An Analysis of the Role of Emerging Information and Communications Technology (ICT) and its Economic Effects on Indian Industry

by

KULKARNI Mandar Vijay

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Approved by the Dissertation Committee:

Naoko SHINKAI (Chairperson) ________________________

Shigeru OTSUBO ________________________

Aya OKADA ________________________

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Abbreviations and Acronyms

ADF	Augmented Dickey-Fuller
APO	Asian Productivity Organization
AR	Auto-Regressive
ASI	Annual Survey of Industries
BFSI	Banking, Financial Services and Insurance
BPO	Business Process Outsourcing
CAD	Computer-Aided Design
CAE	Computer-Aided Engineering
CAM	Computer-Aided Manufacturing
CAGR	Compound Annual Growth Rate
CSO	Central Statistics Office
DEITY	Department of Electronics and Information Technology
DF	Dickey-Fuller
DIT	Department of Information Technology
DoE	Department of Electronics
DoT	Department of Telecommunications
DTS	Department of Telecom Services
EHTP	Electronics Hardware Technology Park
ERP	Enterprise Resource Planning
FCB	Financial, Communication and Business services
FDI	Foreign Direct Investment
FEM	Fixed Effect Model

FERA	Foreign Exchange Regulation Act
FGLS	Feasible Generalized Least Squared
GDP	Gross Domestic Product
GFC	Gross Fixed Capital
GFCF	Gross Fixed Capital Formation
GNI	Gross National Income
GoI	Government of India
GVA	Gross Value Added
HSDC	High Speed Data Communication
ICT	Information and Communications Technology
IDI	ICT Development Index
IIP	Index of Industrial Production
INR	Indian Rupee
I-O	Input-Output
IOTT	Input Output Transactions Table
IPB	ICT Price Basket
IPS	Im-Pesaran-Shin
IT	Information Technology
ITA	IT Agreement
ITES	Information Technology Enabled Services
ISP	Internet Service Provider
ITU	International Telecommunication Union
LLC	Levin-Lin-Chu
MAIT	Manufacturers' Association for Information Technology

MOSPI	Ministry of Statistics and Programme Implementation
MTNL	Mahanagar Telecom Nigam Ltd
NAS	National Accounts Statistics
NeGP	National e-Governance Plan
NIC	National Industrial Classification
NIEs	Newly Industrialized Economies
NIXI	National Internet Exchange of India
NTP	National Telecom Policy
OECD	Organisation for Economic Co-operation and Development
OLS	Ordinary Least Squared
PC	Personal Computer
PCO	Public Call Office
PIM	Perpetual Inventory Method
PPP	Purchasing Power Parity
R&D	Research and Development
REM	Random Effect Model
RHS	Right Hand Side
SDPA	Software Development Promotion Agency
SMB	Small and Medium Size Business
STPI	Software Technology Park of India
TE	Technical Efficiency
TFP	Total Factor Productivity
UNIDO	United Nations Industrial Development Organization
USD	US Dollar

VIO	Variable Input Output
VSNL	Videsh Sanchar Nigam Ltd
WDI	World Development Indicators
WPI	Wholesale Price Index
WTO	World Trade Organization

Chapter 1 Introduction

1.1 Background

Currently the Information and Communications Technology (ICT) industry is one of the leading industries of the Indian economy. In the growing services sector (tertiary), the Information Technology (IT) industry comprises of larger share that alone attributed to 5.8 percent of the national gross domestic product (GDP) in terms of its revenues and 3.5-4.1 percent estimated in terms of net value added for the year 2008-09, compared to its revenue share of 1.2 percent in 1998 (NASSCOM 2009, n.a.). The communication industry accounted for 2.9 percent of the total GDP for 2008-09 at 2004-05 constant prices (Central Statistics Office (CSO) 2011a). According to Ahmed (2009), the growth of services, particularly information communication technology, has allowed for a “leapfrog” effect in Indian development in recent times. The remarkable internationalization of this industry over the past couple of decades in terms of exports, inward foreign direct investment and overseas investment of the industry has caught the attention of many researchers. The IT industry, including software, IT services, IT enabled services (ITES) and hardware, is regarded as the “engine” of growth due to its growing contribution to the national economy such as its GDP share, employment and revenue generating opportunities[1], and foreign exchange earnings. The continuous double digit growth and increasing number of firms (due to an ease of market entry) has this industry poised with a high potential to raise the standard of living of the country’s citizens. Moreover, the rising importance of telecommunications in tandem with the IT industry has made the two industries part of the broader ICT industry which has the potential of stimulating economic growth and serve as a common carrier for other industries of the economy. The telecom industry has also shown exponential growth, reflected in its multi-fold revenue growth and the tele-density (per 000' population) reaching 52.74 percent as on March 2010 from 5.11 percent in 2003 (Central Statistics Office (CSO) 2010). Hence, it is important to investigate the impact of the ICT industry on the Indian economy, particularly its impact on other industries of India.

Some of the emerging economies such as China, South Africa, and India among others are placing the ICT industry, in particular software and IT services, as one of the strategic industries and vehicles of economic growth and development. In the case of India, particularly IT and IT enabled services industry has been given a strategic importance since it is export-intensive in nature, generating foreign exchange earnings and employment. This industry has been growing very fast in the past two decades following an export-led pattern of development, exemplified by the supportive policies and infrastructure provided by the government. The domestic market for this industry is also growing at a faster rate due to increasing adoption of this technology amongst different industries. According to NASSCOM (2009, 78), the domestic market for the IT-ITES industry grew with a compound annual growth rate (CAGR) of over 25 percent between 2003 and 2008, to reach 932 billion Indian Rupees (INR) (approximately 23 billion USD) in 2007-08 from 303 billion INR (approximately 6 billion USD) in 2002-03. Although the share of the domestic market in its total revenue is relatively small compared to exports sales, domestic IT spending is growing fast, led by retail; manufacturing; banking, financial services and insurance (BFSI); and telecom as the key vertical markets emerged during financial year 2009 (NASSCOM 2009). Another feature of this domestic IT demand growth is that not only the large sized firms are IT-friendly in their adoption of IT goods and services, but small and medium size businesses (SMBs) are also showing signs of an increase in the adoption of IT goods and services, contributing 30 percent of the domestic IT spending (NASSCOM 2009). Other than software and IT services, hardware and telecommunications comprise an important part of the ICT industry and are growing in tandem with the computer software and IT services segment. Indeed the role of ICT industry in the economic sphere (as well as in the social sphere) is expanding concurrently with the technological changes and improvements brought about by rapid innovations worldwide. As has been mentioned by Hanna, Guy, and Arnold (1995), "Technology is a key to competitiveness and economic growth. ……..progress in information technology (IT) has no doubt had – and continues to have – the greatest influence on the global economy, making it possible to collect, process, and transmit information at breathtaking speed and declining cost, thereby increasing productivity and improving quality and efficiency in all types of industries and services." Thus, the ICT related goods and services hold the potential to diffuse the innovations of information technology into the businesses adopting them and consequently, making those industries more productive and competitive with the greater use of ICT.

The integration of the national economy with the global economy due to opening up of markets and steady liberalization of India has brought opportunities to various industries of the country. In recent years the growth of the ICT industry by improving its international competitiveness is one good example of the benefits of liberalization and globalization. However, other industries of the economy are also facing the pressure of international competition. To remain competitive, they also need measures of cost reduction and productivity improvement. The diffusion of ICT across the national economy can benefit other industries seeking to become competitive and thus the economy at large.

India's telecommunication network is now the third largest in the world and the second largest among the emerging economies of Asia (Bhide 2010). The total number of telephone subscribers has grown at a high rate, from 54.62 million in 2002-03 to 621.25

million as of March 2010, while internet subscribers have grown from a meagre of 3.64 million in 2002-03 to 13.54 million as of March 2009 (Central Statistics Office (CSO) 2010). The tariff rates have also declined with the increased liberalization and higher competition in the telecom industry. This has been supported by the dynamic changes this industry is undergoing since the introduction of policy reforms in 1999 as well as the opening up of the industry to private sector investment in all the basic and value-added services of telecom (Macroeconomic Policy and Development Division (MPDD) 2006). In addition, foreign direct investment capping in the telecom industry has been raised to 74 percent of the capital which has been a major push for the private sector investment in the industry. The Indian cellular market is also growing at a rapid pace, with the number of mobile subscriptions having grown from 13.29 million subscribers in 2002-03 to 584.29 million subscribers as of March 2010 (Central Statistics Office (CSO) 2010). The broadband subscribers' base is still small, with 6.22 million in 2008-09; on the other hand wireless internet users are on rise, reaching 117.82 million for the same period (Central Statistics Office (CSO) 2010).

1.2 Research Motivation

ICT is considered as a general purpose technology and as an important element of infrastructure that has great implications not only for advanced economies but also for developing countries in their industrial development. Due to the importance of externalities emerging from ICT investment and infrastructure, it is critical to understand whether such externalities affect the non-ICT industries in addition to its conventional role as a factor of production. The motivation of this study lies in the quest to understand the role ICT has to play in the economic growth and development of an emerging economy such as India, in particular its impact on the industrial development of India. In this regard, this study would like to assess the effects of ICT investment and ICT infrastructure on the performance of Indian industry. There are many studies that have focussed on the contribution and latent role of ICT in the economic performance of various developed economies. However, considering the role of ICT as a factor of production and as a common infrastructure for developing countries such as India, this study incorporates them into the analysis while assessing the effects of ICT on the industrial performance. In the case of India, ICT industry is considered to be a key industry and a catalyst of growth and development of other domestic industries. Moreover, the distinction of ICT as hardware and as services (including software) remains important while addressing this issue. Hence, in the second part of the analysis, this study would like to focus on the services segment of the ICT industry in terms of its impact on other Indian industries.

1.3 Research Objectives

1. To examine the role of ICT in enhancing the economic performance of the Indian manufacturing sector and its externalities/spillover effects, if any.

2. To analyze the influence and adoption of ICT services at the industrial level in the light of inter-industrial and inter-temporal linkages and its effect on India's industrial development.

1.4 Research Questions

1. What is the effect of ICT investment on the economic performance of the Indian manufacturing sector?
2. Are the spillovers/externalities emanating from ICT important? If yes, how do they affect

the Indian manufacturing sector?

3. Does the ICT services industry of India influence the rest of the economy in the light of inter-industrial linkages?
4. What is the level of adoption of ICT services among other industries? And does the ICT services industry affect the rest of the Indian economy in the light of inter-temporal linkages?
5. Do other industries of the economy benefit from falling prices of ICT services? If yes, what is the extent of price-responsiveness in other industries?

1.5 Research Methodology

In order to address the aforementioned research objectives and questions, the study relies on quantitative analysis. However, the quantitative methodology is supported by previous empirical literature. The research methodology broadly divides into two parts, in response to respective research objectives. The first objective requires assessing the effect of ICT investment and ICT infrastructure on the Indian manufacturing sector. The production function approach and productivity impact analysis is adopted for that purpose. The advantage of this approach is that it provides a means for empirical testing of conventional role of ICT capital as a factor of production as well as evaluating the role of ICT as an infrastructure. In other words, this approach can be extended to find the role of ICT as a capital and as a social capital. The dimension of social capital is not investigated in this study, but the dimension of capital and infrastructure is investigated instead. Due to limited dataset in the time series of the data, the methodology cannot be extended to explicitly observe the effect of ICT capital and infrastructure on individual industries belonging to the manufacturing sector.

The second part of the methodology is based on input-output (I-O) analysis, since the second research objective requires an inter-industry approach to the analysis. The advantage of IO analysis is that the effect of ICT services industry on the rest of the economy and other industries can be estimated given the inter-industry dynamics. The extension of the I-O analysis using the left causative matrix model and variable input output (VIO) model evaluates the inter-temporal effect of ICT services as well as the price-responsiveness of other industries to falling prices of ICT services. Overall, the methodology used in the study tries to accommodate for the effect of ICT adoption, both ICT investment as well as ICT services, on Indian industry.

