billion and $8.5 billion in 2001-02, reaching $12.8 billion by 2003-04 (NASSCOM, 2005)[1] and is expected to reach $50 billion in exports by 2008 according to a NASSCOM-McKinsey report. Software exports grew at 41 percent annually in the 1980s and 47 percent in the 1990s (in current rupees) and 33 percent and 39.6 percent respectively (in current dollars). Overall growth rates of ICT exports over the last two decades have been 43.7 percent

(in current rupees) and 34.4 percent (in current dollars). As calculated from Table 1, the ICT (Information Technology) software and services industry registered a growth of 55 per cent, touching $21.5 billion in revenues in 2003-04 and expected to reach $28.2 in 2004-05 (NASSCOM, 2005).

Table 1
Sector-wise Break-up

US Dollar billion	**2002-03**	**2003-04**	**2004-05**
ICT Services and Software	**9.9**	**12.8**	**16.5**
- Exports	7.1	9.2	12.2
- Domestic	2.8	3.6	4.3
ITES-BPO (ITES – Information Technology Enabled Services) (BPO – Business Process Outsourcing)	**2.7**	**3.9**	**5.7**
- Exports	2.5	3.6	5.1
- Domestic	0.2	0.3	0.6
Total Software and Services (ICT Services & Software+ ITES-BPO)	**12.6**	**16.7**	**22.2**
-Exports	9.6	12.8	17.3
-Domestic	3.0	3.9	4.9
Hardware	**3.6**	**4.8**	**6.0**
- Exports	0.3	0.5	0.7
- Domestic	3.3	4.3	5.3
Total ICT Industry (Software & Services +Hardware)	**16.1**	**21.5**	**28.2**

Source: NASSCOM.com

Indian companies now hold approximately 2 percent of the global services market and about 16 percent of global work force in this sector. ICT currently accounts for 2 percent of India's gross domestic product (GDP) and 14 percent of the exports and is expected to account for 8 percent of the GDP, a total employment for four million people (including support services), and 30 per cent of India's foreign exchange inflows, in 2008 (The Hindu –Survey of India Industry, 2004).

While the sales data presented in Table 2 is not quite as accurate a measure as GDP, since it is based upon revenue rather than value added, it does illustrate the growing importance of the ICT[2] industry in India's economy. Over a six-year period the ICT sector grew by a factor of 9, whereas GDP slightly more than doubled in the same period. Even though these figures partially reflect the changing exchange rate over the period, with the rupee falling against the US dollar, the dollar value of ICT grew by a factor of six.

ICT offers a unique opportunity for a developing country like India to free itself 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 India, 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 new investments.

Table 2
India's GDP and ICT Sector

Year	GDP at Current Prices (Rs. Billions)*	ICT Sector** (Rs. Billions)	ICT Sector** (US$ Billions)
1994-1995	9,170	63	2.0
1995-1996	10,732	99	2.9
1996-1997	12,435	137	3.8
1997-1998	13,900	187	5.0
1998-1999	16,160	248	6.1
1999-2000	17,865	371	8.7
2000-2001	19,895	554	12.2

Source: *Reserve Bank of India 2003 annual report and **NASSCOM.com 2003.

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 ICT 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 ICT investment and economy wide productivity (for a survey, see Brynjolfsson and Yang, 1996).

LITERATURE REVIEW

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 ICT 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 ICT 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 ICT 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.

During the latter part of the 1990s an immense empirical growth literature developed, which 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".

The case for ICT as an engine of growth and development must rest mainly on standard economic criteria, such as comparative advantage, complementarities, and the dynamic of the global economy. The ICT sector can be an important source of growth for India, if the country has a comparative advantage in providing certain types of ICT-related products and services, if the global demand for these products and services is likely to grow rapidly, and if the growth of the sector has positive spillover benefits to the rest of the domestic economy. One of the most interesting issues is the spillover benefits or positive externalities that arise leading to economic growth in general. This is the area where the ICT sector may be special, and not just another export enclave. Are the spillover effects of entry of large MNCs, by way of technology transfer, training of personnel and export growth, significant such that the inflow of relatively small quantum of capital is supplemented by significant intangible gains, i.e. signaling to others that investment in India is worthwhile?

