Telecommunications Infrastructure and Economic Growth: Evidence from Developing Countries

Kala Seetharam Sridhar
and
Varadharajan Sridhar

Telecommunications Infrastructure and Economic Growth: Evidence from Developing Countries

Kala Seetharam Sridhar*

and

Varadharajan Sridhar**

Abstract

Often, it has been observed that telecommunication infrastructure development and economic growth proceed together. While this relationship has been studied in the context of developed (OECD) countries, in this study, we investigate this simultaneous relationship between telecommunications and the economic growth, using data for developing countries. Using 3SLS, we estimate a system of equations that endogenize economic growth and telecom penetration (respectively production function and demand for telecom services), along with supply of telecom investment and growth in telecom penetration. We estimate this system of equations separately for main telephone lines and cell phones. We find that while traditional economic factors explain demand for main line phones, they do not explain demand for cell phones. We also find significant impacts of cellular services on national output, when we control for the effects of capital and

labour. The impact of telecom penetration on total output is, however, significantly lower for developing countries than that reported for OECD countries, dispelling the convergence hypothesis.

JEL Classification Number: O47, O57, L96, H54
Keywords: Telecommunication, Infrastructure, Economic growth, Reverse causality, Developing countries.

----

* Fellow, National Institute of Public Finance and Policy, New Delhi.
E-mail: kala@nipfp.org.in
** Professor, Information Management Area, Management Development Institute, Mehrauli Road, Sukhrali, Gurgaon - 122 001, India. Email: Sridhar@mdi.ac.in.

Acknowledgements

We are extremely thankful to Nirvikar Singh for helpful comments regarding our paper. Thanks are due to M.Govinda Rao for facilitating preliminary review of the paper. The authors also wish to thank the faculty at Management Development Institute for their useful comments during a seminar where this paper was presented. We thank the Indian Institute of Management, Lucknow, India, for facilitating access to the WDI Online database. Finally, we thank the National Institute of Public Finance and Policy and Management Development Institute for facilitating the research.

Telecommunications Infrastructure and Economic Growth: Evidence from Developing Countries

Introduction

The co-existence of stark poverty and islands of technology innovation in many developing countries has received little attention in the literature. This paradox provides the motivation for our research regarding the relationship between technology and state of economic development in developing countries.

Convergence between Information and Communications Technologies (ICT), in particular the internet, and its related applications, has enabled low-cost diffusion of information technology products and services in developing economies. A number of researchers (Norton, 1992) have hypothesized that ICT infrastructure lowers both the fixed costs of acquiring information and the variable costs of participating in markets. They point out that as the ICT infrastructure improves, transaction costs reduce, and output increases for firms in various sectors of the economy (Roller & Waverman, 2001). Thus investment in ICT infrastructure and derived services provide significant benefits to the economy. In the recently concluded First World Summit on Information Society, Professor Klaus Schwab, Founder and Executive Chairman of the World Economic Forum pointed out that ICT continues to be the best hope for developing countries to accelerate their development process. However, in terms of the Network Readiness Index (NRI) published by the World Economic Forum (2003), developing countries[1] continue to be far behind (*see* Table 1).[2] Wong (2002) finds that the disparity in the intensity of ICT adoption among Asian countries is wider than disparities in their GDP per capita, and that Asia's share of global consumption of ICT goods, while gradually increasing over time, was consistently lower than its share in global production. This implies that the competence of the developing economies to benefit from ICT developments is limited.

Since the intensity of ICT adoption is itself significantly dependent on the level of economic development and competitiveness of nations (*see* Wong, 2002), it is important to study the relationship between ICT and economic development, if developing countries have to benefit from ICT developments and further their economic growth.

II. Motivation and Objectives

There are empirical investigations (refer to Roller & Waverman, 2001) that specifically look at how telecommunications infrastructure affects economic growth in developed economies, taking into account the two-way causation between them. However, these relationships have not been studied in the context of developing economies. Although there are islands of technology innovation in developing countries such as Bangalore in India, the observation is that Asian countries such as India, China, Thailand, and Philippines have had generally lower levels of ICT adoption than can be predicted based on their current level of economic development (Wong, 2002). This has effects on their economic development, which has not been studied.

The objective of this research is to analyse the effect of penetration of ICT on the economic development of developing economies, taking into account the two-way causation that exists between them. Economic growth parameters (GDP) are estimated as a function of telecommunications infrastructure such as main line tele-density. Based on the research, the contribution of ICT towards economic growth can be used as benchmark to gain insights for ICT diffusion in developing countries.

The paper addresses these questions to understand the dynamics of this causal connection i.e. is it telecommunication services that accelerates economic growth or overall economic growth that creates the demand for more telecommunication services for their growth to occur? In the context of developing economies, what are the factors that determine demand for and supply of telecom services. Finally, given the importance of telecom infrastructure in growth, what determines the change in telecom penetration in these economies?

The following section summarizes the literature on the subject. The section following the literature survey describes the methodology adopted. Then we describe the sample, data and the sources. Following description of the data, we report results from the estimations. The final section summarises the policy implications, then discusses data limitations, and concludes.

III. Review of Literature

The literature on the subject investigates the feasibility of telecommunication as one of the determinants of the economic development, and attempts to entangle the reverse causality between economic development and the demand for telecommunication services. Most infrastructure investments can positively affect the economy in three ways. First, it can reduce the cost of production. Second, it can increase revenues. Third, it can increase employment through both direct and indirect effects (Alleman *et al*.2002). Similar to other infrastructure investments, investing in telecommunication will increase the demand for the goods and services used in their production and increase total national output.

The impact of telecommunications on growth was first found by Andrew Hardy (Hardy, 1980) based on data from 45 countries, with the largest effect of telecommunication investment on GDP found in the least developed economies, and the smallest effect, in the most-developed economies.

Telecommunication infrastructure is also a little different from other infrastructure, as a determinant of economic growth because of the existence of network externalities, a phenomenon that increases the value of a service with increase in the number of users. Because of this, the impact of telecom infrastructure on economic development is more pronounced as compared to other traditional infrastructure. This phenomenon has been demonstrated by Kim *et. al.* (1997) in the analysis of online service competition. There exists a negative network externality resulting from congestion, which affects the subscription level of telecom services at the particular moment. But it forces service providers and regulators to accelerate the investment in telecom infrastructure. Norton (1992) showed that convergence could occur if developing countries could add to their stock of telephones rapidly, since they reduce transaction costs.