1.6 Significance of the study

There is a vast body of literature that provides discussion and empirical evidence on the role of ICT as a technology to be played in the New Economy of advanced countries (see, for instance, Kraemer and Dedrick 2001; Jalava and Pohjola 2002; Lee, Gholami, and Tong 2005). These studies have identified the contribution of ICT to economic growth in many developed countries and newly industrialized economies (NIEs). There seems to be consensus about the contribution of ICT at the aggregated (at the cross-country, and economy-wide) as well as at the disaggregated level (including industry-level and firm-level studies) as far as developed economies and some NIEs are concerned. There are also some studies that focus on the role of ICT and its contribution to developing countries, and provide inferences about the potentials of ICT for those economies (see, for instance, Meng and Li 2002; Joseph and Abraham 2007). However, studies of the effect of ICT investment and its contribution to the overall economy of developing countries are limited due to scarcity of data, and are inconclusive since the incidence of ICT at the national level is not as high and mature as in the case of developed countries. Hence, there is a greater need to investigate the role ICT can play in the economic and industrial development at the disaggregated level in the case of developing countries.

The significance of this study lies in its attempt to fill the empirical as well as theoretical gap in studies of ICT and its impact, particularly in the case of developing countries. As far as the empirical gap is concerned, there is less empirical evidence of the importance of ICT in economic and industrial development, particularly in the case of India. There are many studies that investigate various aspects of the export-oriented Indian IT and ITES industry; however empirical studies highlighting the effect of ICT investment and ICT services adoption are scarce (see, for instance, Roy, Das, and Chakraborty 2002; Joseph and Abraham 2007). This study, in the first part of the analysis, utilizes panel data techniques, and applies time series concepts of stationarity and co-integration of the dataset to avoid spurious regression results. In the second part of the analysis, the study tries to investigate the inter-industry effect of ICT services on the Indian economy. ICT services, being an important aspect of the broader information and communications technology, can influence the economic performance of other industries through intermediate demand and final demand. This study provides the inferences about the potential of ICT services in the industrial development of India using deeper analysis of ICT services adoption.

In its theoretical approach, this study departs from others in that the emphasis is given to the role of network externalities that are associated with the aggregate ICT investment. In an attempt to better understand the role of ICT, this study incorporates the infrastructure nature of information and communications technology. The applicability of network theory suggests that network effects are dominant in ICT infrastructure. Hence, the aggregate ICT capital at the sector level is considered as an important component of such infrastructure. This viewpoint is particularly important when considering that firms from developing countries find it difficult to invest in ICT capital, given the fact that there are high costs associated with organizational change and technological improvement. In addition, the benefits of ICT investment are underestimated while its externalities and/or spillover effects are neglected. Hence, the externalities associated with ICT capital are considered by incorporating aggregate ICT capital into the analysis.

The Indian experience of industrialization makes it an interesting case for investigating the effect of ICT on the Indian industry. India, traditionally being an agrarian economy —contributing close to 30 percent of the total GDP in 1999-2000 (at 1993-94 constant prices)— increased its industrialization through services sector growth, which accounts for the largest share of the total GDP. However, India lags behind in terms of its industrial performance. The percentage share of the Indian industry in total GDP (at 2004-05 constant prices) is close to 26 percent in 2009-10, which is relatively small. In particular, the share of manufacturing has remained small, at close to 16 percent of the total GDP. On the other hand, as mentioned earlier, ICT services sector including telecommunications consisted of approximately 6-7 percent of the national GDP in 2008-09. These facts suggest that the Indian pattern of industrial development is different than other countries, being preceded by the tertiary sector. One of the goals set by India's New Manufacturing Policy is to increase the competitiveness of the Indian industry, in particular of the Indian manufacturing sector and to increase the sector's GDP contribution substantially by increasing value added per output. However, Indian manufacturing faces many supply side constraints including infrastructure bottlenecks, weaker supply chains, high input costs, and labor immobility. On the other hand, the services sector is growing very fast and the tradability of services has increased over the years, an indication of its specialization and competitiveness. In particular, the high growth of ICT services in addition to that of financial and other business services has been the striking feature of the Indian pattern of industrialization. The export-competitive software and IT services industry has increased its share of total exports over the past decade, and is increasingly being considered the strategic industry for India.

Based on these facts, it is important to understand to what extent ICT affects the competitiveness and performance of Indian industry. Here, ICT in a broader sense refers to the technology that disseminates through various ICT capital goods and services. The Indian industry is losing opportunities to benefit from trade liberalization and globalization, for the aforementioned reasons. The high costs of input materials and utilities, for instance, erodes the profit margin and labor cost advantage of the Indian industry in general, and affects its international competitiveness. ICT capital and complimentary ICT services can make the Indian industry competitive by affecting its efficiency and production. The introduction of ICT can reduce transaction and storage costs as well as change the way in which other factors of production operate. In addition, better ICT infrastructure can reduce utility costs and improve the delivery of ICT services, in addition to affecting overall productivity performance. Hence, it becomes important in the Indian context to investigate the role of ICT as an ‘enabling technology’, and assess its effect on Indian industry.

1.7 Outline of the study

The overall structure of the thesis, including research objectives and questions, research motivation, significance of the study, and limitations of this thesis are discussed in Chapter 1. This chapter provides the overall outline of this research.

Chapter 2 elaborates the overall policy framework that contributed to ICT development in India. The focus of this chapter is to provide insights into the evolution of ICT policy by emphasizing the changing role of the government and the concomitant development of the Indian ICT industry. It also briefly compares the Indian ICT development vis-à-vis rest of the world.

Chapter 3 is one of the core analytical chapters, investigating the direct and indirect effect of ICT investment on the Indian manufacturing sector. The role of ICT as a factor of production and as an infrastructure is discussed extensively, followed by an empirical assessment by applying econometric analysis of the same on the Indian manufacturing sector.

Chapter 4 specifically investigates the effect of ICT services on the Indian economy, using variants of I-O analysis. The purpose of this chapter is to evaluate the inter-industry and inter-temporal effects of the Indian ICT services, which constitute an important element of the overall ICT. Using the I-O analysis, this chapter establishes the influence of the ICT services industry on the rest of the economy, and investigates the inter-temporal relationship of the ICT services industry with other industries of the economy. As a part of the inter-temporal analysis, ICT services intensity of other industries is measured between two time periods and the industries with high ICT services intensity are identified.

Chapter 5 provides the extension of the I-O analysis in order to estimate the price-responsiveness of the Indian industries to the falling prices of ICT services. The simulation analysis is performed to understand whether industries gain from a decrease in the prices of ICT services.

Chapter 6 concludes the whole thesis, by synthesizing the results of the analyses carried out. In addition, some relevant policy implications from the results of the study are discussed.

1.8 Terminologies used in the study

ICT infrastructure: It is composed of telecommunications, the internet, and the manufacturing sector’s aggregate ICT capital stock.

Telecommunications and *the internet infrastructure*: Telecommunications and the internet infrastructure correspond to ‘access to telecommunications’ and ‘internet density’ respectively, in a narrow sense.

ICT investment externalities: Here, externalities mean an effect of ICT investment beyond its usage as a factor of production; that is, the effect which is not internalized when investment in ICT is made at a firm level. These are captured at a sector/industry level by estimating the effect of aggregate ICT investment and other ICT infrastructure indicators on sectoral/industrial total factor productivity (TFP), since TFP performance is one of the most important ways to understand the effect of externalities.

ICT services industry: It is composed of ‘Computer & related activities’ industry and ‘Communication’ industry as per the Indian Input Output Transactions Table (IOTT) of 2003-04 and 2006-07.

1.9 Limitations of the study

The limitation of this study lies in its inability to account for human capital when providing insights into the role of ICT investment and its effects on Indian industry. The lack of data on quality of labor inhibits the possibility to account for human capital into the analysis of production function. However, the importance of human capital in the analysis of ICT will be incorporated in the future research agenda.

Chapter 2 Evolution of ICT Policy in India and the Current Scenario of ICT Development: An Overview

2.1 Introduction

The main focus of this chapter is to present an overview of India's ICT policy, corresponding to information technology (IT) and telecommunications, towards strengthening ICT as a catalyst of economic growth and development as well as to achieve inclusive growth through ICT penetration. This description is essential to understand an endeavor of the state to strategically develop ICT and its diffusion into the socio-economic sphere of India. ICT policy in India evolved towards an attempt to build ICT infrastructure as well as a strategically important ICT industry (mainly, ICT services industry) to stimulate the economy. The major policy initiatives and incentives related to ICT industry are explained in the chapter. The evolution of policy initiatives towards development of the ICT industry, which is composed of IT and telecommunications, can be broadly divided into two periods, i) pre-reform period (before 1991) and, ii) post-reform period (after 1991). The remaining chapter is divided as follows. Section 2.2 is about ICT related policies focusing on the pre-reform period, followed by Section 2.3 discussing post-reform ICT policies. In Section 2.4 an overview of ICT development in India is given along with international comparisons. The last section, Section 2.5 concludes the chapter.

2.2 ICT Policy in the pre-reform period

The ICT industry, as has been mentioned earlier, is divided into two sub-industries called IT and telecommunications. Hence, the policy initiative is also explained for the two industries separately.

2.2.1 Pre-reform IT policy

Computerization was initiated in India with the installation of a first-generation computer at the Indian Statistical Institution, Calcutta in 1955, and the period that followed (1955-65) was recognized as the first, introductory phase of computerization (Ahmad 1986, 402). The period of 1960s and 1970s was marked by policy attempts to gain self-sufficiency in electronics and hardware (computers). As a result, the Department of Electronics (DoE) and new Electronics Commission came into place in 1971-1973 for national policy formulation and implementation, encouraging development of electronics and computer hardware (Ashraf 2004, 311). At the same time, due to stringent Foreign Exchange Regulation Act (FERA) rules, IBM, which was engaged in computerization of India during the 1960s and first half of 1970s, had to quit India in 1977 (Athreye 2005, 399). This period experienced regulated IT development with an emphasis of the national policy on indigenization and self-reliance in electronics and computer hardware. The import duties on hardware components and the licensing of hardware imports during the period inhibited technological progress while discouraging market entry of private players and software development.

IT policy in the 1980s departed partially from the import substitution approach of the past, to encouraging exports of software and peripherals and conditional import of mainframes and supercomputers. The new computer policy of 1984 liberalized the imports of hardware by lowering import duties on hardware (from 100 percent to 60 percent) to promote manufacturing of computers (Ashraf 2004, 311). The policy of 1984 partially encouraged software development by drawing on institutional and policy support that saw the setting up of a separate Software Development Promotion Agency (SDPA) under the DoE (Kumar and Joesph 2006). The 1986 Policy on Computer Software Export, Software Development and Training by the DoE aimed at integrating the development of software in the country for domestic as well as export markets (Ashraf 2004, 311). For the first time, software growth and development was seen independent of hardware growth under this policy, and software was regarded as one of the key elements for promoting exports of the country (Kumar and Joesph 2006). Although the 1986 policy aimed at the liberalization of hardware imports and software exports by abolishing duties on them, import duties of 60 percent of value were imposed on imported software (Athreye 2005, 402). However, export obligations (of software) on hardware importers remained high during the period and attempts were made to promote software exports through satellite based communication links (Athreye 2005, 402). Hence, the IT policies of 1980s remained a mixed baggage by initiating de-regulation of hardware imports although making it conditional on software exports.

A new initiative towards the promotion of software exports came in 1988 when Software Technology Park of India (STPI), an autonomous body established under the DoE[1] to encourage and support small software exporters. This was the beginning of software export-promoting post-liberalization policy initiatives.