During 2000-01, India exported software and services to 102 countries around the world. Out of the total software exports, almost 62 per cent went to the US and Canada, 24 per cent to Europe and 4 per cent to Japan (Kapur 2002). The industry's strong value proposition- high- skill manpower, competitive billing and low development costs- had helped the country emerge as a key ICT services outsourcing destination. These intrinsic strengths and advantages gave India a leg up in the burgeoning ITES/BPO[3] space as well, taking it beyond the realms of ICT services.

There is good reason to believe that the present strong momentum will continue to drive the expansion of this industry. Among the growth drivers is the fact that Indian companies have so far focused primarily on only two of the largest service markets-the U.S and the U.K.; other under penetrated markets like Canada, Japan, Germany and France represent a huge growth potential. Other countries that have large English-Speaking populations, such as the Netherlands, Sweden, and Australia, also offer significant possibilities for market growth. Significant under-penetrated segments exist at both country and industry levels, indicating scope for further expansion.

The Indian ICT services industry has so far tapped only two service lines to any significant extent: application development and application outsourcing. The off-shoring models have become more mainstream, they are already penetrating new service lines such as packaged software support and installation; ICT consulting; network infrastructure management; systems integration; IS outsourcing; ICT training and education; hardware support and installation; and network consulting and integration. The industry is looking at new service lines and extended its range of offerings horizontally to its global customers. Broadening the services portfolio will not only be useful in building scale, but will also facilitate a stronger value proposition for customers and better capacity utilization for vendors. Within the ITES/BPO segment, customer care, administration and finance continue to be dominant segments. There is greater effort by the industry to broaden its reach and target new service lines such as content development and HR. A significant potential also lies in new service lines such as sales, legal, engineering/R&D and logistics.

Most of the firms investing in India are from the USA and Western Europe, together accounting for 78 percent of the firms. Multi-national companies (MNCs) from Germany (11 percent) and the UK (9 percent) are the leading European investors. This pattern of investment is consistent with India's trade patterns. Much of the European investment is concentrated in the intermediate goods and machinery and equipment sectors. The majority of the North American firms, almost all of which are from the USA, on the other hand, have invested in the ICT and financial services

sectors. (See Table 3) Much of the investment from Japanese and East Asian firms has been concentrated in the "old economy" machines and equipment sector and in the "new economy" ICT sector (Bhaumik et. al. 2003).

Table 3
India's Contribution to the U.S economy

Projected Software and services exports to the U.S in 2003-04	$8.5 billion
Savings to the U.S Economy by Offshoring to India	$10-11 billion
Hi-Tech imports from the U.S to India	$3 billion
Contribution by Indian ICT professionals to the U.S social security	$0.5 billion
Income Tax paid by Indian ICT professionals in the U.S	$0.5 billion
Spending by Indian ICT professionals in the U.S	$1.8 billion
Total benefits to the U.S economy	$16.8

Source: The Hindu – Survey of Indian Industry 2004.

However we must also take account of deeper and broader changes in the global economy, especially the spread of the 'New Economy', and the new information and communication technology (ICT). This factor is reshaping the global system. There is a large literature on FDI, some of it dating 40 years or more. But the global economy has undergone massive change over the last 20 years, and what was relevant to attracting FDI in the 1970s may no longer be the case today (Addison and Heshmati 2002).

The key determinants of FDI frequently appearing in the literature and their expected impacts, including natural resources, market size, sociopolitical instability, business operating conditions, wage costs, exchange rate, trade barriers, export orientation, openness of developing host countries, democratization and risk, infrastructure, human capital, political instability in addition to one control for several other observable and unobservable time-specific and country-specific effects (see Dunning 1980; Lunn 1980; Root and Ahmed 1979; Chakrabarti 2001; Dollar 1992).