Garbade and Silber (1978), find strong statistical support for the hypothesis that the two innovations in communication technology – the telegraph and Trans-Atlantic cable -- led to efficient market places world wide through significant and rapid narrowing on inter-market price differentials. The research by Bayes *et. al.* (1999) finds that half of all telephone calls involved economic purposes such as discussing employment opportunities, prices of the commodities, land transactions, remittances and other business items. Bayes *et. al*. also noted that, the average prices of agricultural commodities were higher in villages with phones than in villages without phones. Leff (1984) argues that firms can also have more physically dispersed activity with increased telecom services (for instance, encourage telecommuting of their employees) and enjoy economy of scale and scope.[3]

De Long and Summers (1993) find, based on several regressions and instrumental variable methods, strong connection between investment and productivity growth in developing countries, which imply that developing economies have to import and install machinery and equipment, in order to grow. Using the Peterson Index, Cronin *et. al*. (1993b) finds a statistically significant causal relationship between productivity growth and portion attributable to telecommunications.

Eggleston *et. al.* (2002) show how basic telecommunication infrastructure can create a "digital provide" by making market efficient through information dissemination to isolated and information-deprived locals and improve the living standards of the world's poor, which in turn accelerates growth. As the authors themselves point out, their analysis is based on references and examples, and that more careful analysis is needed in the context of developing countries. Souter (1999) provides a survey of the ways in which ICT can be employed for the social and economic development of remote or rural communities.

Overall, the literature estimates that one percent growth in telecommunication services generates three percent growth in the economy (Gupta, 2000).

But we know that increases in purchasing power (contributed by increased telecom services) also increase demand for such services. Chatterjee *et. al*. (1998) point out that income patterns decide the disposable income levels i.e. purchasing power for telecommunication services, and in turn the growth of services.

This reverse causality has also been investigated by Cronin *et. al*. (Cronin *et. al.*1991, Cronin *et. al.*1993a). Cronin *et. al.* (1991) employ the Granger, Sims and modified Sims tests to confirm the existence of feedback process in which economic activity and growth stimulates demands for telecommunication services. As the economy grows, more telecommunications facilities are needed to conduct the increased business transactions. Cronin *et. al.* (1993a) investigate this relationship at the state and sub-state levels. This study confirms at both the state and county levels, using data from the state of Pennsylvania, U.S., and finds that telecommunication investment affects economic activity and that economic activity can affect telecommunications investment.

Roller and Waverman (2001) were the first to use simultaneous approach to incorporate both effects in the economic model in order to validate the hypothesis of reverse causality. They use data for OECD countries that are all high-income.

Contribution of the study

In this study, we examine the sparsely studied relationship between telecom infrastructure and economic growth in developing economies, as these countries can use ICT diffusion for spreading growth more rapidly. In developing countries rural teledensity is very low. One of the reasons is high cost of providing telecommunication services in rural areas and low purchasing power of rural population. While in developed countries, 90 percent of the households can afford monthly expenditure of US dollar 30 on telecommunication services, only 5-6 percent of the households can afford in developing countries such as India (Jhunjhunwala, 2000). One way to improve rural teledensity is to reduce the cost of access loop for providing telecom services using technologies such as wireless local loop (Jain and Sridhar, 2003). It is also imperative to improve the economic activity of the rural areas using telecommunication related services so that the rural population has enough disposable income to purchase telecom services (Souter, 1999). For an understanding of relevant issues in rural telecom in India, *see* Sridhar *et. al.* (2000).

Thus there are a number of issues that are relevant to be considered only in the context of a developing country. This provides the motivation for us to more comprehensively model the growth of telecommunication services and investigate the strength of its causal relationship with the level of economic growth, and examine how to use ICT as a tool to enable growth in developing countries. In this study, we also estimate the price and income elasticities of demand for telecom services for low-income economies defined by the World Bank. We use panel data from these 63 economies to model this relationship. We use demographic and general economic data, for these economies for 1990-2001 from World Development Indicators (WDI), and telecom indicators for the same period for these economies from the International Telecommunications Union (ITU) Year book (ITU, 2003a).

Below we discuss our approach, methodology, model, and the data.

IV. Approach and Methodology

We use systems method to do the various estimations. We estimate demand for and supply of telecom infrastructure, and endogenize telecom investment and the change in telecom infrastructure penetration. We estimate these equations along with the macro economy production function, using data over 1990-2001 period for 63 developing countries. Further, we estimate the system of equations separately for main telephone lines, cell phones and all telephone lines which includes both main lines and cellular services. Note that Roller and Waverman (2001) report estimation results for main telephone lines, and for OECD countries.

As Jha and Majumdar (1999) note, for developing countries, where penetration rates of telephones are extremely low, catching up with developed countries in terms of telecom infrastructure has meant investment in wireless and mobile systems local loops, bypassing investment in fixed lines. This is especially so because mobile networks are a quick and inexpensive way for developing green field projects. Our calculations show that in the developing economies, the compounded annual growth rate (CAGR) of cell phones over the period 1996-2001 was 78 percent compared to a growth of mere 7 percent for main telephone lines over 1990-2001 (Table 2). Reduced per line cost, quick deployment and better available technology are reasons for such growth of cellular services in developing countries (Jain and Sridhar, 2003, Jha and Majumdar, 1999).

Given this growth in cellular service, we use demand for cellular services in a different model specification, as part of the system of equations, to analyse comparatively the contributions of main line and cellular mobile penetration to economic growth.

Simple Pearson's correlation coefficients between GDP per capita and total, main and cell phone penetration are found to be respectively 0.59, 0.58 and 0.24 (all statistically significant). Although these correlations are not as high as those found by Roller and Waverman (2001), given their statistical significance, it is not surprising that we subsequently find quite substantial effects of telecom penetration on GDP.

We use 3SLS to estimate the system of equations.[4] We deploy the structural model which endogenizes telecommunication investment, similar to that in Roller & Waverman (2001). Further, we identify certain variables that are of specific relevance in the context of developing economies.

We have developed three models, the first one considering both main telephone lines and cellular services, the second one only the main telephone service and the third model considering only the cellular mobile service. List of the variables used in the models and their descriptions are given in Table 3.

Note that in each model we estimate a system of equations. In the first equation (all models), we relate the national aggregate economic activity measured in GDP to Annual real Gross Fixed Capital Formation net of Telecom investment (K), total labour force (LF) and stock of telecommunications infrastructure measured in tele-density (number of telephones per 100 population).

The aggregate production function, relating total telecom service (or main lines only (second model) or cellular penetration (third model)), to national output, is as follows:

$$\text{Log}\,(GDP_{it}) = a_{0i} + a_1 \log (K_{it}) + a_2 \log (LF_{it}) + a_3 \log (TPEN/MTEL/CELL_{it}) + a_4 t + e^1_{it} \qquad (1)$$ [5]

In (1), t is a linear time trend. We expect all the inputs – capital (net of telecom), labour, telecom infrastructure to have a positive effect on total national output.[6]

Our next equation in the system of equations (all models) is demand for telecom service. In most of the developing countries, initially, the government was providing telecommunications service and there was a huge waiting list for main telephones. Hence we define effective demand for telecommunications infrastructure as the sum of existing teledensity and waiting list for mainlines.[7]

We model the demand for telecom as for a normal good or service, as being dependent on income and price. This demand is a function of real price of telecommunication services and real per capita GDP. In contrast to Roller and Waverman (2001) who use telephone service revenue per mainline, we use the monthly subscription charge as measure of telephone price. These charges are normally referred to as rentals, and we use the rental charges for main lines, cellular services and the average of the two in the model for total telecom penetration. We use rental as a measure of telephone price owing to the following reasons:

- Telephone service revenue per mainline may not be a suitable measure of telephone price if revenue does not necessarily increase or decrease with price. This itself depends on the price elasticity of demand.
- Monthly rentals are normally used to recover the capital cost of providing telecom services. The user also pays for usage. Since we are interested in penetration, it is only access to telecom

infrastructure, not the usage of the infrastructure itself that is of interest to us.