2.2.2 Pre-reform Telecommunications Policy

The telecommunications industry which was under the purview of the Department of Posts and Telegraphs was highly regulated and was functioning as a monopoly in the pre-reform period until 1984. The deregulation of this industry, particularly the partial deregulation of telecom equipment manufacturing, began in 1984 when the manufacturing of subscriber premises equipment were allowed to the private sector (Mani 2000, 194). In 1985,

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[1] Under this initiative, 100 percent export-oriented firms were given income-tax waivers for 5 years within the first 8 years of operation, and were provided with office space and computer equipment, access to infrastructure such as high-speed satellite links and uninterrupted electricity, and other services (Athreye 2005, 402-403).

the Department of Telecommunications was established with a separate Board for the telecom industry which was until then under the erstwhile Department of Posts and Telegraphs. This was followed by the corporatization of telecom distribution in Delhi and Bombay and of the overseas communication wing of DoT by establishing Mahanagar Telecom Nigam Ltd (MTNL) and Videsh Sanchar Nigam Ltd (VSNL) in 1986, respectively. The government introduced an in-dialing scheme in 1988 and Telecom Commission was established in 1989[2]. Hence, there was little focus on the telecom industry and its development in the pre-reform period, with partial de-regulations not beginning until 1984.

2.3 ICT Policy in the post-reform period

This section will focus on ICT policy of the post-reform period since 1991 for the IT and telecommunications industries separately as follows.

2.3.1 Post-reform IT Policy

Due to policy initiatives of the second half of 1980s, the momentum for further liberalization of the IT industry proceeded in line with the overall industrial reforms of 1991. The imports of software were further liberalized by reducing import duties on software from 110 percent in 1992 to 85 percent in 1993, split in 1994 to 20 percent for applications software and 65 percent for system software, and reduced to 10 percent for both categories in 1995 (Ashraf 2004, 312). Moreover, the import duties on computers were also reduced to 25 percent in 1992. The STPI scheme, which commenced in 1988 to overcome infrastructure bottlenecks and promote software exports, was further consolidated by reducing

[2] The details of this paragraph related to the Telecom policy are referred from Mani (2000, 194-195; 2005, 282-283).

telecommunication charges for satellite links and by removing export obligations for hardware imports (Athreye 2005, 403). Moreover, under the scheme software exports were exempt from income-tax for 10 years besides allowing duty-free import of capital goods and permitting 100 percent foreign equity. Duplication of software in India was permitted for the first time in 1993 (Ashraf 2004, 312). The number of STPIs increased across the country during this period, which encouraged more private entry into the industry and software development.

After the successful implementation of the STPI scheme, the Indian government set up a national task force on Information Technology and Software Development in 1998[3]. With a mandate to formulate the draft of a national informatics policy, the task force came up with IT Action plan- part I, II and III in order to provide with immediate and long term recommendations to remove bottlenecks and make India a global IT superpower. Recommendations of the Action plan were made for software development, hardware development and long term IT policy in part I, II and III, respectively.

India enacted the IT Act 2000 in the year 2000 in order to enable digital signatures, provide the legal infrastructure for the promotion of e-commerce, and prevent computer crime in addition to accelerating the application of IT in critical industries of the economy (Ashraf 2004, 312; Chakraborty and Dutta 2002, 19). In 2008, the government announced amendments to the IT Act 2000 in order to upgrade the existing legal framework for e-commerce. This helped to boost users and investors' confidence in the area of IT. Besides the promotion of software development, IT policy also emphasized the development of the electronics and computer hardware manufacturing industry. Along the lines of the STPI scheme, the government also initiated Electronics Hardware Technology Park (EHTP)

[3] Refer to the web page http://it-taskforce.nic.in/ for more details.

Scheme for the promotion of manufacturing and exports of electronics and computer hardware.

2.3.2 Post-reform Telecommunications Policy

The telecom policy in the post-reform (from 1991 onwards) period began with the de-licensing and opening up of telecom equipment manufacturing to the private sector in 1991. This brought major international companies such as Alcatel, AT&T, Ericsson, Fujitsu and Siemens into the equipment manufacturing market of India. In 1992, the value-added telecom services industry was opened to private competition, following which radio paging, cellular mobile and other value added services were gradually opened to the private sector. In 1993 and 1994, private networks were allowed in industrial areas and licenses for radio paging were issued in 27 cities[4]. Hence, the national telecom policy embarked on liberalization and privatization in line with the New Economic Policy of 1991.

A major milestone in the national telecom policy towards the strengthening of the industry was achieved when the new telecom policy was announced in May 1994. The new telecom policy reflected the government's view (i) that the rapid improvement and development of telecommunications was vital to the success of the wider economic reforms; and (ii) that such development could not take place under the public monopoly model that had governed the industry since the country became independent in 1947 (Sinha 1996, 23). This policy emphasized improving the quality of telecom services in India to world-class levels, by defining certain objectives to be achieved: (a) ensure the availability of telephones on demand; (b) achieve universal service covering all rural areas as early as possible at affordable prices; (c) ensure quality of telecom services to world standards; and (d) plan for making India a major manufacturer of telecom equipment and a base for exporting to other

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[4] The details of this paragraph are referred from Mani (2000, 194-195; 2005, 282-283).

countries (Department of Telecommunications (DoT) n.a.; Mani 2000, 197). There were also certain targets set by the government to achieve the aforementioned objectives. Thus, this policy introduced competition in local loop by the liberalization of basic services with priority (different than the common practice of liberalization that begins with long-distance services), and forced Indian and foreign companies to form joint ventures in order to enter the bidding for basic services (Sinha 1996, 23). In 1997, The Telecom Regulatory Authority of India began functioning as a regulatory authority of the telecom industry.

The year 1996 saw a great leap forward when VSNL started internet service in India (Ashraf 2004, 312). The subsequent new policy on Internet Service Providers (ISPs) was announced by the Department of Telecommunications (DoT) in 1998 (Mani 2005, 282). Under this policy of free licensing to ISPs, the setup of gateways to the internet and laying fibers and cables were freely permitted, and internet services were facilitated with tax incentives and infrastructure status (Ashraf 2004, 312).

Due to less satisfactory results in achieving some of the targets set in the national telecom policy of 1994, the new telecom policy was announced in 1999. The objectives set in the new telecom policy of 1999 include, (a) strive to provide balance between the provision of universal service to all uncovered areas and the provision of high-level services capable of meeting the needs of the country’s economy; (b) create a modern and efficient telecommunications infrastructure taking into account the convergence of IT, media, telecom and consumer electronics; (c) convert public call offices (PCOs), wherever justified, into Public Teleinfo centres with multimedia capability; (d) transform, in a time bound manner, the telecommunications industry into a more competitive industry in both urban and rural areas by providing equal opportunities and level playing field for all players; (e) strengthen research and development (R&D) efforts in the country and provide an impetus to build world-class manufacturing capabilities; (f) achieve efficiency and transparency in spectrum management; and (g) enable Indian telecom companies to become truly global players (Department of Telecommunications (DoT) n.a.). There were also some specific targets set to achieve the aforementioned objectives.

Besides this, there were also other policy initiatives introduced in 2000 that include the opening up of national long-distance services to the private sector, raising the cap on foreign equity in telecom services from 49 to 74 percent, reducing basic customs duties for several types of telecom equipment, corporatization of the Department of Telecom Services (DTS), and approving a proposal to allow foreign direct investment (FDI) of up to 100 percent in ISPs that do not have satellite or submarine landing stations, among others (Mani 2005, 283).

In order to improve internet services, particularly improving the quality of the internet services, the DoT introduced Broadband Policy 2004. The policy aimed to improve broadband connectivity by recognizing the importance of the spread of telecommunications infrastructure. The policy encouraged development of the internet infrastructure within a framework to promote broadband connectivity through various access technologies. Under the policy, National Internet Exchange of India (NIXI) has been set up by the Department of Electronics and Information Technology (DEITY) to ensure that internet traffic be routed within India and to increase utilization of these facilities (Department of Telecommunications (DoT) n.a.). In recent times, the government has also announced the National Telecom Policy (NTP) 2012 which will further strengthen and develop the telecom and internet industries, recognizing the infrastructure nature of these services.

The evolution of policies and schemes related to the ICT industry of India over the years led to the development of domestic ICT infrastructure, composed mainly of IT (computers and personal computers (PCs)), telecommunications and the internet. Moreover, the synchronization of ICT policies is necessary given the convergence of technologies related to IT, telecom, media, electronics and the internet world-wide. The overlook of these policies provide important insights into how the ICT has emerged as an important industry and how the government initiatives provided necessary policy environment for its development. The aforementioned policies recognize the infrastructure nature of this industry and its role in the economic and industrial development of India.

In the next section, the chapter will focus on the current scenario of the Indian ICT development given its spread and penetration as an infrastructure.

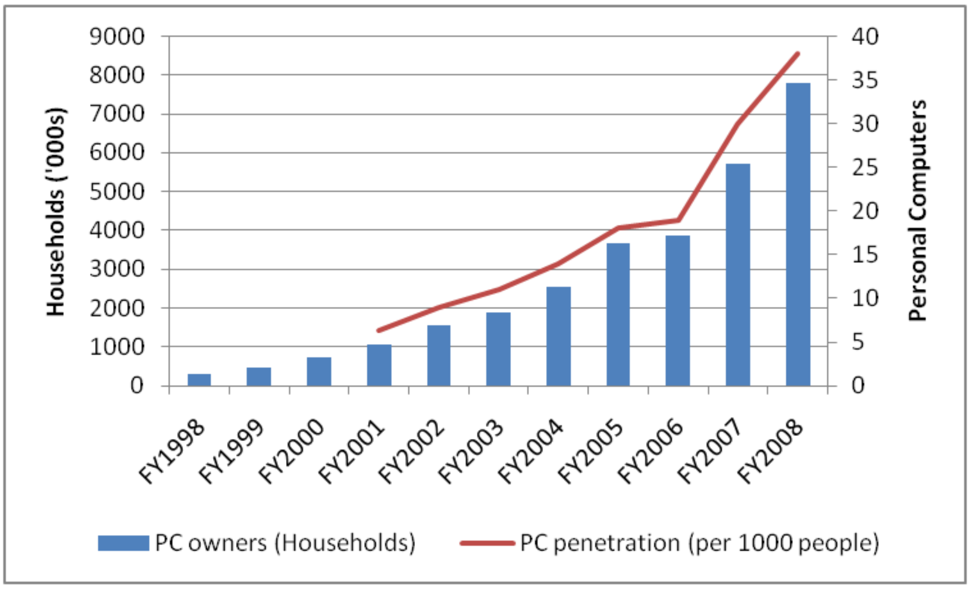
2.4 Current Scenario of the Indian ICT Development

This section describes some of the main indicators of Indian ICT growth and development in the recent years and compares the ICT development of India vis-à-vis other countries to provide insights about where the penetration and diffusion of the Indian ICT stands.

2.4.1 Proliferation of ICT in India

Over the years, particularly in the twenty-first century, India has witnessed increasing usage of ICT. In particular, the core components of ICT represented by PCs, mobile telephony (telecommunications), and the Internet found growing penetration and diffusion into the Indian society and economy. This section highlights the penetration of these core components of ICT which, as a whole, are also indicative of the status of Indian ICT infrastructure.