ICT is considered as the main new determinant of FDI[4] (Addison and Heshmati 2004). The world is rapidly moving toward an economic system based on the continuous and pervasive availability of information. Recent advances in ICT have been an important vehicle in permitting information exchange to develop as a valuable commodity. Countries and sectors equipped with the requisite telecommunications systems have been rapidly moving into post-industrial, growth orientated information based economy.

However, the mixed results regarding the causality between ICT and FDI reported in the empirical 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 may increase due to the existing ICT capacity within a country. Foreign direct investment 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 in India.

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).

India has become one of the most favored destinations for sourcing software and ICT enabled services[5], achieving an export value of US$ 12.8 billion in 2003-04. India in comparison to other locations ranks high in several critical parameters including level of government support, quality of the labor pool, English language skills, cost advantages, project management skills and over-all quality control. Additionally, a favorable time zone difference with North America and Europe helps organizations achieve 24x7 internal operations and customer service.

India's strengths include:

- Highly skilled, abundant labor pool and market-driven education system
- Labor cost advantages
- Process and quality focus – a large number of companies have received SEI-CMM Level 5 certifications
- Project management and complex project execution skills and experience
- Entrepreneurial culture
- Indian diasporas and strong customer relationships
- Friendly government policies for IT exports

Therefore, the objectives of this paper are to investigate (i) to see if the data supports a causal relationship between ICT (using investment in telecommunication as a proxy), and FDI in a developing country like India and (ii) to explore in the Indian context if ICT and FDI benefit economic growth (measured as output growth).

This issue is analyzed using time series analysis tools of co-integration 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 (Ordinary Least Squares) 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.

To undertake a study that can show that the data supports a causal relationship between ICT, FDI and economic growth in India will add to the expanding body of developing countries literature in this field. The long time series data we use in this study will better help in testing our hypothesis of the existence of a causal relationship between ICT, FDI and Economic growth.

The rest of the paper is organized as follows. In the following section the empirical model is explained and a description of the data sources is presented. The empirical results are then presented along with a comparison of our results with previous studies. The last section of the paper provides a discussion about the implication of the results and some conclusions.

MODEL AND DATA

The Model

Since Granger (1969) and Sims (1972), the most widely used operational definition of causality is the Granger definition of causality. It is defined as follows: x is a Granger cause of y (denoted as $x \rightarrow y$), if present y can be predicted with better accuracy by using past values of x rather than by not doing so. Later on, Granger

(1980) pointed out that the Granger causality test might produce spurious results if variables are cointegrated with a first order of integration. In this case, an error-correction model (ECM) should be used to establish true causality relationship. The residual of the co-integrating vector becomes the error correction term (ECT) that is used in the error correction model to eliminate the spurious results.

First, we need to apply the Augmented Dickey Fuller (ADF) test to determine the variables' stationarity and order of integration (Dickey and Fuller 1979, 1981). If variables have a different order of integration, then obviously they are not cointegrated and no further investigation of co-integration is needed. Otherwise, if they are integrated, we use the Johansen (1988) model, which was extended by Johansen and Juselius (1990) for conducting the co-integration test.

This paper uses the co-integration and error-correction models, to test the causal relationship between ICT, FDI and economic growth. The analysis has to be done in a multivariate setting. We start by considering the three-variable vector autoregressive (VAR) model comprised of ICT, gross domestic product (GDP), and FDI, all expressed in natural logs. As shown in equation (1), all variables are systematically and endogenously considered at first.

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

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 co-integration among the three variables, ICT, real GDP, and 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, $I(0)$, 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 with the inclusion of a constant and a trend of the form

$$\Delta X_t = \beta_0 + \mu t + \theta_1 X_{t-1} + \sum_{j=1}^{p} \beta_j \Delta X_{t-j} + \varepsilon_t \quad (2)$$

where $\Delta X_t = X_t - X_{t-1}$ and X is the variable under consideration, p 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

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

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 4.