The demand equation, hence, can be written as follows (note that in each specification, we replace demand for total telephone services, mainlines and cellular services and their respective prices):

$$\text{Log}\,(\text{TPENWL/MTELWL/CELL}_{it}) = b_{0i} + b_1 \log(GDPCAP_{it}) + b_2 \log(TELP/MLPRCE/CELLPRCE_{it}) + e^2_{it} \quad (2)$$

As in traditional microeconomics, we expect the price elasticity of demand to be negative, and the income elasticity, to be positive.

To model the supply side of telecommunications, we determine annual telecom investment (TTI) as a function of certain geographic, economic, and regulatory variables. We operationalize these factors using geographic area of the country (GA), and telecommunication service price, measured using the monthly subscription charges, and regulatory structure of the telecom industry.

Note here a technical point. In the demand equation, for mainline and cell phone specifications, we use the price of getting a main landline and cellular service respectively, as the telecom price. In the supply equation (all models), however, we use the average telephone (average of main and cell phone) price, in all specifications, as determining the supply of telecom infrastructure. This is because, while price of landline/cellular service determines the demand for landline/cellular service, the supply of telecom infrastructure is more complex. Telecom infrastructure is composed of access networks (landlines and cellular access) and backbone networks that interconnect access networks. Completing a landline or a cellular call depends on the existence of interconnection across these networks. This makes it wrong or inadequate specification to make supply of telecom depend only on mainline price or cell phone price in any specification. Also it is to be noted that annual telecom investment reported in ITU (2003a) is not available by landline/cellular services for the reasons mentioned above. Hence we use average telephone price as the appropriate price variable in the supply equation in all models. In general, price has a positive effect on supply.

Further, the supply of telecom investment depends on potential demand measured by the waiting list for main telephone lines. Next, note that given the service-price nexus in the sector (unlike road infrastructure, for instance), investment opportunities are lucrative, and the market structure plays an important role in determining the supply of telecom investment. Most of the countries migrated from a government monopoly operation to duopoly and eventually competition in basic and cellular mobile services. The liberalisation in telecom industry brought in both fresh—domestic and foreign—investment into the country. For example, India witnessed an increase in telecom investment from $2.82 billion in 1998 to $3.98 billion in, an increase of over 40 percent (ICRA, 2002). We have indicated whether there is monopoly (1) or competition (0) in either the basic or cellular service by a dummy variable (MKTDUM). In general, competition encourages more investment. Noll (2000) refers to certain aspects of market structure that favour competition over monopoly in telecom services. One is technological progress that has stimulated heterogeneous demand among consumers such as mobility (cell phones), speedy transmission of large data files and high-speed digital transmission. These, as he points out, favour entry by specialised firms that cater to a specialised niche area. Second, the inefficiency of incumbent monopolies. That is, in countries where service is poor and penetration low, entrant firms (service providers) can take advantage of excess demand to build a network of superior performance that is attractive to the customers. Finally, Noll (2000) points out a politically attractive feature of competition as well–increasing foreign capital flows into the industry. We have included only the current market structure due to non-availability of data for previous years in our study. This is not a serious limitation as most of the countries started out with duopoly in cellular service and continue to remain so. Most of the developing economies as indicated before continue to have monopoly in basic services**.** Since we use the price of telephone service in the supply equation along with regulatory structure, it can be argued that there can be correlation between price and market structure. Competitive markets force prices to be lower compared to monopoly markets. However, in most of the developing countries regulator fixes the price of basic services to make it affordable, and hence the evolving competition does not have an effect on price. Even in cellular service where price is market driven, imposition of high license fees and interconnection charges forces prices to settle down at cost plus levels and introduction of additional players does not have notable effect on service prices (also *see* Singh 2002). We have noted from the ITU website (*www.itu.int*) information for all countries on whether/not interconnection charges and license fees are regulated, and who the regulator is, but not the actual charges.

Taking into account these considerations, the supply function is estimated as given in equation (3).

$$\text{Log}\ (TTI_{it}) = c_{0i} + c_1 \log(GA_{it}) + c_2 WL_{it} + c_3 \log(TELP_{it}) + c_4 MKTDUM_{it} + e^3_{it} \quad (3)$$

Note that there is no variation in model specification for total, main or cellular service for reasons mentioned above. We expect geographic area to have positive effect, so that the larger the land area of the country, larger will be the investments required, to maintain a certain level of penetration. The waiting line for main lines is an indicator of market demand, and so will have a positive impact.

Finally, equation (4) shown below, characterises the growth of telecom penetration as a function of the telecommunications investment and geographic area of the country. Note that here also, the specification within the system is the same for total, mainlines and cellular service. We expect that investment will have a positive impact, and geographic area, negative impact on the penetration rate.

$$\text{Log}\ (CHGTEL/CHGMTEL/CHGCELL_{\ it}) = d_{0i} + d_1 \log(TTI_{it}) + d_2 \log(GA_{it}) + e^4_{it} \quad (4)$$

For all models, the list of instruments we used were: time trend t, levels of capital stock (net of telecom investment) and that of labour force, geographic area, market structure dummy, and average telephone price (average of subscription charges for main line and cell phones). These variables are exogenous to all equations in the various models.

V. Description of Full Sample

Tables 4-5 give descriptive details of relevant variables, for observations used in the main line and cell phone estimations respectively. The minimum and maximum values for the time trend show that we have used 12 years for our study (1990-2001). Because of our calculation of change (over the previous year) for various forms of telephone penetration, for the estimations, we lose a year for all countries. The observations for cell phones are lower than those for main lines, as most of the countries started experiencing rapid cell phone penetration only after 1995 (Table 5). The change in penetration for land lines and cell phones are greater than 1 (Tables 4-5) suggesting continual increase in land line penetration, and more so for cell phones. Interestingly, the average and maximum waiting list for landlines in countries with cell phone (the smaller sample, Table 5) are much smaller than those in the full sample. This shows that countries with rapid cell phone penetration did not have waiting lists to the same extent as those without.