Figure 2.1 Penetration of Computers in India

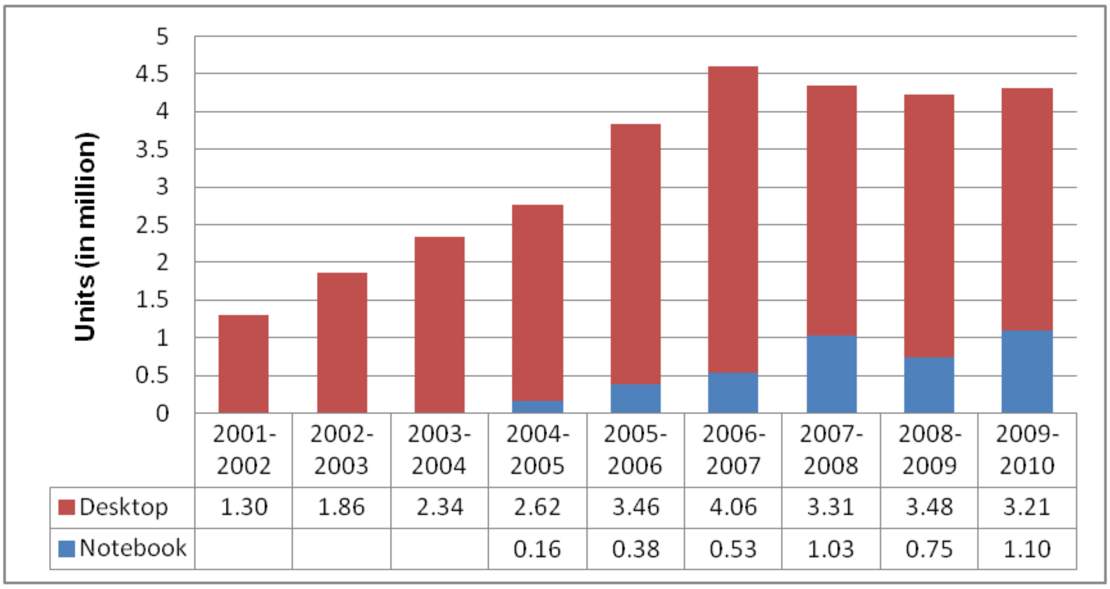


Note: FY indicates financial year (April to March).
Source: Author's compilation based on the data from Department of Information Technology (DIT) (2006, 20); (2011b, 140); and NASSCOM (2009, 89).

As is shown in Figure 2.1, the penetration of computers in India is rising in recent years. The number of households owning computers increased from 0.29 million households in 1998-99 to about 7.8 million households in 2008-09, with a growth of close to 40 percent in the last decade (NASSCOM 2009, 89). However, when the penetration is observed against the population, it is still very low. The red line in the figure indicates PC penetration per 1000 people. As can be observed from the figure, PC penetration in terms of computers per 1000 people also grew rapidly during the period, increasing from 6.3 in 2001-02 to 38 in 2008-09 to 43 in 2010-11. However, this increase is far less significant when compared to the total population. As of 2007, only 3.7 percent of households had access to computers, suggesting the need for deeper and faster penetration of computers.

The usage of computers in businesses has also shown upward trend in the last decade. In particular, the sale of notebook computers in businesses is rising as compared to that of desktops. Figure 2.2 highlights the sales of desktop and notebook computers in businesses in India, based on the surveys conducted by Manufacturers' Association for Information Technology (MAIT). As is indicated in the figures, total PC sales in Indian businesses, composed of desktop and notebook computers, increased between 2001-02 and 2006-07. However, the survey results show falls in the sales of desktops in businesses in 2007-08 and desktop sales remained below the peak of 4.06 million of 2006-07. On the other hand, except for 2008-09, sales of notebook computers have increased during the period, reaching 1.10 million units in 2009-10. This is also an indication of more demand for new and sophisticated technology.

Figure 2.2 Total PC Sales in Businesses

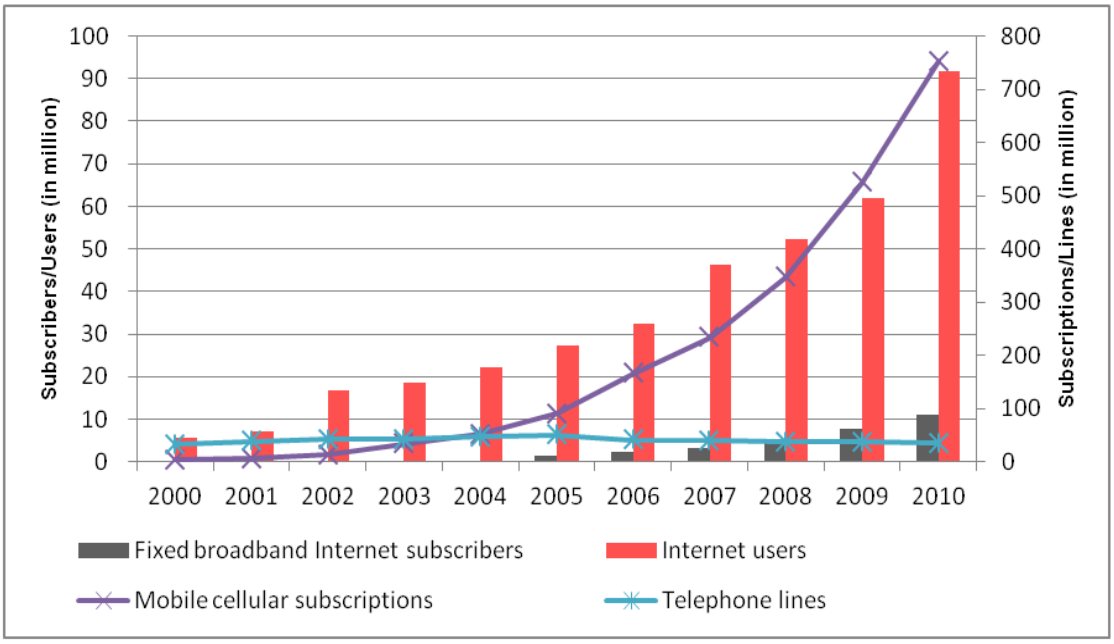


Source: Author's compilation based on the data from various surveys of Manufacturers' Association for Information Technology (MAIT) (n.a.), retrieved October 2, 2012, from http://www.mait.com/index.php?option=com_content&view=category&id=41:Indian%20IT%20Industry%20Performance%20over%20the%20years&Itemid=8&layout=default.

In addition to the penetration of computers, other core Indian ICT infrastructure indicators such as telecommunications and internet access improved during the last decade. Partly driven by favorable government policies and market opening to private participation, access to telecommunications and the internet increased. Figure 2.3 shows the annual pattern of access to telecommunications in terms of the number of telephone lines and mobile cellular subscriptions (second vertical axis on the right hand side (RHS)), and access to the internet in terms of internet users and fixed broadband internet subscribers (first vertical axis on the LHS) during the last decade. As far as the access to telecommunications is concerned, the number of mobile cellular subscriptions— providing a proxy for the availability of telecommunications— increased exponentially in the last decade as is shown by the corresponding line and figures on the second vertical axis on the RHS of the graph. In terms of absolute numbers, the number of mobile cellular subscribers reached 752.2 million in 2010, a growth of about 43 percent from 2009. On the contrary, the users of fixed telephones began shrinking from its peak of about 50.2 million telephone lines in 2005. The decrease in the number of telephone lines is taken over by the increase in mobile cellular subscriptions. This also indicates changing preferences for the new technology as well as improvement in the value added part (mobile cellular services) of telecommunications infrastructure.

Moreover, with regards to internet access, the number of internet users in absolute terms increased from a small number of 5.6 million users in 2000 to 91.8 million users in 2010, recording an average growth of 36 percent in the last decade. The number of fixed broadband internet subscribers, indicating faster speed and improved quality of internet access, is increasing since the second half of the last decade. As is shown in the above figure, the number of fixed broadband internet subscribers reached 11 million in 2010 from a meager number of 50000 users in 2001.

Figure 2.3 Access to Telecommunications and the Internet



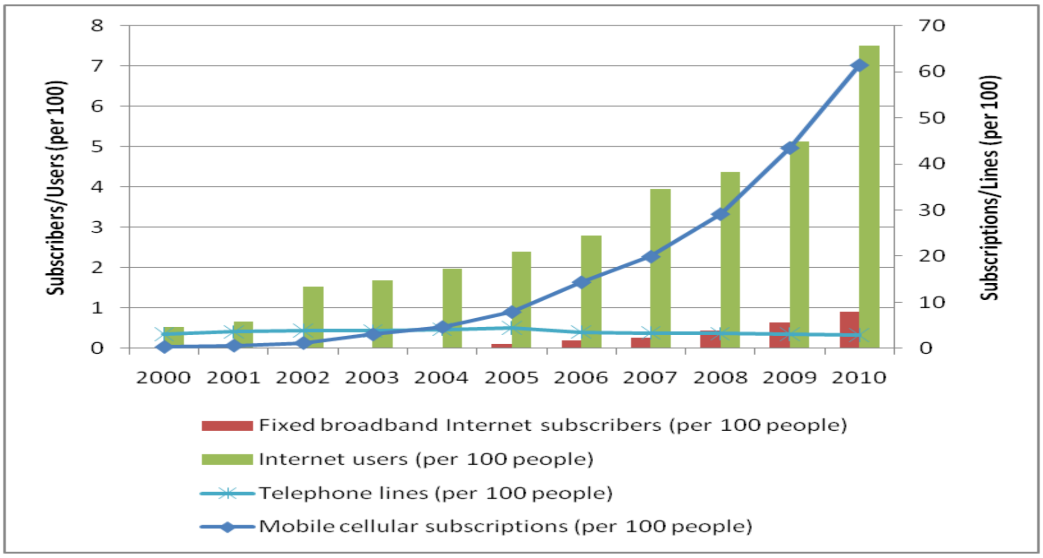
Source: Author's compilation based on the data from The World Bank (n.a.), retrieved January 29, 2011, from http://databank.worldbank.org/ddp/home.do?Step=1&id=4.

The number of broadband internet subscribers is small compared to overall internet users, indicating the requirement for facilitation of deeper penetration of improved quality internet. The above figure indicates progress made at the availability of and access to telecommunications and the internet, representing two of the core components of ICT infrastructure in absolute terms.

The access to and availability of telecommunications and the internet in terms of its intensity per 100 people explain ICT development scenario in line with the growing population of India. Figure 2.4 provides telecommunications (second vertical axis on the RHS) and the internet (first vertical axis on the LHS) intensity per 100 people. In terms of intensity, all the indicators show relatively low penetration except for mobile cellular subscriptions. The intensity of mobile cellular subscriptions increased very rapidly, reaching 61.4 per 100 people in 2010 against 0.34 in 2000. The average growth of mobile cellular intensity in the last decade was about 71 percent, suggesting faster and deeper penetration of telecommunications. The penetration of fixed lines per 100 people remained low at 2.9 in 2010, decreasing from its peak of 4.4 in 2005.

Internet intensity increased from 0.5 in 2000 to 7.5 in 2010, recording an average growth of 33.8 percent in the last decade. However, broadband intensity remained low at 0.9 per 100 people in 2010. This suggests that the intensity of internet in general and broadband in particular remains low, though it is growing fast in recent years.

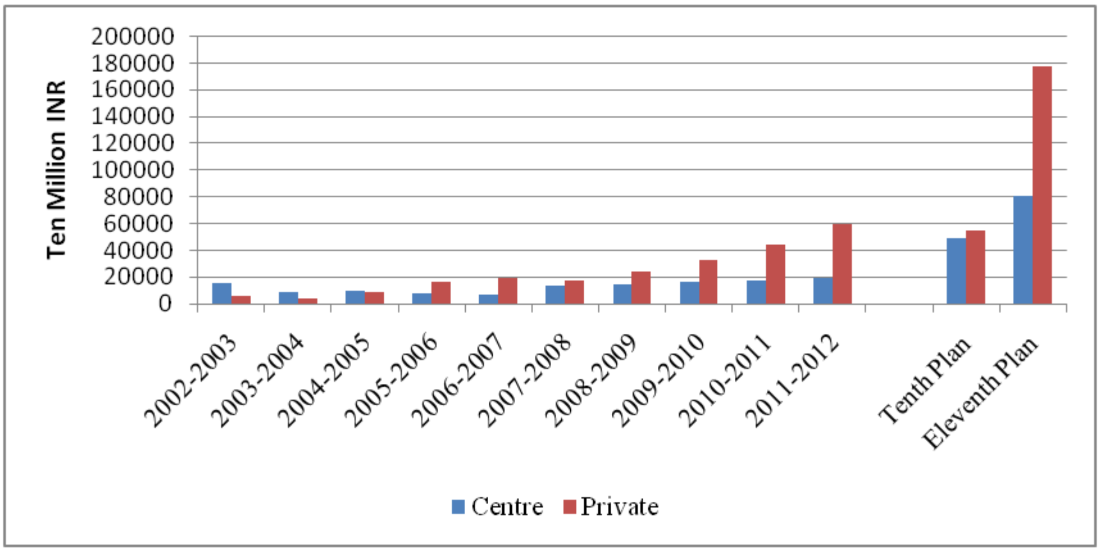
Figure 2.4 Telecommunications and the Internet Intensity



Source: Author's compilation based on the data from The World Bank (n.a.), retrieved January 29, 2011, from http://databank.worldbank.org/ddp/home.do?Step=1&id=4.