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

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

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

$$\Delta \ln FDI_t = \gamma_0 + f\upsilon_{t-1} + \sum_{i=1}^{k} \gamma_{1i} \Delta \ln FDI_{t-i} + \sum_{i=1}^{k} \gamma_{2i} \Delta \ln ICT_{t-i} + \sum_{i=1}^{k} \gamma_{3i} \Delta \ln GDP_{t-i} + \varepsilon_{1t} \quad (6)$$

where δ_{t-1}, ρ_{t-1} and υ_{t-1} are the error-correction terms. If the series are cointegrated, then the error-correction models given in equations (4), (5) and (6) are valid and the coefficients g, h and f are expected to capture the adjustments of $\Delta \ln ICT_t$, $\Delta \ln GDP_t$ and $\Delta \ln FDI_t$ towards long-run equilibrium, while $\Delta \ln ICT_{t-i}$, $\Delta \ln GDP_{t-i}$ and $\Delta \ln FDI_{t-i}$ are expected to capture the short-run dynamics of the model.

Data

Annual data for the period 1970-2005 are used for estimation. Investment in telecommunications is taken as a proxy for ICT. Data on ICT (Figure 1), gross domestic product (GDP) (Figure 2) and inward FDI (Figure 3) for India are from International Telecommunication Union's, World Telecommunication Indicators Database; several issues of the UNCTAD, *World Investment Report*; and International Monetary Fund's *International Financial Statistics Yearbook*. Nominal figures of inward FDI, ICT, and GDP were deflated by the GDP deflator (1990=100) for India to express them in real terms. The GDP deflator was collected from the International Monetary Fund's *International Financial Statistics Yearbook*.

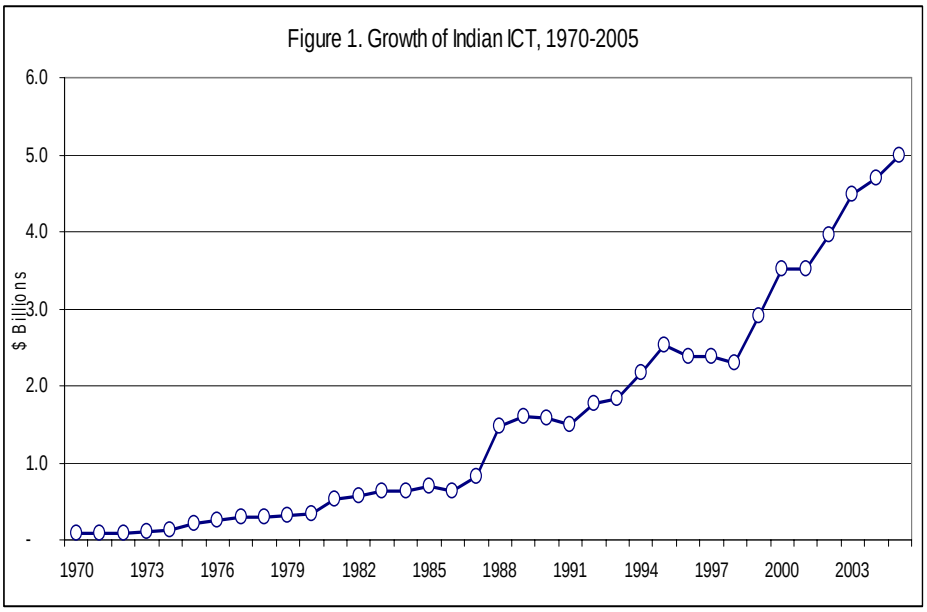


Figure 1. Growth of Indian ICT, 1970-2005
$ Billions
6.0
5.0
4.0
3.0
2.0
1.0
-
1970
1973
1976
1979
1982
1985
1988
1991
1994
1997
2000
2003