On average, the total telephone penetration in the developing countries we have studied, is much lower (being 2.5 per 100 inhabitants) than that observed in the OECD countries (30 per 100 inhabitants). In our sample, the maximum total tele-density is itself 20, observed for Ukraine in 1999. The landline penetration is even less. On average the GDP per capita for these countries is much lower than that observed for the OECD group of countries.

The average telephone price and mainline price are quite small in constant 1995 US dollar, when compared to that for cell phone subscription. Here it may be relevant to note that in developing economies, for basic mainlines, the tariffs are always kept low by the regulator to make the service more affordable.

The mean for market structure dummy in the full sample shows that 60 percent of countries continued to have monopoly in providing telephone services.

VI. Results from Estimation

Tables 6-7 show the estimation results for the three specifications of system of equations. These tables show estimates of the production, demand, supply, and finally of the change in telecom penetration.

Estimation for all telephone lines (main lines and cell phones)

Estimates of the production function for all telephone lines are as expected. These estimates indicate that capital, labour force and total telephone penetration positively impact aggregate output.[8] The elasticities we obtain for capital, and labour are respectively 0.49 and 0.47. This indicates that 1 percentage increase in labour and capital inputs roughly increases aggregate national output by 0.5 percent each. Roller and Waverman (2001) find output elasticities of 0.41 and 0.69 each for capital and labour. Our estimates show that a 1 percent increase in tele-density (total telephones per 100 population) increases national output by 0.14 percent, whereas Roller and Waverman (2001) find output elasticity of 0.05 for main lines *per capita*, after allowing for country-specific fixed effects. We find elasticity of 0.13 for main line tele-density (Table 6). Thus it is possible that the impact of telecom penetration on total output, is significantly lower for developing countries than that observed for high-income countries, dispelling the convergence hypothesis.

Estimates of the demand for telecom infrastructure, when we take into account all telephone lines, show the dominance of traditional economic factors – income and price. The income elasticity of demand for telecom services is positive and greater than 1 (being 1.64), indicating elastic demand. This implies that the reverse causation we suspect exists between telecom and economic growth, indeed is true. So any increases in GDP translate to increases in personal disposable income, and hence increase demand for telecom services. The price elasticity of demand is as expected, negative (-0.30), less than what Roller and Waverman (2001) find with respect to OECD countries.

Estimates of the supply equation indicate that the market potential (WLMLNS) is an important determinant of investment in telecom, despite the small magnitude of its coefficient. The dummy for market structure is positive and significant. This shows that in developing countries that are characterised by monopoly in the telecom industry, more investment in telecom may be expected when compared with their counterparts that have competition in these services. This is an anomaly, as we expect that with open markets and competition, more investments follow. One reason for the anomalous result could be that the telecom investment data obtained by ITU is normally from the government operators. For example, the annual telecom investment of INR 165 million in 2001 reported by ITU (2003a) refers to only investment by the largest government operator, which contributed to 88 percent of the total investment in the telecom sector for that year (ICRA, 2002). Thus, with increased competition, less may be invested by the government operators, but private investment could have increased. This appears to be more of a data issue than a problem with our finding.

The final equation estimates changes in telecom penetration as dependent on investment and geographic area. As we expect, holding other factors constant, telecom investment always increases penetration. Specifically, a 10 percent increase in investment increases telecom penetration by 2 percent. Similarly, holding others constant, larger countries (those with larger geographic area) have lesser telecom penetration compared to smaller countries, as we expect.

Estimation for main landlines

As discussed earlier, we estimate separate systems of equations for main telephone lines and cell phones, to disaggregate their effects in poor countries. When compared to the effect of total telecom penetration, the elasticity of aggregate national output with respect to main telephone lines is smaller (being 0.12, compared to an elasticity of 0.14 for all telephone lines). The capital and labour elasticities of output remain positive.

The demand equation for telecom shows that when it comes to main landlines, the price elasticity of demand is larger than that for total penetration. Given the fact that our price variable measures the monthly fixed connection charge for installing landline telephone service, a 10 percent reduction in this price can be expected to lead to a 5 percent increase in the demand for main telephone services in these developing countries. This is because, during monopoly regimes, the erstwhile government monopolies cross subsidised basic services in the form of lower rental and usage charges, from their other revenues. Even after competition was introduced, basic service provided through landlines have lower rental ceilings prescribed by the regulator to make it affordable to much of the population. Even a small increase or decrease in main line price will affect telecom penetration much. On the other hand, cellular prices are market driven.

Estimates of the supply of telecom infrastructure are very similar to what they were for all telephone lines. As in the supply equation for all telephone lines, the potential demand (WLMLNS) has a positive and significant influence on investment decisions, despite its small magnitude. Similarly, like before, countries with monopoly have more telecom infrastructure than those with competition. This, as before, we suspect is a reflection of data problems rather than an inherently opposite trend.

Finally, estimates of the change in telecom penetration equation are as we expect. This shows that a 10 percent increase in investment can lead to a 1 percent increase in telecom penetration for land lines, lower than for all telephone lines.

Estimation for cell phones

As we indicate, we estimate a separate system of equations for cell phones (Table 7). First, note that developing countries with low penetration rates for main telephone lines, find cell phones to be quite inexpensive and less time-consuming to install. Second, demand for mobile communication devices such as cell phones need not be always driven by economic factors even in developing economies.

Note that the sample size here is much smaller (being based on 63 observations) because of the non-availability of cell phone related data from a number of countries during our study period.

Estimates of the production function taking into account cell phones show that when the contributions of capital and labour in total national output are controlled for, cell phones are the only ones that contribute significantly to national output. The elasticity shows that a 1 percent increase in cell phone penetration can cause output to increase by 7 percent. So far, our review of the literature has shown output increases of up to 3 percent as being normal with telephone penetration increases.

Although our estimate of this effect may seem a little exaggerated, there are some reasons to believe why we may expect this to be the case:

- Cell phone penetration in the developing countries in our sample started increasing rapidly during the second half of the 1990s due to changes in telecom regulation (*see* Table 2), and move to competitive market structures. Most of the developing countries leap-frogged into second-generation mobile cellular systems, bypassing deployment of main lines.
- Cell phone penetration can lead to dramatic increases in output by reducing transaction costs, including, but not limited to, decisions relating to production of goods and services. For instance, value added services such as stock quotes and commodity prices provided by cellular service providers at affordable prices using the latest digital cellular technologies, may be expected to produce tangible economic outcomes.

Estimates of the demand for cell phone services show that traditional economic factors that explain the demand for other services (including main landlines) do not explain demand for cell phones. None of the traditional price or income elasticities of demand for cell phone services are significant at the conventionally accepted levels. This shows that micro, household decisions relating to cell phone services are dependent on non-economic factors. These could be related to necessity, whether or not long commutes to job are involved, and nature of job (for instance, on-site workers). Since we could not capture these micro-level variables in our data set, we are unable to explain well the changes that occur in the demand for cell phones. But we find that price and income variables are not important in explaining demand for this service.