Although, the number of subscriptions for telecommunication and internet services depends on individual incomes, it can be a proxy for the availability of and access to the infrastructure and related services as has been used in the previous literature as well as by international organizations for cross country comparisons. As has been described in the previous section, the role of government policy initiatives to create favourable conditions and to attract more private participation in the telecom industry was crucial in developing ICT infrastructure in the country. Although private participation was encouraged and supported by favourable policies, the telecom and internet industries remained under the active regulation of the government, since it is recognized as infrastructure. Figure 2.5 shows the composition of public and private investment in telecommunications infrastructure over the past ten years, divided into 10th and 11th five year plans of the Indian government.

Figure 2.5 Anticipated and Projected Investment in Telecommunications Infrastructure



Source: Author's compilation based on the data from Planning Commission (2008a, 257-258, 263).

The above figure shows anticipated and projected investment in telecommunications infrastructure for the 10th (2002-03 to 2006-07) and 11th (2007-08 to 2011-12) five year plan period, respectively. As has been indicated, private investment is expected to rise substantially during this period and is estimated to be twice that of the public (central government's) investment during the 11th plan. This may suggest that the role of the private sector in this industry is increasing over the period; however, the government plays an important role in policy framework and basic telecommunications infrastructure investment. With these aspects in mind, this study aims to analyze the indirect effects of ICT infrastructure on the productivity of the Indian manufacturing sector.

2.4.2 ICT Development Index and India

This section briefly compares the Indian ICT infrastructure development with that of other countries in the Asia and the Pacific region. This comparison provides some insights into the status of the Indian ICT infrastructure indicators vis-à-vis that of other countries.

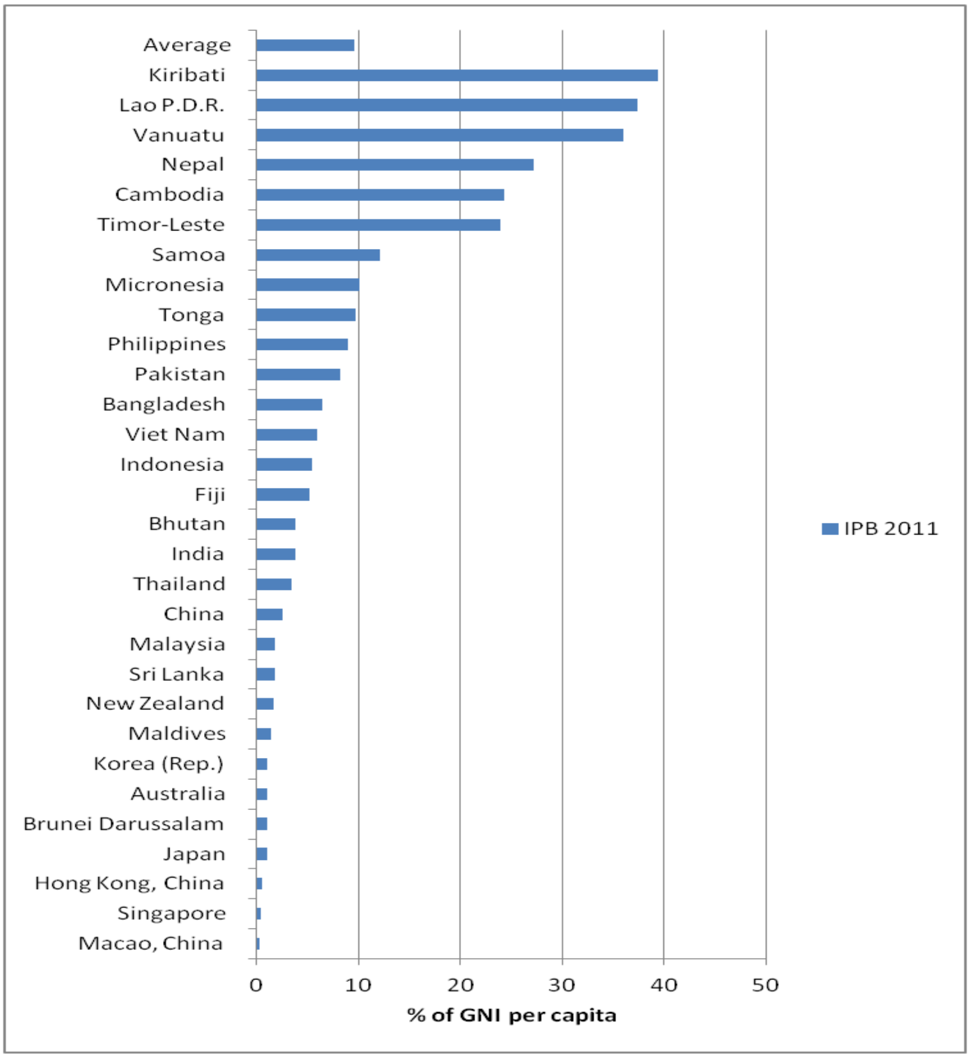
Overall, India does not perform well in terms of ICT Development Index (IDI) developed by International Telecommunication Union (ITU). According to IDI rankings, in 2011 India ranked 119th among 155 countries in the world and 23rd among the 30 countries of Asia and the Pacific region (International Telecommunication Union (ITU) 2012, 21). IDI is based on three sub-indices, i) ICT access, ii) ICT use, and iii) ICT skills. ICT access consists of the indicators such as fixed-telephone lines per 100 inhabitants, mobile-cellular telephone subscriptions per 100 inhabitants, International Internet bandwidth (bit/s) per internet user, percentage of households with a computer, and percentage of households with Internet access. The second sub-index, ICT use consists of the indicators such as percentage of individuals using the Internet, fixed (wired)-broadband Internet subscriptions per 100 inhabitants, and active mobile-broadband subscriptions per 100 inhabitants. The last sub-index, ICT skills, is comprised of adult literacy rates, secondary gross enrolment ratio, and tertiary gross enrolment ratio as its indicators (International Telecommunication Union (ITU) 2012, 18). The weights for the three sub-indices are 40, 40 and 20 respectively.

According to IDI sub-indices, India ranks 116th, 120th, and 115th in terms of ICT access, ICT use, and ICT skills sub-index, respectively in 2011. When compared among countries of Asia and the Pacific region, India ranked 25th, 19th and 20th in the three categories of ICT access, ICT use, and ICT skills, respectively in 2007 (International Telecommunication Union (ITU) n.a.). India's position in Asia and the Pacific region suggests that ICT penetration and diffusion needs to be improved substantially to match the international standard.

The penetration of ICT infrastructure and access to different indicators of ICT infrastructure, in particular telecommunications and the Internet, depend heavily upon the affordability of these services. The ICT Price Basket (IPB) constructed by ITU measures the ICT prices in various economies in United States dollar (USD), in purchasing power parity (PPP$) and as a percentage of monthly gross national income (GNI) per capita. The ICT Price Basket is a composite basket that includes prices of fixed telephones, mobile cellular phones, and fixed broadband Internet services (International Telecommunication Union (ITU) 2012, 66). In 2011, India ranked 85th among 161 countries, with its IPB value of 3.8 as a percentage of GNI per capita. When observed against individual prices of fixed telephones, mobile cellular phones, and fixed broadband Internet services in 2011 as the three main components of the price basket, India stands 107th, 80th, and 91st, respectively.

Figure 2.6 shows the ranking of countries in Asia and the Pacific region based on their IPB value as a percentage of GNI per capita in 2011. As is shown in the below figure, when compared with the 30 countries of Asia and the Pacific region, India ranked 14th in terms of ICT prices in 2011. Its IPB value is less than the regional average of 9.5, showing that India has improved in terms of affordability of ICT services, particularly telecommunications and the internet. However, it ranks lower than some of the neighboring countries such as China and Sri Lanka, suggesting the need for further improvement in providing affordable ICT services.

Figure 2.6 ICT Price Basket 2011, Asia and the Pacific



Source: Author's compilation based on the data from International Telecommunication Union (ITU) (2012, 101).

2.5 Conclusion

This chapter provides an overview of the evolution of ICT policy in India over the past two decades in the first two sections. The last section discussed the development of ICT infrastructure related indicators of India in the last few years as well as highlights the position of Indian ICT development among other countries of the world and Asia and the Pacific region.

The policy environment that guided the supply of ICT infrastructure, and thus the proliferation of ICT goods and services due to improved ICT infrastructure in the country is broadly divided into two phases. The first phase is the pre-reform period, in which IT and telecom policies shaped the technological uptake in the country. The pre-reform period prior to 1991 was marked by market distortions and heavy government regulations, leading to lagging in technology and other factors required for the development of the ICT industry in particular and infrastructure in general. However, some policy initiatives in the late 1980s, such as the partial de-regulation of the telecommunications industry, and partial liberalization of hardware imports and promotion of software development was the starting point of a favourable policy environment much needed for the ICT development in the country. The policies in the post-reform period from 1991 focused on de-regulation of the telecom industry by encouraging private players' participation. It also promoted software and hardware development by liberating import tariffs and encouraging foreign direct investment. Many other policy initiatives were taken during the 1990s and later on that saw further development of the ICT industry in India.

The proliferation of ICT infrastructure has improved in the recent past as has been shown by improved access to telecommunications, the Internet and PC penetration. Partly due to a favorable policy environment that removed supply side bottlenecks and encouraged liberalization of the ICT industry, availability of telecommunications services such as fixed telephone and mobile cellular services, access to the internet and broadband services, and computer usage have surged in recent years. These indicators provide a proxy for the ICT development since they are the culmination of government policies and regulations, and increased private investment. The convergence of technologies of communication and information technology make it necessary to consider telecommunications and information technology as the core components of ICT infrastructure. India has seen considerable increases in the use of telecommunications, the internet, and personal computers. In particular, the number of mobile cellular subscribers has increased dramatically in recent years showing a higher penetration of telecommunication services. The overall ICT proliferation outcome is a result of prioritizing this industry as a core infrastructure, and the entry of more and more private players with an enabling government policy environment.

Although some of the ICT indicators improved during the past decade in India, there is still much scope for improvement considering the level of ICT penetration against the population. In addition, India's ICT development, when compared with other economies, particularly from Asia and the Pacific region, shows that the ICT infrastructure is in an emerging phase, and more initiatives are necessary for the proliferation of ICT in India. There is also some indication that the business sector in India is increasingly adopting ICT in its activities, which is observed in increasing usage of personal computers. Hence, it is important to understand the role and effect of ICT on Indian industry.

Chapter 3 Direct and Indirect Effect of ICT Investment on the Indian Manufacturing Sector

3.1 Introduction

In Chapter 3, the focus is on the first research objective i.e. to examine the role of ICT through its direct and indirect effects on the Indian manufacturing sector. Subsequently, this chapter will try to address the first two research questions which correspond to the first research objective.