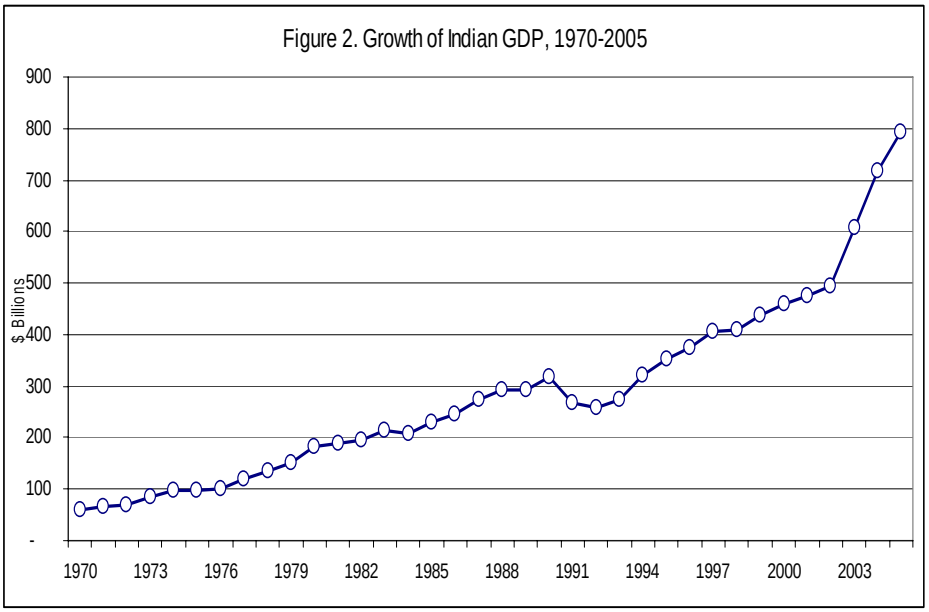
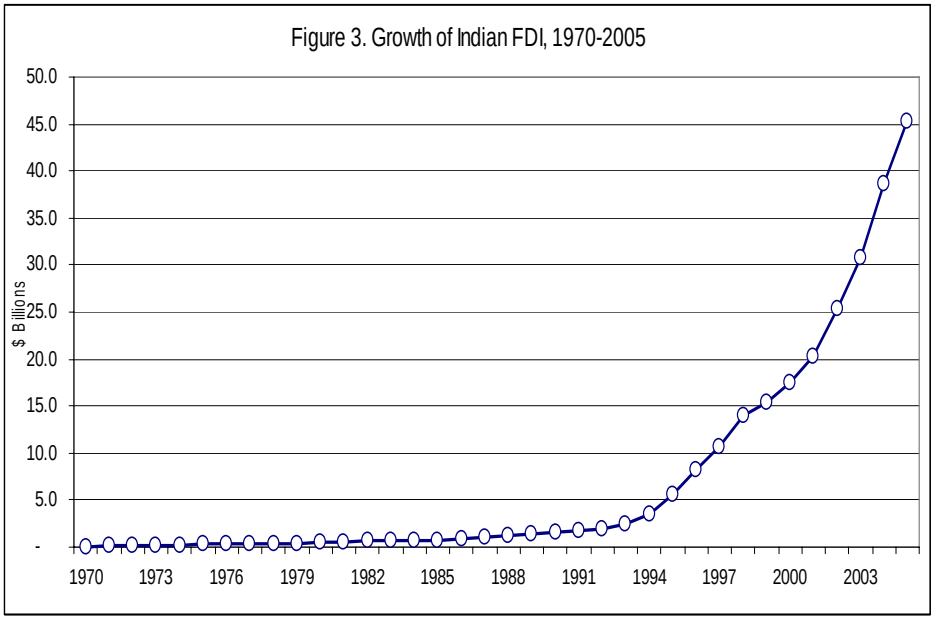


Figure 2. Growth of Indian GDP, 1970-2005
$ Billions
900
800
700
600
500
400
300
200
100
-
1970
1973
1976
1979
1982
1985
1988
1991
1994
1997
2000
2003



In developed countries there already exists an ICT capacity which causes inflow of FDI as observed from previous studies, while in developing countries like India, 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). Telecommunications and information technology increases information availability and accuracy and provides better conditions for businesses. ICT is considered as a production factor with great impact on skill and productivity of labor. Therefore, ICT can attract more FDI to developed countries.