Estimates of the supply equation for telecom investment when we take into account only cell phones, show that market potential (WLMLNS) has a powerful positive influence on its supply. This effect is the same as what we have found with respect to all telephone lines and main telephone lines. Unlike the other equations, however, the land area has a positive and significant influence on supply of telecom infrastructure. This shows that having large geographic areas necessitates increased investment in infrastructure to increase penetration. Frequently it is this investment in infrastructure that facilitates adoption of cell phone services as compared to landlines.

Finally, estimates of the equation that explains changes in cell phone penetration do not yield expected results. Telecom investment has a negative effect on cellular penetration, contrary to expectation. Note that in most of the developing countries cellular services are green field projects, requiring a huge capital investment to commence. Initial investment in interconnection facilities to connect to other networks does not immediately translate into increase in subscriber base. It is possible that there could be some time lag before green field projects translate to increased penetration. There is a large and positive impact of land area on change in cell phone penetration. This is unusual as larger areas require more infrastructure for providing service and hence will have low penetration rates. However, the geographic reach of wireless cellular service is superior compared to wired landline services.

VI. Policy Implications of the Research

Our research shows, how, for the first time, in the context of developing economies, we can expect telecom penetration to affect GDP and how telecom investment can impact penetration. This has implications for how developing economies can increase their penetration with increases in telecom investment, and if they do, how much they can expect their national output to grow.

We work through an example to show what our findings mean for India. Our model (for total telecom penetration) predicts the total GDP for India to have been US $454 billion (constant 1995 dollars). Note that India's actual GDP for 2001 was US $496 billion (again in constant 1995 dollars). The error in prediction is roughly –9 percent.

We note that India's National Telecom Policy (NTP), 1999 envisages a tele-density of 7 (main lines + cell phones) by the year 2005, and 15 by 2010. This, we assume, is the expected total telecom penetration. At these envisaged levels of tele-density, India's GDP, using our model (for total telephone penetration), taking into account the 9 percent prediction error, in 2005 would be US $ 529 billion, 7 percent increase over its 2001 actual GDP. In 2010, with tele-density of 15, India's GDP would be US $589 billion, 19 percent increase over its actual 2001 GDP. Alternatively, if India were to have Ukraine's tele-density (20, which is the highest in our sample), holding its capital and labour resources constant, India's GDP would be $614 billion, 24 percent increase over its actual 2001 GDP.

How can India achieve this tele-density? The Telecom Regulatory Authority of India (TRAI, 2001) noted that "…by the year 2010, the tele-density is targeted to reach 15 percent. ….To achieve all this, both the basic and the cellular mobile services will have to achieve a high rate of growth involving a very substantial investment of the order of about US $ 70 billion" (ICRA Report, 2002)).

To evaluate the implications of TRAI's suggestion, we convert their envisaged level of investment to average, annual constant US $ using India's implicit price deflator.[9] This turns out to be US$72 billion (in 1995 constant dollars) over a period of 10 years, or US $7.2 billion per year.[10] At India's 2001 investment of US $3 billion (constant 1995 dollars), our model predicts India's telecom penetration to have increased by 1.11 times its penetration in 2000. However, in reality, India's actual penetration over 2000-01 increased by 1.23 times. Again, factoring into account the 11 percent prediction error, we find that at the levels of telecom investment envisaged by TRAI, India's telecom penetration can increase by 1.26 times every year. Given this growth, our model predicts a tele density of 14 by 2006 for India, at the investment level envisaged by TRAI.

Our research also shows in developing countries wireless mobile networks contribute significantly to national output. Hence policymakers need to create a conducive competitive climate for the growth of this industry segment. Traditional compartmentalisation and separation of licenses for landline and mobile services is blurring owing to convergent technologies. For example, in India, Unified Access License that integrates basic and cellular services has been initiated by the government and the regulator (DoT, 2004). This allows basic services to provide mobile services using appropriate technologies. The license fees and spectrum charges for mobile services are still high in most of developing countries (Singh, 2002). The interconnect charges are fixed to favour the incumbent government firms which in turn increases the price (Sridhar, 2003). Hence the regulator and the government should fix optimal license, spectrum, and interconnect charges which provides enough revenue for the government without affecting the competitive climate.

Being green field projects, setting up telecom infrastructure requires huge investment, especially in developing countries. Domestic market in developing economies cannot generate required funds due to their smaller size. Countries such as India, set upper limit on Foreign Direct Investment and cite security concerns for restricting the flow of foreign investment in the telecom sector. Foreign investors also are reluctant to invest when telecom policies are not transparent and stable (Sridhar, 2000). Policymakers and regulators should promote a conducive climate for foreign investment so that the huge capital investment required for building telecom infrastructure can be met.

VII. Summary of Findings and Limitations

In this study, we investigate the simultaneous relationship between telecommunications and the economic growth, using data for developing countries. We estimate a system of equations that endogenise economic growth and telecom penetration (respectively production function and demand for telecom services), alongwith supply of telecom investment and growth in telecom penetration. We find significant effects of main landline and cell phone penetration on economic growth, when we control for the effects of capital and labour, but lower than that found for OECD countries, dispelling the convergence hypothesis. We also find that while traditional economic factors explain demand for main land phones, they do not explain demand for cell phones.

When we use the model to predict the level of telecom penetration for India, we find that India's teledensity will reach 14 by 2006. In fact, what has occurred in our post-sample period, in India validates the model. The total number of mobile subscribers in the country touched 24 million in November 2003.[11] Taking this and the main landlines into account, teledensity in the country has reached 7 in 2003, and is expected to reach 15 percent by 2006 well ahead as specified in NTP (ET, 2003).

Remember that there are data limitations that could limit the value of the estimations. The cell phone sample is quite small since data on cell phone related information are reliable and available only post 1996. For regulatory structure, we have used only the most current year regulatory structure and assumed that it was valid for the entire study period. Our assumption here is that anyway, since the regulatory structure has evolved to what it is today, that is reflective of current and future market structure in the industry. It would probably be a good idea to use number of service providers instead of a dummy for denoting market structure. However, this data is not available from ITU. Further, license fees and interconnect agreements affect telecom penetration and are important especially in the context of developing economies, as Singh (2002), points out. Again, however, these detailed data are not available for developing economies.

Government deficit, as used by Roller and Waverman (2001), may have been a good indicator of governments' ability to invest in telecom given the ITU database, but reliable estimates of government deficit were not available either from ITU or from WDI. Data on central government debt, as a proportion of GDP, available from WDI, seemed to be highly erratic across countries, time periods and sparse. So we were unable to use a good measure of this indicator to determine the supply of telecom investment. It is possible that we may have obtained better estimates of the supply function if we had access to better data.