The importance of ICT investment has been analyzed for many advanced economies, particularly for the U.S. due to its rapid development of ICT producing industries, and the diffusion of ICT capital into the rest of the economy accompanied by major technological innovations and the decline in the prices of ICT related goods and services. According to Jalava and Pohjola (2002, 190), the defining characteristics of the ICT revolution are the fast improvements in the quality of ICT equipment including software vis-à-vis a sharp decline in the quality adjusted prices of ICT equipment. In highlighting the importance of ICT in economic development, the role of ICT capital in improving productivity and economic growth has been discussed in the previous literature (see, for example, Jorgenson and Motohashi 2005; Kim 2002; Oliner and Sichel 2003; Jalava and Pohjola 2002), which mainly draws from the experiences of some of the advanced and newly industrialized economies such as the U.S., Finland, Japan, and South Korea. There is also some evidence of the rising importance of ICT investment and capital in developing economies, since ICT has been regarded as one of the key technologies for industrial development. In the case of China, Heshmati and Yang (2006, 16-17) has shown that ICT has contributed significantly to the economic growth and TFP growth of the Chinese economy, particularly in the 1990s.

The main channels through which ICT affects output and labor productivity growth include, 1) ICT as a capital input; 2) TFP increases in the ICT producing sector; and 3) TFP increases associated with the spillover effects related to the usage of new technologies, particularly ICT (see, for example, Oliner and Sichel 2003, 477-503). In estimated production functions, ICT is linked to improved production of a firm, industry or economy through 'capital deepening' and TFP growth via change in capital quality (Dedrick, Gurbaxani, and Kraemer 2003, 5 and 20). These studies have highlighted the role of ICT as a capital input, the importance of ICT production, and particularly its wider usage. The role of human capital, in particular the quality of labor has also been discussed as an important aspect while assessing the effect of ICT investment on output and labor productivity growth of an economy (see, for instance, Jorgenson and Motohashi 2005; Jalava and Pohjola 2002). In addition, some studies divide human capital into IT and non-IT components. Having a skilled and IT-friendly labor force can help to absorb the changing technology faster. However, in the production function analysis, the labor input is assumed homogeneous due to lack of data on human capital at the industry level. This is one of the limitations of this analysis.

In addition to its direct link to the production processes as a factor input, ICT also includes an important element of infrastructure which can substantially augment industrial activity of a region. A number of benefits of ICT infrastructure lead to improvements in TFP at the industrial level. In particular, the network externalities emanating from ICT infrastructure make it highly relevant in industrial development. Here, externalities of ICT investment mean an effect of ICT investment beyond its usage as a factor of production; that is, the effect which is not internalized when investment in ICT is made at a firm level. These externalities, however, are captured at a sector/industry level by estimating the effect of aggregate ICT investment and ICT infrastructure on sector/industrial TFP, since TFP performance is an important way to understand the effect of externalities. One of the reasons externalities occur is the pervasiveness of ICT. According to Avgerou (1998, 4), ICT is characterized as the most *pervasive* technical innovation of the post WWII era, the pervasiveness of which affects almost all sectors of the economy. Moreover, there are externalities related to the size of ICT networks; in other words, an increase in network size generates network externalities[5] (Bedi 1999, 5). Hence, in addition to analyzing the role of ICT as a factor of production, this chapter seeks to examine the importance of ICT infrastructure including aggregate manufacturing ICT investment, in exploring the direct and indirect impact of ICT on the Indian manufacturing sector[6].

The remainder of this chapter is organized as follows. The next section, Section 3.2, briefly discusses the previous literature. In Section 3.3, the source of the data and variable definitions are explained in detail. This is followed by Section 3.4 that estimates the direct and indirect effect of ICT investment on the Indian manufacturing sector. Sub-section 3.4.2 reports the first stage analysis in which the direct effect of ICT investment has been considered, while Sub-section 3.4.3 explores the indirect effect of ICT infrastructure through productivity analysis. The last section, Section 3.5 concludes the chapter by considering ICT's potential as a technology that can drive the performance of the Indian manufacturing sector.

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[5] Although the terms 'externalities' and 'network externalities' are used interchangeably, the term 'externalities', excluding the one referred to in the previous literature, indicates 'network externalities' of ICT infrastructure. Due to the network effect and pervasiveness of ICT, externalities of ICT infrastructure are largely explained by the network externalities. It also helps to understand the rationale behind the relationship between ICT infrastructure and manufacturing sector's TFP.

[6] The term 'sector' is used to indicate the Indian manufacturing sector as a whole and the term 'industry' is used to indicate two-digit level industry/industries that fall under the manufacturing sector category.

3.2 Literature Review

There is a growing body of literature that estimates ICT investment and its impact at the industrial level and that looks into particular industries. O'Mahony and Vecchi (2005), using a dynamic panel data estimation approach, have established a positive and significant effect of ICT capital on the output growth of the non-agricultural industrial sector for the U.S. and the U.K. Using production function econometric estimations for U.S. industries, Stiroh (2002, 11-22) also found positive and significant output elasticity of ICT capital, which corresponds to computer and communications equipment. The link between ICT investment and manufacturing sector's output and labor productivity in the Indian context has been analyzed by Joseph and Abraham (2007), who found a positive and significant impact of ICT investment on both output and labor productivity of the Indian manufacturing sector for the period of 1998-99 to 2001-02. The results from the previous studies suggest a correlation between ICT capital and output and productivity performances at the industrial level.

Roller and Waverman (2001, 910), in analyzing the relationship between telecommunications infrastructure investment and economic growth of 21 OECD countries, proposed that telecommunications infrastructure creates externalities. In other words, it helps to reduce transaction costs and increase output for firms in various sectors of the economy. The telecommunications infrastructure is said to affect revenues and costs in more indirect ways than many other types of infrastructure investment, in that it increases the available information, and thereby increases the efficiency of commercial activity (Alleman et al. 1994, 3-3). In addition to telecommunications and internet, the aggregate stock of ICT capital also serves as an information infrastructure platform due to the network externalities it generates. According to Duggal *et al.* (2007, 486), the information infrastructure nature of ICT capital helps to reduce transaction costs and to increase organizational efficiency, which in turn becomes a source of TFP growth. The latent characteristic of network externalities – the more users, the more value is derived by those users – differentiates this type of infrastructure from others, and provides opportunities for a firm to interact and communicate with others at a lower cost and more efficiently (Roller and Waverman 2001, 911).

Another important characteristic of ICT infrastructure is its public-private nature that requires it to take private aggregate ICT capital into account along with other telecommunications infrastructure. Duggal *et al*. (2007, 486) pointed out that, "....Even though much of the investment in the information sector is private, it depends strongly on public licensing, regulation, and support in being a 'common carrier' that serves industry and the population at large, just as infrastructure, in the broad sense, is supposed to do". According to the spillover effect of ICT, firms benefit not just from private investment in an asset but also from growth in the asset stock of all firms which may drive the increase in labor productivity via capital deepening, and may lead to TFP growth in a constant or increasing returns to scale (Dedrick, Gurbaxani, and Kraemer 2003, 20). Moreover, the importance of private ICT capital and the spillovers emerging from aggregate ICT investment available across the economy have also been discussed by Meijers (2007, 12-23) using the Barro model of spillovers (Barro 1999, 125-126). The network effect of ICT, which is made possible due to standardisation of the technology, has been the point of discussion in Meijers (2007, 8-9).

Based on the aforementioned literature on ICT infrastructure and the importance of private ICT investment due to its infrastructural nature, this study incorporates aggregate ICT investment in the Indian manufacturing sector as a whole in the Indian ICT infrastructure analysis and its impact on the Indian manufacturing sector. In the case of India, there are a number of studies establishing a link between availability of different forms of infrastructure and its impact on the Indian manufacturing industries. In particular, Mitra *et al.* (2002, 406-415) did extensive work showing that the endowment of infrastructure at the state level is critical for the manufacturing sector in terms of TFP and technical efficiency (TE) improvement. Hulten *et al.* (2006, 299-303) did also show the positive externalities of public infrastructure and its impact on the productivity of the manufacturing industries across the states of India. There has been less focus on the ICT infrastructure other than the number of telephone lines, since the emergence of ICT infrastructure is relatively recent. In a recent study, Sharma and Sehgal (2010, 107-114) explored the impact of different types of infrastructure including ICT infrastructure on the Indian manufacturing sector. They found relatively weaker links of ICT infrastructure with industrial performance. However, the growing importance of ICT infrastructure has been clearly demonstrated in the previous literature mentioned earlier.

3.3 Data and Methodology

3.3.1 Production Function

The data utilized for the first stage analysis is primarily collected from the Annual Survey of Industries (ASI), made available by the Central Statistics Office (CSO), a division of the Ministry of Statistics and Programme Implementation (MOSPI), the Government of India (GOI). The information on all the variables at the two digit level of sector disaggregation is used from the ASI dataset. The sample period of the data used for this study is from the fiscal year 1999-2000 to 2007-2008 (ending as on March 31st). The choice of this time frame relies heavily on the latest availability of data on all the variables, particularly on (unpublished) ICT investment which has been used by the author to compute ICT capital at the two-digit level of sector disaggregation using the ASI data. The ICT and non-ICT capital is derived from the unit-level dataset and aggregated at the two-digit level so that it can be plugged into other variables made available by the CSO. The number of two-digit level industries utilized in this study is twenty two, all of which fall into the manufacturing sector category. The time series of the ASI data used for this analysis covers only the registered manufacturing sector[7]. All the variables are at the two digit level of sector disaggregation.

Variable names and definition:

Output (Y):

Output of all the industries is measured as the gross value added (GVA). Following ASI's definition, net value added and depreciation figures are added to compute the nominal GVA. The figures in nominal value have been deflated and converted into constant figures. The deflators are taken from the Wholesale Price Index (WPI) of India with 1993-1994 as a base year. The two-digit level industry classification (as per the National Industrial Classification (NIC) 1998 of the Indian industry) is matched with the WPI commodity index and the suitable price index is utilized to deflate the figures. For industries where specific WPI index is not available, a corresponding group index is taken as the second best choice.

Non-ICT capital (K^{N}):

Non-ICT capital is the type of capital that includes land, buildings, plant and machinery, transport equipment, and others. The annual figures of non-ICT capital are in nominal value. To calculate capital stock from the fixed assets, perpetual inventory method (PIM) in its simplest form is adopted. The time series of the non-ICT capital stock is calculated into two stages. In the first stage, the initial capital stock is computed for non-ICT

[7] Classification of the 'registered manufacturing sector' is given in Appendix A.

assets. Due to the lack of detailed information on the investment pattern and detailed age structure of non-ICT and ICT assets by industry prior to 1998-1999, the initial capital stock for the year 1999-2000 for non-ICT assets is calculated following Goldar *et al.* (Jan. 31 - Feb. 6, 2004, 443). The gross fixed capital value (GFC) in 1999-2000 has been multiplied by 2 for firms in the Census category and by 1.5 for firms in the Sample category to get the replacement value of non-ICT assets[8]. This figure, being a nominal value, is converted into the real value by using WPI index for the category of ‘Machinery & Machine Tools’ with 1993-94 as a base year. In the second stage, annual gross fixed capital formation (GFCF) figure of the non-ICT assets is considered as nominal investment. This figure is then deflated by using the aforementioned category of ‘Machinery & Machine tools’. The time series of the non-ICT capital stock is calculated as,

$$K_{\mathrm{t}} = (1 - d)K_{\mathrm{t}-1} + I_{\mathrm{t}}$$

where d is the annual (arithmetic) depreciation rate and I_{t} is the annual investment. The depreciation rate for non-ICT capital is taken as 5 per cent annually following Unel (2003, 18) and Joseph and Abraham (2007, 28).

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[8] By taking clues from Goldar *et al.* (Jan. 31 - Feb. 6, 2004, 9), the replacement value which has been calculated in this manner, is a compelled choice due to data limitations. The census category of the dataset has firms with 200 or more workers during the sample period until 2003-04 and 100 or more workers from 2004-05. On the other hand, the sample category of the dataset has the remaining firms with less than 100 workers. Due to this classification, the census category firms are assumed to be large-sized and relatively old firms compared to the sample category firms. Hence, the gross fixed assets of the census category are multiplied by 2 and that of the sample category by 1.5.