ICT benefits are reduced transport costs; improved marketing information and increased efficiency of industrial production. A large number of studies show that telecommunications infrastructure is not only essential for domestic economic growth, but also for attracting FDI and involvement in increasingly competitive world markets. Insufficient availability of ICT services is an inhibiting factor for economic growth in less developed countries (Addison and Heshmati, 2004). Advanced telecommunication services facilitate international communications between parent companies and their overseas affiliates. The current trend of economic integration in the world economy is driven by cross-border investment by Multinational companies. Technological developments, particularly in ICT, have facilitated new ways of conducting business on a global scale (Pajarinen and Ylä-Anttila 2001).

EMPIRICAL RESULTS

The co-integrating properties of the variables involved are examined and the empirical results are discussed in this section. Table 4 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 India. 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.

Table 4
Augmented Dickey-Fuller Unit Root Test

Level

$\ln ICT$		$\ln GDP$		$\ln FDI$	
ADF_1	ADF_2	ADF_1	ADF_2	ADF_1	ADF_2
-2.5231	-0.3201	-1.7341	-0.5711	-2.1332	-2.3150

First Difference

$\Delta \ln ICT$		$\Delta \ln GDP$		$\Delta \ln FDI$	
ADF_1	ADF_2	ADF_1	ADF_2	ADF_1	ADF_2
-4.1867***	-5.1278***	-3.7003***	-4.0603**	-3.7818***	-3.8941**

Notes:

ADF_1 tests $H_0 : \theta_1 = 0$ in $$\Delta \ln X_t = \beta_0 + \theta_1 \ln X_{t-1} + \sum_{j=1}^{m} \beta_j \Delta \ln X_{t-j} + \varepsilon_t \qquad (7)$$

ADF_2 tests $H_0 : \theta_2 = 0$ in $$\Delta \ln X_t = \varphi_0 + \varphi_1 t + \theta_2 \ln X_{t-1} + \sum_{j=1}^{m} \varphi_j \Delta \ln X_{t-j} + \varsigma_t \qquad (8)$$

*, **, 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.

Having confirmed the existence of unit roots for all the data series, the next step is to check the results of Johansen-Juselius co-integration tests presented in Table 5. The Johansen-Juselius co-integration test provides evidence for the existence of one co-integration vector implying that the three variables are cointegrated. Thus, the results of Johansen-Juselius co-integration test imply a long-run association between ICT, real GDP, and inward FDI for India. Therefore, equations (4), (5) and (6) have been estimated including the error-correction terms.

Table 5
Johansen Multivariate Co-integration Tests

Trace Test	Null Hypothesis		
	$r = 0$	$r \leq 1$	$r \leq 2$
	39.04***	11.83	1.12
Maximum Eigen values Test	Null Hypothesis		
	$r = 0$	$r = 1$	$r = 2$
	27.21**	10.71	1.12

Co-integration Equations Normalized on $\ln FDI_t$				
	Constant	$\ln ICT_t$	$\ln GDP_t$	Log Likelihood
	22.7115	0.9698 (0.374)	0.3886 (0.021)	56.12

Note: *, **, and *** denote statistical significance at the 10% 5%, and 1% levels, respectively. Figures in parentheses are standard errors.