VIII. Concluding Remarks

Everything said and done there is no doubt regarding the fact that most of these developing economies have leap-frogged in cellular telephony as a quick and inexpensive way of increasing telecom penetration. Most of these economies have actually significantly deregulated their telecom sector, and investment to increase telecom penetration (especially using the wireless local loop route) does not seem to be the big issue any more. The big question that continues to haunt many of these economies is, however, how increased telecom penetration can be used to accelerate their economic growth and alleviate poverty. This, it may be realized, is largely possible only with the effective use of a very important resource, information, ICT has enabled all to acquire. Telecom services may be used to obtain information regarding prices, job opportunities, and markets. This is not a substitute for actual economic growth, but a good enabler for economic growth to *trickle down*, once it occurs.

Table 1: Network Readiness Index Ranking (1=high; 102=low) of Developing Economies

Country	Network Readiness Index
Angola	99
Bangladesh	93
Cameroon	83
Ethiopia	101
Ghana	74
Gambia	82
Haiti	100
Indonesia	73
India	45
Kenya	84
Madagascar	92
Mali	96
Mozambique	97
Malawi	88
Nigeria	79
Nicaragua	94
Pakistan	76
Senegal	81
Chad	102
Tanzania	71
Uganda	80
Ukraine	78
Zambia	85
Zimbabwe	95

Source: World Economic Forum, 2003

Table 2: Annual Growth of GDP Per Capita, Main Telephone Lines and Cell Phone Penetration in Developing Economies

(Percent)

Country	CAGR, 1990-2001, GDP Per Capita	CAGR, 1990-2001, Mainlines per 100 inhabitants	CAGR, 1996-2001, Cell phones per 100 inhabitants
Afghanistan	NA	-4.29	NA
Angola	-2.29	-2.09	66.54
Armenia	-2.95	-0.96	101.53
Azerbaijan	-2.33	2.10	81.94
Burundi*	-1.19	0.88	NA
Benin	1.54	9.49	83.99
Burkina Faso	2.06	8.70	100.00
Bangladesh	2.75	5.74	NA
Bhutan	3.03	17.41	NA
Central African Republic	-0.65	2.92	45.95
Cote d'Ivoire	-0.53	9.29	88.32
Cameroon	-0.85	5.68	101.53
Republic of Congo	-1.20	0.00	NA
Comoros	-45.66	4.14	NA
Eritrea	3.67	7.71	NA
Ethiopia	0.95	4.28	NA
Georgia	-6.78	4.84	130.89
Ghana	1.08	12.25	53.90
Guinea	1.17	4.97	62.26
Gambia	0.21	12.18	57.49
Guinea-Bissau	-0.77	4.03	NA
Haiti	-45.26	2.88	NA
Indonesia	2.48	15.85	49.45
India	3.34	16.66	66.10
Kenya	-1.08	2.65	140.19
Kyrgyz Republic	-3.93	0.72	NA
Cambodia	1.30	19.33	40.05
Lao PDR	3.52	16.30	37.89
Liberia	0.66	-4.02	NA

Country	CAGR, 1990-2001, GDP Per Capita	CAGR, 1990-2001, Mainlines per 100 inhabitants	CAGR, 1996-2001, Cell phones per 100 inhabitants
Lesotho	1.53	2.95	87.89
Moldova	-7.93	2.65	152.07
Madagascar	0.23	3.90	90.30
Mali	1.76	11.50	87.89
Myanmar	NA	11.80	6.99
Mongolia	-1.11	4.15	142.43
Mauritania	1.48	10.49	NA
Malawi	1.11	4.40	54.31
Niger	-1.06	4.66	NA
Nigeria	0.80	3.63	87.17
Nicaragua	-0.39	7.32	70.62
Nepal	2.62	12.76	NA
Pakistan	1.33	9.91	49.58
Rwanda	-1.54	3.93	NA
Sudan	3.05	15.57	NA
Senegal	0.96	12.44	132.02
Solomon Islands	-2.29	1.93	16.06
Sierra Leone	-4.78	3.07	NA
Somalia	NA	6.20	NA
Sao Tome Principe	-44.01	5.50	NA
Chad	0.04	5.95	NA
Togo	-1.14	11.23	NA
Tajikistan	-8.22	-1.92	NA
Tanzania	0.61	3.84	86.69
Uganda	2.75	3.44	96.75
Ukraine	-5.80	3.80	104.74
Uzbekistan	-1.49	-0.25	35.72
Vietnam	5.07	31.55	60.53
Yemen	0.32	6.11	54.31
Democratic Republic of Congo	17.06	18.78	NA
Zambia	-2.03	-0.69	83.62
Zimbabwe	-0.68	4.93	NA
Average, all developing countries	**-2.03**	**6.61**	**77.99**

Table 3: Variable Description

Variable	Description
GDP*	Real Gross Domestic Product in US$
GDPCAP*	Real GDP per capita in US$
MTEL	Number of main telephones per 100 inhabitants
CELL	Number of cellular subscribers per 100 inhabitants
TPEN	Total Telecom Penetration computed as the sum of main line (MTEL) and cellular (CELL) teledensity
WLMLNS	Waiting list for main lines
MTELWL	Sum of main line teledensity and waiting list for main lines per 100 inhabitants
TPENWL	Sum of total telecom penetration (TPEN) and waiting list for main lines per 100 inhabitants
CHGTEL, CHGMTEL, CHGCELL	Growth of total telecom, mainline and cellular penetration
K	Annual real Gross Fixed Capital Formation (GFCF) net of Telecom Investment in US$
MLPRCE*	Real Residential Telephone Monthly Subscription in US$
CELLPRCE*	Real Cellular Monthly Subscription in US$
TELP*	Average of monthly subscription charges for main line (MLPRCE) and cellular service (CELLPRCE)in US$
TTI*	Real Annual Telecommunications Investment in US$
LF	Total Labour Force
MKTDUM	Dummy variable for nature of market structure: 1 for monopoly and 0 for competition
T	Time period
GA	Geographic Area

*Values of macro variables, GDP, GDPCAP, and TTI have been converted in to 1995 constant US$ using Implicit Price Deflator. Values of micro variables, MLPRCE, CELLPRCE and TELP have been converted in to 1995 constant US$ using Consumer Price Index.

MKTDUM is derived from ITU (2003b). All the other variables are from ITU (2003a).