ICT capital (K^{I}):

Here ICT capital is a category of investment in computer equipment including software. It does not include telecommunications equipment per se. The calculation of initial capital stock of ICT capital and time series of the same follow the same steps and method as for the non-ICT capital mentioned above. The nominal values of this type, both for the initial capital stock and annual investment figures, are deflated by using the WPI index of 'Computer & Computer Based System' taking 1993-94 as a base year. Moreover, the depreciation rate used for this category is 18 per cent[9] which is more than three times higher that of the non-ICT capital. This rate is lower than the one suggested by advanced country studies which is 31.5 percent. The reason for using a lower rate is that though the physical decay of ICT capital is faster, partly due to technological improvements and resulting falling relative prices of ICT goods, the productive stock of this asset for a developing country could last longer than that in an advanced country due to some lag in technology dissemination.

Labor (L):

To calculate this variable, the number of employees by industry is taken as a proxy. This includes workers, and employees other than workers.

Time trend (T):

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[9] The service life of computers is considered to be around 5 years on average (Meinen, Verbiest, and deWolf 1998, 25). Although Jorgenson and Stiroh (1999, 111) have used a depreciation rate of 31.5 per cent on ICT capital for the U.S., it seems too high in the case of a developing country such as India. Heshmati and Yang (2006, 10) have used different rates, but have preferred 15 percent depreciation rate for the Chinese ICT capital. Considering the service life of around 5-6 years for ICT capital, depreciation of 18 percent as an annual average rate of wear and tear has been applied in this case.

This variable is a time trend for each industry i.

3.3.2 ICT Infrastructure

The ICT infrastructure is composed of telecommunications, the internet, and the manufacturing sector's aggregate ICT capital stock following previous studies (see, for example, Duggal, Saltzman, and Klein 2007; Sharma and Sehgal 2010). The telecommunications and internet infrastructure correspond to 'access to telecommunications' and 'internet density', respectively in a narrower sense[10]. The 'access to telecommunications' related data is retrieved from the Compendium of Selected Indicators of Indian Economy (Central Statistics Office (CSO) 2009a). The 'internet density' related data is collected from World Development Indicators (The World Bank n.a.), and the aggregate ICT capital is calculated using the ICT capital variable from the first stage analysis.

Variable names and definition:

Access to telecommunications (*Tele*):

The access to telecommunications is represented by the number of telephones (sum of fixed-lines plus wireless in millions). This is an annual time series for a period of 1999-00 to 2007-08, common for all the manufacturing industries.

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[10] Although the proxies such as "sum of fixed lines and wireless in millions" and "number of users per 100 people" refer to users, they are the proxies used in the previous literature to approximate the availability of ICT infrastructure. Since there are many factors, including government policies that enable the availability of ICT infrastructure as well as many indicators of the same, the outcome in terms of number of users may explain the availability of this infrastructure.

Internet density (*Net*):

Internet density, that is, the number of users per 100 people is used as a proxy for internet infrastructure. These are the annual figures at the national level for a period of 1999-00 to 2007-08, common across the manufacturing industries.

Aggregate manufacturing ICT capital stock (*ICTCap*):

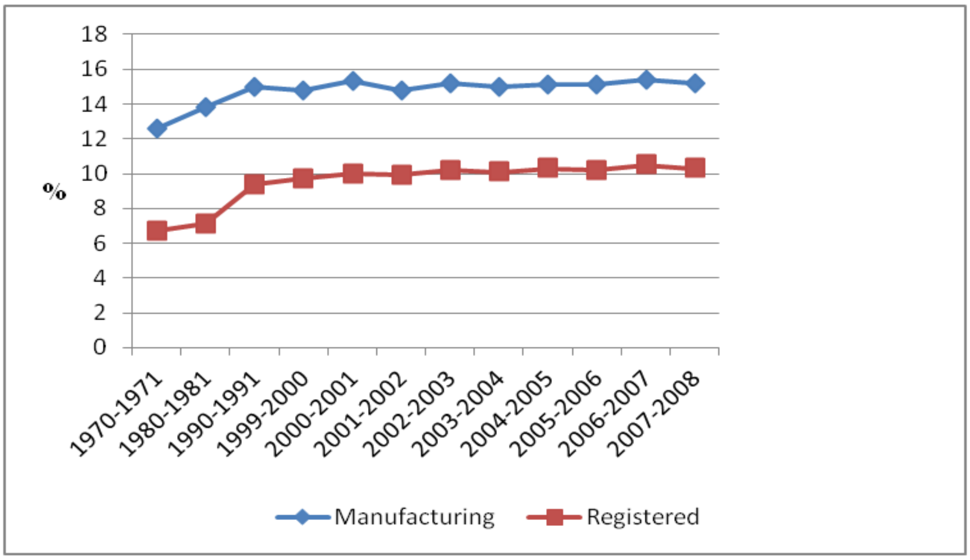
The aggregate ICT capital is the annual sum of ICT capital stock across the manufacturing industries. This is an approximation for the ICT environment and infrastructure available across the industries.

3.4 Estimating the direct and indirect effect of ICT investment on the manufacturing sector

3.4.1 Background of Estimation

The Indian manufacturing sector has experienced a transformation since the 1980s and in particular in the 1990s, the period marked by the gradual industrial policy reforms and liberalization of the trade regime of 1990-91. The impact of trade liberalization and industrial policy reforms on the productivity of the manufacturing sector has been discussed in Goldar and Kumari (2003). The sector grew steadily and experienced a modest increase in its value added over the period in terms of the share it occupies in the GDP of the economy, as can be seen from Figure 3.1.

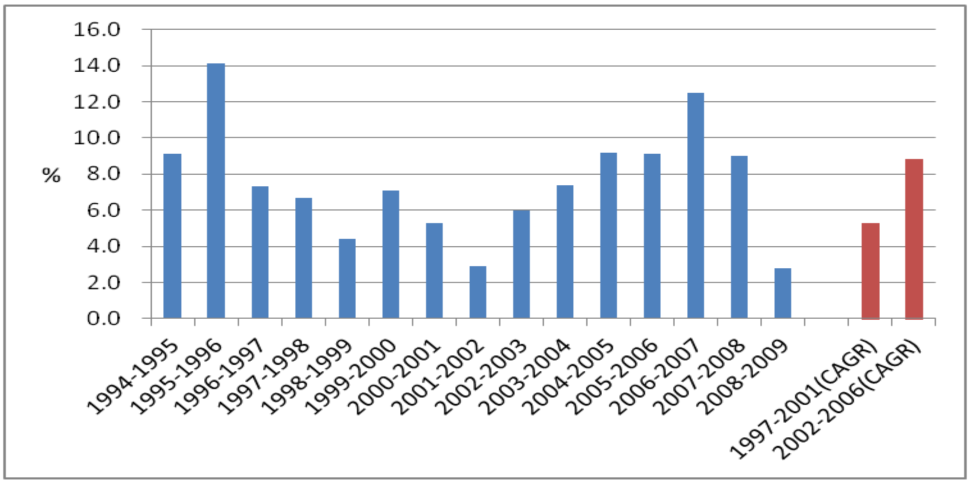
Figure 3.1 Percentage Share of GDP (at 1999-2000 prices)



Source: Author's compilation based on the data from Central Statistics Office (CSO) (2008, 2009a).

The manufacturing sector as a whole and the registered manufacturing sector both recorded a modest increase, as a percentage share of national GDP, from 12.6 and 6.7 percent in 1970-71 to 15.2 and 10.3 percent in 2007-08, respectively at 1999-2000 constant prices. It has been estimated at 15.9 and 10.7 percent in 2009-10 (at 2004-05 prices), respectively. Compared to the services sector which is estimated to have accounted for 57.2 percent (at 2004-05 prices) of the GDP, the share of manufacturing is very low and remained between 14-16 percent in the last decade. However, in terms of the annual growth rate (of the Index of Industrial Production (IIP)), the manufacturing sector witnessed two different trends that can be observed between two sub-periods, namely, 1997-2001 and 2002-2007. As can been seen from Figure 3.2, the period of 1997-2001 witnessed a relatively low annual growth rate with a CAGR of 5.27 percent, whereas that of the period 2002-2006 was 8.82 percent(Planning Commission 2008b).

Figure 3.2 Manufacturing Sector's Annual Growth Rate (at 1993-94 prices)

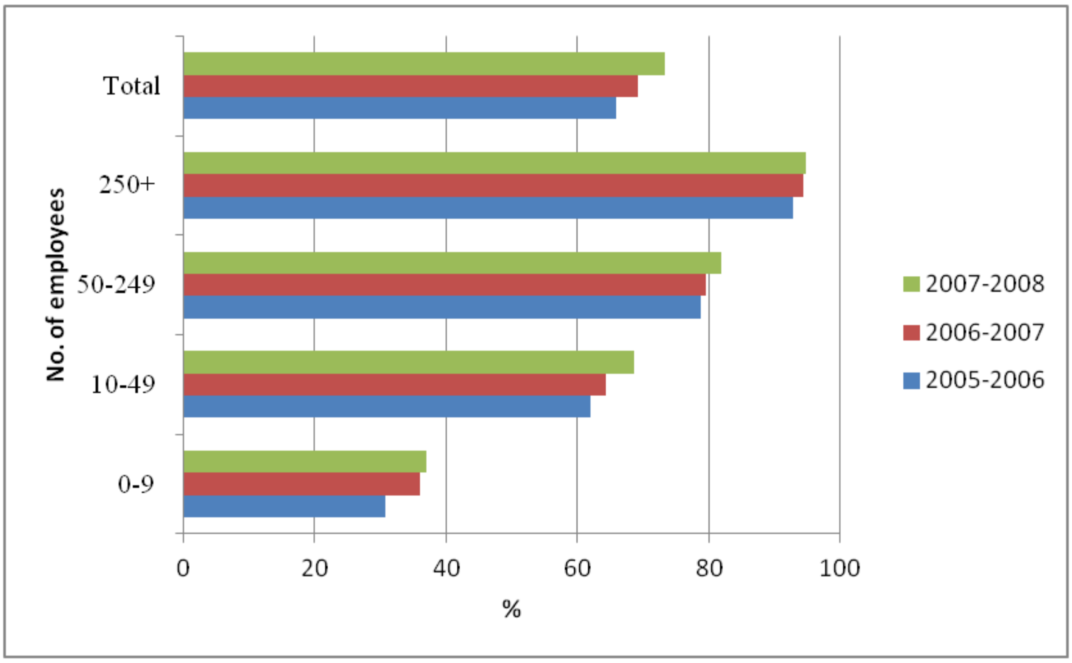


Source: Author's compilation based on the data from Office of the Economic Adviser (n.a., 90), retrieved January 2, 2011, from http://eaindustry.nic.in/Industrial_Handbook_0809_Main.html; and Planning Commission (2008b, 141), respectively.

The annual growth rate declined to 2.9 percent in 2001-02 before it picked up again from 2002-03 to reach a two-digit growth rate of 12.5 percent in 2006-07. There are numerous explanations behind this fall in the first sub-period. These include the Asian Financial Crisis of 1997-98, the fall in domestic demand due to low agricultural output, and the high interest rate (Sharma and Sehgal 2010, 103-104). Moreover, the deterioration in capacity utilization with the rise in investment activities and imports, though not in tandem with demand, caused slowdown in TFP growth in the 1990s, while the recovery was observed in the second sub-period due to a time lag in the manifestation of results of the reforms introduced in the 1990s (Goldar and Kumari 2003, 443).