Table 6
Results of Error Correction Models

	Source of causation			EC_{t-1}	**Causal inference**
Dep. Variable	ΔICT	ΔGDP	ΔFDI	(t-value)	
ΔICT	-	7.4824 (0.004)	6.8227 (0.002)	-0.0037** (-2.663)	$GDP \xrightarrow{SR} ICT$; $FDI \xrightarrow{SR} ICT$ $GDP, FDI \xrightarrow{LR} ICT$
ΔGDP	6.7645 (0.002)	-	9.9314 (0.001)	-0.1729 (-1.308)	$ICT \xrightarrow{SR} GDP$; $FDI \xrightarrow{SR} GDP$
ΔFDI	7.4758 (0.002)	4.2030 (0.019)	-	-0.2927 (-0.685)	$ICT \xrightarrow{SR} FDI$; $GDP \xrightarrow{SR} FDI$

Notes:
EC denotes the error-correction term. *, ** and *** indicate the statistical significance at the 10%, 5% and 1% levels of significance respectively. 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 empirical results of the estimated error-correction models are presented in Table 6. Beyond the analysis of the long-run relationship among the three variables in the system for India, 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 6. 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.

The first interesting observation from our results is that India shows evidence of bi-directional association or correlation, consistent with the notion of causality for ICT and economic growth (GDP). These finding are quite consistent with the theory on ICT and growth indicating positive spillovers and ICT is an engine of economic growth in India.

The second observation from our results is that India shows evidence of bi-directional relationship consistent with the notion of causality for FDI and economic growth (GDP). These findings are consistent with standard literature in this field.

A third important observation of this study is that there is a two-way relationship consistent with the notion of causality between ICT and FDI indicating that ICT is an important determinant of FDI and FDI promotes ICT.

The results of this study find evidence to support the claim that ICT is a strong engine of growth in this region. In India, there is some evidence of either ICT-led growth or growth-led ICT; ICT led FDI or FDI led ICT; and FDI led growth or growth led FDI Granger causality in the short-run. A summary of our findings are presented in Table 7.

Table 7
Comparative Evaluation of Major Findings

Causation	Present
ICT $\Leftrightarrow$ *GDP*	√
ICT $\Rightarrow$ *GDP*	√
GDP $\Rightarrow$ *ICT*	√
FDI $\Leftrightarrow$ *GDP*	√
FDI $\Rightarrow$ *GDP*	√
GDP $\Rightarrow$ *FDI*	√
ICT $\Leftrightarrow$ *FDI*	√
ICT $\Rightarrow$ *FDI*	√
FDI $\Rightarrow$ *ICT*	√

Notes: √ denotes the presence of causality.

While the findings of our study are decidedly different from other empirical studies by Dewan and Kraemer (1998; 2000), Matti Pohjola (2000; 2002), and Addison and Heshmati (2003), it is however more consistent with theory. Our

analysis for India shows positive results with regard to a complementary relationship between Growth, FDI and ICT.

SUMMARY AND CONCLUSIONS

In this paper the co-integration and error-correction modeling techniques used indicate that there is a significant bi-directional relationship consistent with a theoretical proposition of causality between the three variables FDI, ICT and GDP. The outcome of our India study is consistent with theory.

The growing importance of India's ICT sectors share in exports, in GDP; in technology spillovers or in the labor force participation is now a fact rather than just a promise. It has allowed India to leapfrog vintage technologies thereby accelerating economic growth. The notion that unlike in developed countries where there already exist a built up ICT capacity which causes inflow of FDI, in developing countries like India, ICT capacity must be build up by attracting FDI, is long past. India's software industry has migrated upward to high value-added or higher value chain[6]. The bi-directional relationship between ICT and FDI indicates that ICT sector has matured enough that this sector is attracting the inflow of FDI all by itself. This suggests that in India, ICT infrastructure is an important factor in attracting foreign investors to undertake investment. This sector seems to have developed a virtuous cycle between the three FDI, ICT and GDP.