Table 4: . Description of Relevant Data for full sample (N=225)

Variable	Mean (Std.dev)	Minimum	Maximum
Time trend	6.78 (2.99)	2	12
Change in total telephone penetration (over previous year)	1.17 (0.29)	0.65	3.90
Change in main landline penetration (over previous year)	1.09 (0.16)	0.65	2.70
Waiting Line for main landlines	278534.09 (721792.06)	255	3681000
GDP	30,611,015,815 (84,416,477,597)	354,989,937	496,028,886,060
Capital stock (net of telecommunications capital)	6,386,960,765 (18,855,477,214)	41,883,395	110,590,496,989
Labour force	32,767,919 (88,590,503)	491,196	460,535,269
Total telephone lines per 100 population	2.49 (4.40)	0.07	20.32
Total Landlines per 100 population	2.25 (4.22)	0.07	19.89
GDP per capita (in US Constant $, 1995=100)	418.66 (217.17)	92.21	1076.21
Average telephone price	0.10 (0.16)	0.002	1.97
Main landline price	0.05 (0.06)	0.009	0.41
Land area	605,794.59 (667,393.08)	9,999.60	2,973,053.21
Telecom investment	192,307,349 (561,916,943)	13095	3,620,941,819
Market structure dummy	0.60 (0.49)	0	1

Table 5: . Description of Relevant Data for Cell Phones (N=63)

Variable	Mean (Std.dev)	Minimum	Maximum
Time trend	9.32(2.16)	4	12
Change in cell phone penetration (over previous period)	3.50 (7.03)	0.16	54.40
Waiting Line for main landlines	188,812 (523,209.93)	255	2962200
GDP	19,658,907,411 (63,423,925,054)	378,603,484	496,028,886,060
Capital stock (net of telecommunications capital)	3,879,303,429 (14,047,921,278)	60,654,234	110,590,496,989
Labour force	20,189,380 (59,028,196)	550,785	460,535,269
Cell phone penetration, per 100 population	0.58 (0.94)	0.01	4.46
GDP per capita, in constant US $ (1995=100)	457.68 (221.26)	115.99	1069.56
Average telephone price	0.10 (0.10)	0.001	0.52
Cell phone price	0.17 (0.19)	0.02	0.95
Land area	429,289.31 (444,135.65)	9,999.60	2,973,053.21
Telecom investment	123,845,742 (453,196,877)	673,336	3,620,941,819
Market structure dummy	0.65 (0.48)	0	1

Table 6: Estimation of System of Equations: All telephone lines (Model 1) and Main Land lines (Model 2) (N = 225)

Equations/Variables	Model 1: Estimate (t ratio)	Model 2: Estimate (t ratio)
Production function	Dependent Variable: Logarithm of GDP	Dependent Variable: Logarithm of GDP
Constant	4.80 (15.65)	4.72 (15.94)
Logarithm of Capital	**0.49 (9.93)**	**0.52 (10.85)**
Logarithm of Labour	**0.47 (8.88)**	**0.45 (8.73)**
Logarithm of Total telephone penetration	**0.14 (3.02)**	**--**
Logarithm of Main land line penetration	**--**	**0.13 (2.86)**
Time trend	0.00 (0.89)	-0.01 (-1.98)
Demand Equation	**Dependent Variable: Logarithm of total telephone and waiting lines**	**Dependent Variable: Logarithm of main telephone and waiting lines**
Constant	-10.23 (-13.33)	-9.92 (-15.97)
Logarithm of GDP per capita	**1.64 (12.94)**	**1.42 (13.58)**
Logarithm of Average telephone price	**-0.30 (-6.14)**	**--**
Logarithm of Main land line price	**--**	**-0.50 (-8.95)**
Supply Equation	**Dependent Variable: Logarithm of total telecom investment**	**Dependent Variable: Logarithm of total telecom investment**
Constant	18.04 (12.00)	18.06 (12.44)
Waiting line for main lines	**0.34×10^{-5} (9.35)**	**0.33×10^{-5} (9.57)**
Logarithm of Geographic area	-0.17 (-1.42)	-0.15 (-1.32)
Regulatory structure	**1.07 (3.49)**	**0.99 (3.33)**
Logarithm of average telephone price	0.08 (0.72)	0.14 (1.19)
Change in Telecom Penetration Equation	**Dependent Variable: Logarithm of change in total telecom penetration over previous year**	**Dependent Variable: Logarithm of change in main landline penetration over previous year**
Constant	-0.04 (-0.25)	-0.07 (-0.71)
Logarithm of Telecom investment	0.02 (2.54)	0.01 (2.44)
Logarithm of Geographic area	-0.02 (-1.87)	-0.01 (-1.27)

Table 7: . Estimation of System of Equations: Cell Phones (Model 3) (N=63)

Equations/Variables	Estimate (t ratio)
Production function	**Dependent Variable: Logarithm of GDP**
Constant	16.16 (7.32)
Logarithm of Capital	0.51 (1.18)
Logarithm of Labour	0.57 (1.35)
Logarithm of Cell phone penetration	**6.75 (28.19)**
Time trend	-.21 (-1.46)
Demand Equation	**Dependent Variable: Logarithm of total telephone and waiting lines**
Constant	-1.89 (-2.93)
Logarithm of GDP per capita	0.04 (0.73)
Logarithm of cell phone price	-0.01 (-0.85)
Supply Equation	**Dependent Variable: Logarithm of total telecom investment**
Constant	12.81 (8.70)
Waiting line for main lines	**0.21×10^{-5} (4.21)**
Geographic area	**0.35 (3.16)**
Regulatory structure	0.20 (0.62)
Average telephone price	0.03 (0.14)
Change in Telecom Penetration Equation	**Dependent Variable: Logarithm of change in cell phone penetration over previous year**
Constant	1.86 (1.21)
Telecom investment	-0.19 (-1.62)
Geographic area	0.19 (2.14)

End Notes

[1] Low-income economies as defined by the World Bank (2002).
[2] NRI is defined by as a nation's degree of preparation to participate and benefit from ICT developments (WEF, 2003).
[3] Sridhar and Sridhar (2003) look at the impact of telecommunication infrastructure and the telecommuting it enables, on spatial dispersion of population, using data from the United States. They find that technology is a complement, not a substitute, for face-to-face interaction.
[4] The panel data procedure Time Series Cross Section (TSCS) estimates a form of panel data model in which data are (typically) observed for a relatively large number of periods for a relatively small number of cross sectional units, which is not our case. Seemingly Unrelated Regression (SURE) models are used for estimating systems of equations in which the endogenous variables are related, and cross-equation error terms are correlated. Since simultaneity is present in our case, we resort to an instrumental variables method like 3SLS.
[5] The form of the production function is Cobb-Douglas, consistent with Roller and Waverman (2001).
[6] We use a macro production function approach that relates inputs to output. We are not estimating the determinants of national output. This explains why we have not included measures of government deficits or of trade openness that the literature shows affect national output. Government deficits could well affect the supply of telecom investment, as Roller and Waverman (2001) point out, but reliable data on government deficits are not available for developing countries for us to include that in the supply equation.
[7] For example, in India, even after private operators were allowed to provide competitive service, waiting line for main telephones was around 1.649 million in 2001. Even after the introduction of cellular services in 1995, the waiting list continued to grow from 2.277 million to 2.894 million in 1996 and 2.706 million in 1997.
[8] Remember here that we have estimated a Cobb-Douglas production function, and the fact that the sum of coefficients is greater than 1 implies increasing returns to scale. This may be, in fact, reasonable to expect, since the countries in the sample on average, experienced Compounded Annual Growth Rates (CAGR) of 3% and 5% respectively in their labour force and capital stock (net of telecom). Further, the average CAGR of mainlines and cell phones were 7% and 78% respectively (Table 2), which may have all collectively led to increasing returns to scale in the national output of countries in our sample over the period of study.
[9] This is obtained by taking the ratio of nominal to constant GDP for any given year with a certain base.
[10] Remember we do this because our measure of telecom investment is annual.
[11] In fact, mobile phone connections are expected to overtake fixed phone subscribers in India in the third quarter of 2004 as cellular penetration is expected to double from 2.7% (at the end of 2003) to 5.2% by end-2004, according to a study by Gartner (The Economic Times, January 24, 2004).

References

Alleman,J.*et.al.,* 2002. Telecommunications and economic development: Empirical Evidence from South Africa. Technical report. International Telecommunication Society, Sydney. Retrieved from *http://www. colorado.edu/engineering/alleman/print_files/soafrica_paper. pdf.*

Bayes, Abdul, J. V. Braun and R. Akhter. 1999. Village pay phone and poverty reduction: Insights from a *Grameen* Bank initiative in Bangladesh. Center for Development Research (AEF), *Universitat* Bonn, Bonn, Germany, Discussion papers on development policy no. 8. Retrieved from *http://www.zef.de/publications.htm.*

Chatterjee, S., C.S. Thachenkary, and J. L. Katz, 1998. Modeling the Economic Impacts of Broadband Residential Services, *Computer Networks & ISDN Systems* 30(14): 1295-1310.

Cronin, F.J. *et.al*., 1991. Telecommunications infrastructure and economic growth: An analysis of causality, *Telecommunications Policy* (December): 529-535.

Cronin, F.J. *et.al.*, 1993a. Telecommunications infrastructure investment and economic development, *Telecommunications Policy* (August): 415-430.

---------------------, 1993b. Telecommunication and growth, *Telecommunications Policy* (December): 677-690.

De Long, Bradford and Lawrence Summers, 1993. How Strongly do Developing Economies Benefit from equipment Investment? *Journal of Monetary Economics,* 32: 395-415.

Department of Telecommunications (DoT), (2004). Guidelines for Unified Access (Basic & Cellular) Services License. Retrieved from *http://www.dotindia.com* February, 25, 2004.

Economic Times, 2003. Every 14th Indian has got the tingle. Retrieved from *http://www.economictimes.com,* November 6.

-------------------, 2004. Cell connections to outnumber fixed lines in '04, January 24.

Eggleston, K. R. Jensen, and R.Zeckhauser, 2002. Information and communication technologies, markets, and economic development. Department of Economics, Working Paper, Tufts University. (*RePEc:tuf:tuftec:0203*)

Garbade, K. D. and W. L. Silber, 1978. Technology, communication and the performance of financial markets: 1840-1975. *Journal of Finance,* 33 (3): 819-831.

Gupta, N.K., 2000. *The Business of Telecommunication*. New Delhi: Tata McGraw-Hill Publishing Company Limited.

Hardy, A.1980. The role of the telephone in economic development,. *Telecommunications Policy*. 4(4): 278-286.

ICRA Information Services (ICRA), 2002. *The Indian Telecommunicat-ions Industry:* June, New Delhi.

International Telecommunications Union (ITU), 2003a. *Year Book of Statistics: Telecommunication Services:* Geneva, Switzerland: ITU.

International Telecommunications Union (ITU), 2003b. Country and Regulators Profile. Geneva, Switzerland: ITU. Retrieved on November 17, 2003, from *http://www.itu.int*.

Jain, P., and Sridhar, V. 2003. Analysis of Competition and Market Structure of Basic Telecommunication Services in India. *Communications & Strategies,* 52 (4): 271-293.

Jha, Raghbendra and Sumit Majumdar, 1999. A Matter of Connections: OECD Telecommunications Sector Productivity and the Role of Cellular Technology Diffusion, *Information Economics and Policy,* 11: 243-69.

Jhunjhunwala, A. 2000. Unleashing Telecom and Internet in India. India Telecom Conference, Asia/Pacific Research Center, Stanford University. Retrieved from *http:www.tenet.res.in/papers/unleash.html,* March 3, 2003.

Kim, D.H., Jae-Ho Juhn, Won-Gyu Ha, 1997. Dynamic Modeling of Competitive On-line Services in Korea. *System Dynamics: An International Journal of Policy Modeling,* 9 (2): 1-23.

Leff, N.H. 1984. Externalities, Information costs, and Social Benefit-Cost Analysis for Economic Development: An Example from Telecommunication, *Economic Development and Cultural Change,* 32(2):255-276.

Noll, Roger G. 2000. "Telecommunication Reform in Developing Countries," in Anne O' Krueger (*ed*.), *Economic Policy Reform: The Second Stage.* London: University of Chicago Press.

Norton, S.W. 1992. Transaction Costs, Telecommunications, and the Microeconomics of Macroeconomic Growth. *Economic Development and Cultural Change,* 41(1): 175-196.

Roller, L.H. and L. Waverman. 2001. Telecommunications infrastructure and economic development: A simultaneous approach, *American Economic Review,* 91 (4): 909-923.

Souter, D. 1999. The Role of Information and Communication Technologies in Democratic Development. *Info: Journal of Policy, Regulation, and Strategy for Telecommunications Information and Media,* 1 (5) October: 405-417.

Sridhar, V. 2000. Create FDI-friendly Conditions in Telecom. Retrieved from *http://www.economictimes.com,* December 11.

Sridhar, V. 2003. Tariff Forbearance for Competition, Economic Times, Retrieved from *http://www.economictimes.com,* May 19.

Sridhar, Kala S and V.Sridhar. 2003. The Effect of Telecommuting on Suburbanisation: Empirical Evidence, *Journal of Regional Analysis and Policy,* 33 (1): 1-25.

Sridhar, V., P. Rameshan, and K.G. Sahadevan, 2000. Indian Telecom: Analysis of Pricing, Technology & Policy, IIML Monograph Series 01. Indian Institute of Management, Lucknow, India.

Singh, N. 2002. “Information Technology as an Engine of Broad-Based Growth in India,” in P. Banerjee and F. J. Richter (*eds*.). the Information Economy in India: 24-57. London: Palgrave, Macmillan.

Wong, Poh-Kam 2002. ICT Production and Diffusion in Asia: Digital Dividends or Digital Divide? *Information Economics and Policy,* 14: 167-187.

World Bank, 2002. World Bank Country Groups. Washington, DC. Retrieved from http://www.worldbank.org, September 12, 2002.

World Bank, 2003. World Development Indicators Online (WDI Online), 2003. Washington, DC: World Bank. Retrieved from *http://www. worldbank.org/*

World Economic Forum. The Global Information Technology Report, 2003-04. Geneva, Switzerland: World Economic Forum. Retrieved from *www.weforum.org/*