At the same time, there are many concerns with the ICT boom in India (Kapur, 2002). Linear projections of future growth extrapolating from the past should be treated with skepticism. If it were to turn out to be true, it would create a new set of macroeconomic problems for India. ICT related exports alone could well exceed all current account payments by the end of the decade, completely dominating all other parts of the economy.[7] This could put strong upward pressure on the Indian currency with inimical consequence on other sectors of the economy. The more troubling effect is that the inordinate focus on the ICT sector will only amplify India's inequality – Income inequality and urban-rural divide.

Despite the fact that rest of the Indian economic sectors are still in a developing country context and India is ranked lower in the Human Development Index, the growth of ICT sector and its role in economic growth has proven that it is now dynamic and globally competitive. The nature of the ICT puts it in a category called "general purpose technologies[8] (GPTs)" with large spillover effects in other sectors like bio-informatics, pharmaceuticals, media and entertainment in specific and higher productivity for all others sectors of the economy in general. The flood gates seem to have been opened up, there is already signs of new investments into other sectors of the economy as well, like infrastructure, automobile, pharmaceuticals, etc.

ENDNOTES

1. NASSCOM - National Association of Software and Service Companies
2. In this paper, IT (Information Technology) is synonymous with ICT (Information and Communication Technologies)
3. ITES/BPO - IT Enabled Services/Business Process Outsourcing
4. The economic role of ICT in determining FDI inflows as shown in Addison and Heshmati (2004) can also be explained by a conceptual framework of the Ricardian two-country model of trade (Dornbusch et al., 1977; Dornbusch and Park, 1987) to illustrate the effects of ICT on the host country's economy. A

Ricardian model is constructed so that the only difference between countries is in their production technologies and highlights one of the main reasons why countries trade (host country identified by FDI here); namely, differences in technology. It deals with the effects of technology on relative wages and the decision to (re)locate production to developing countries. In this paper we are testing an already existing hypothesis of a deemed causal link between ICT and FDI. Our purpose is to explore and explain the booming ICT sector in India.

5. NASSCOM categorizes ten different types of ICT-enabled services, varying widely in terms of skills required and value added - Customer Interaction Services, Business process Outsourcing /Management; Back Office Operations, Insurance Claims Processing, Medical Transcription, Legal Databases, Digital Content, Online Education, Data Digitization/GIS, Payroll/HR services, Website services.
6. An extension of this paper can be to look at the Intra-Industry Trade (vertical and horizontal) of India's ICT sector with other countries. This will certainly shed more light on how India ICT sector has moved up the value chain from being just a off-shoring model where companies outsource both their development (ICT services) and ITES/BPO activities to vertical specific skills like ICT consulting, network infrastructure management, systems integration, ICT training and education, hardware support and installation, network consulting and Integration to sales, legal, engineering/R&D, logistics and design and strategy.
7. If software exports continue to rise at 50.9 per cent per annum, they will reach $158 billion in 2008-09. If payments for visible and invisible imports continue to rise at 7.6 per cent — the average rate between 1990-91 and 1999-2000 — they will reach $138 billion. In other words, India could very well finance all its imports of goods and services from exports of software alone by that year. If nothing else changed, it would not need any other exports — or foreign investment. And if other exports continued and foreign investment kept coming in, India would have to increase its import intensity. Ashok Desai, unpublished manuscript, 2001.
8. GPTs – General purpose technologies is an idea introduced by Bresnahan and Trajtenberg (1995) , who define them in terms of having three key characteristics: pervasiveness, technological dynamism, and innovational complementarities. Helpman and Trajtenberg (1998) have developed a model of growth led by GPTs, in which sustained growth comes from the periodic, exogenous introduction of new GPTs. Other mechanisms that would give endogenous R&D, monopolistic competition, and introduction of new intermediate inputs as the mechanism of growth are similar to endogenous growth models. Dudley(1999), using a different theoretical approach, but the same overall idea, makes a case for ICT as a fundamental GPT.

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