Computer usage has seen some increase in the Indian manufacturing sector during the past few years. Figure 3.3 shows the percentage of enterprises, under the manufacturing sector of India, using computers and their break down as per the number of employees. The information is available for a period of three years from 2005-06 to 2007-08. The break down of computer usage, as per the size of enterprises in terms of number of employees, shows increasing usage of computers during the same perid. The number of enterprises, responding to the ASI survey question about computer usage for the three years given above, is 140160, 144710 and 146385, respectively[11]. The enterprises surveyed regarding the usage of computers fall under the ASI survey of Indian industry, the same source of the dataset used for the manufacturing sector in the first-stage analysis.

Figure 3.3 Usage of Computer as per the size of Manufacturing Enterprises



Source: Author's compilation based on the data from Godavarkar and Malik (2010).

As can be seen from Figure 3.3, the number of enterprises using computers is increasing as a whole; moreover, the usage of computer is highest for enterprises with 250+ employees followed by enterprises with 50-249 employees, whereas it is relatively low in the case of enterprises with 0-9 employees. This trend suggests that there is an increasing awareness of using ICT in the manufacturing sector, particularly as shown by the growing

[11] The information used in the paragraph is taken from Godavarkar and Malik (2010).

percentage of computer usage. Hence, this study seeks to analyze the effect of emerging ICT usage on the manufacturing sector.

3.4.2 First-stage: Estimating the Production Function

To estimate the direct effect of ICT investment on the Indian manufacturing sector, a production function approach is utilized. With this approach, the effect of ICT capital as a factor input will be estimated by adding it into the basic Cobb-Douglas production function of two factor inputs for the Indian manufacturing sector. Following Mitra *et al.* (2002, 401-403) and Sharma and Sehgal (2010, 104), a basic log-linear form of Cobb-Douglas production function is specified as,

$$\ln Y_{i,t} = \alpha + \alpha_1 \ln K^{\mathrm{N}}_{i,t} + \alpha_2 \ln K^{\mathrm{I}}_{i,t} + \alpha_3 \ln L_{i,t} + \alpha_4 T_i + \gamma_t + \varepsilon_{i,t} \qquad [3\text{-}1A]$$

where Y, K^{N}, and K^{I} are the output, non-ICT capital, and ICT capital, respectively in INR at 1993-94 constant prices. L is the labor input in numbers. T_i is the time trend specified for each industry *i*. The term γ_t is a fixed time effect. α_1, α_2, α_3 and α_4 are the parameters to be estimated common for all the industries. The subscripts *i* and *t* suggest industry at the two-digit level and time period, respectively. ln represents log form of the variables included. This model is estimated using both fixed and random effect estimators. However, the fixed (time) effect and random effect tests failed to reject the null hypothesis, suggesting applicability of a *pooled ordinary least squared* (OLS) technique.

In addition, the effect of ICT capital on labor productivity is estimated using the production function approach as utilized in the previous model.

$$\ln y_{i,t} = \alpha + \alpha_1 \ln k^{\mathrm{N}}_{i,t} + \alpha_2 \ln k^{\mathrm{I}}_{i,t} + \alpha_3 T_i + \gamma_t + \varepsilon_{i,t} \qquad [3\text{-}1B]$$

where y, k^{N} and k^{I} are the output per labor, non-ICT capital per labor and ICT capital per labor, respectively. The other variables and subscripts are similar to the previous model. In a similar way to the earlier analysis, this model is also estimated using both *fixed effect model* (*FEM*) and *random effect model* (*REM*) estimators, and the test supports the *REM*. However, the results of the *REM* estimation and that of the *pooled OLS* are not different. Hence, to avoid redundancy, only the results of the latter are reported alongside that of the Model [3-1A] in Table 3.1.

Table 3.1 Effect of ICT Capital on Output and Labor Productivity: Pooled OLS

Model [3-1A] (Output): ln*Y*		Model [3-1B] (Labor productivity): ln(*Y*/*L*)	
Variables	Coefficients	Variables	Coefficients
$\ln K^{\mathrm{N}}$	0.539 *** (0.047)	$\ln k^{\mathrm{N}}$	0.449*** (0.049)
$\ln K^{\mathrm{I}}$	0.127* (0.072)	$\ln k^{\mathrm{I}}$	0.263*** (0.067)
$\ln L$	0.107 ** (0.051)	T	0.066*** (0.013)
T	0.075*** (0.013)	constant	3.232*** (0.405)
constant	6.152*** (0.888)		
F val.	238.27	F val.	162.43
Prob > F	0.000	Prob > F	0.000
R-sq.	0.823	R-sq.	0.679
Obs.	198	Obs.	198

Notes: Dependent Variable: lnY and lny; *** denotes significance at 1%, ** at 5% and * at 10% critical level; Robust standard errors are reported in parenthesis.
Source: Author’s estimates

The estimates show that the coefficients of ICT capital are positive and significant in both the models. The other factor inputs, namely, non-ICT capital and labor in the case of first model and non-ICT capital per labor in the case of second model are also positive and significant. The coefficients of ICT capital and ICT capital per labor in Model [3-1A] and [3-1B] explain 13 percent and 26 percent of the variation in the dependent variable, respectively. The coefficient of the 'trend' is also positively significant, controlling for the common time trend affecting the dependent variable. Overall, the results under the poolability assumptions are indicative of the importance of ICT capital in its direct effect as a factor input. Moreover, due to the presence of heterogeneity in the form of different industry groups in the dataset, the analysis is extended to account for the heterogeneity of industries. The group (industry) effect model is estimated by modifying Model [3-1A] and [3-1B], as follows.

$$\ln Y_{i,t} = \alpha + \alpha_1 \ln K_{i,t}^{\mathrm{N}} + \alpha_2 \ln K_{i,t}^{\mathrm{I}} + \alpha_3 \ln L_{i,t} + \alpha_4 T_i + \mu_i + \varepsilon_{i,t} \qquad [3\text{-}2A]$$

$$\ln y_{i,t} = \alpha + \alpha_1 \ln k_{i,t}^{\mathrm{N}} + \alpha_2 \ln k_{i,t}^{\mathrm{I}} + \alpha_3 T_i + \mu_i + \varepsilon_{i,t} \qquad [3\text{-}2B]$$

where μ is a group effect term for each industry *i*. All the other variables and subscripts are the same as those for Model [3-1A] and [3-1B].

These models are estimated using fixed effect as well as random effect estimators. In the case of Model [3-2A], the 'Hausman specification test' fails to reject the null hypothesis that the individual effects are uncorrelated with the other regressors of the model, suggesting preference for the random effect model. The *REM* is estimated using the *feasible generalized least squared* (*FGLS*) estimator following Green (1997, 626-631). Since the heteroscedasticity and autocorrelation tests of the panel dataset indicate group wise heteroscedasticity and autocorrelation of first order in the error term, a group wise heteroscedastic *FGLS* model is applied to account for heteroscedasticity and autocorrelation. The results of both the models, *FEM* and *FGLS*, are reported in Table 3.2.

The estimated coefficient of ICT capital in the *FEM* model has shown negative sign though it is insignificant, contrary to the results of Model [3-1A]. However, the estimator of *FGLS*, after accounting for the heteroscedasticity and correcting autocorrelation in the error term, has shown a positive and significant impact of ICT capital. Except for the *FEM* estimation, the results are comparable to those of Joseph and Abraham (2007, 18-21) and corroborating the view that ICT capital does have positive effect as a factor input on the manufacturing sector.

Model [3-2B], which estimates the effect of ICT capital (per labor) on the labor productivity, is also estimated using both the fixed and random effect estimators. The 'Hausman specification test' result[12] supports the *REM* estimator; thus to account for heteroscedasticity and first order autocorrelation in the error term, as is the case of Model [3-2A], the *FGLS* estimator is applied. Table 3.2 reports the results from both the estimators, *FEM* and *FGLS*. In the case of *FEM*, ICT capital per labor is insignificant with negative sign, in contrast to the results of Model [3-1B]. This suggests that the impact of ICT capital on labor productivity turns insignificant when the within group estimation is applied, removing industry effects. However, the *FGLS* coefficient of ICT capital per labor is positive and significant.

[12] The 'Hausman Specification Test' results of Models [3-2A] and [3-2B] are specified in Appendix B and Appendix C.

Table 3.2 Effect of ICT Capital on Output and Labor Productivity: Group Effect

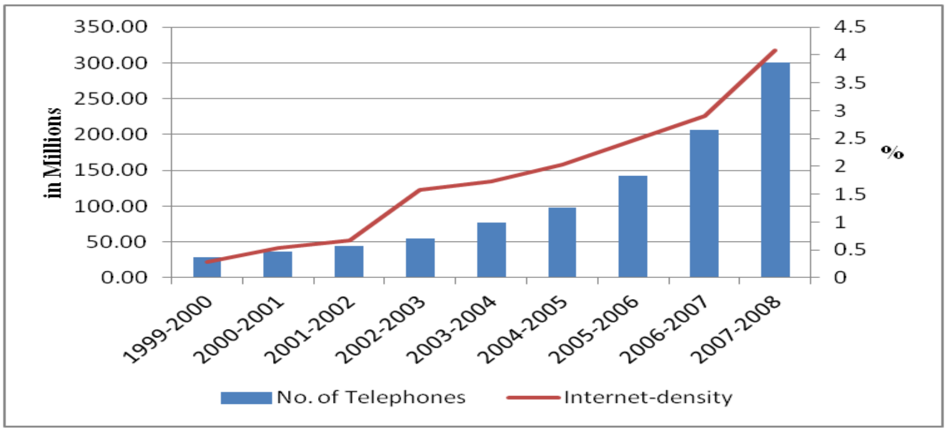
Model [3-2A] (Output): ln$Y$			Model [3-2B] (Labor productivity): ln(Y/L)		
Variables	*FEM*	*FGLS*	Variables	*FEM*	*FGLS*
$\ln K^{N}$	0.603*** (0.133)	0.429*** (0.044)	$\ln k^{N}$	0.482** (0.177)	0.390*** (0.050)
$\ln K^{I}$	-0.060 (0.045)	0.228*** (0.047)	$\ln k^{I}$	-0.070 (0.045)	0.250*** (0.045)
$\ln L$	0.718*** (0.186)	0.220*** (0.042)	T	0.065*** (0.008)	0.049*** (0.008)
T	0.055*** (0.009)	0.056*** (0.007)	constant	6.101** (2.380)	4.269*** (0.470)
constant	1.171 (3.112)	5.487*** (0.626)			
F value/ Waldchi2	55.19	1320.90	F value/ Waldchi2	30.09	349.93
Prob >	0.0000	0.000	Prob >	0.0000	0.000
R-sq.	overall=.722		R-sq.	overall=.550	
No. of observations	198	198	No. of observations.	198	198

Notes: Dependent Variable: lnY and lny; *** denotes significance at 1%, ** at 5% and * at 10% critical level; Standard errors are robust and adjusted for clusters in the industry groups (for FEM), and are reported in parenthesis.
Source: Author’s estimates

3.4.3 Second-stage: ICT Infrastructure and Productivity

In this section, the study explores the indirect effect of ICT on the manufacturing sector by analyzing the relationship between ICT infrastructure and the estimates of TFP. In the first sub-section, the estimates of TFP are computed followed by the second sub-section in which the impact of ICT infrastructure is analyzed based on the estimated TFP. The ICT infrastructure, in particular the ‘access to telecommunications’ in terms of the number of telephones (including fixed-line and wireless), has seen a rising trend during the period of the study. In the case of the internet, although the number of subscribers is small, it is also growing at a higher rate as can be seen from Figure 3.4.

Figure 3.4 Telecommunications and Internet Trends in India



Note: The internet density is reported for the year ending December 31.
Source: Author's compilation based on the data from Central Statistics Office (CSO) (2009a), and The World Bank (n.a.), retrieved January 29 , 2011, from http://databank.worldbank.org/ddp/home.do?Step=1&id=4.

3.4.3.1 Estimating TFP of the Manufacturing Sector

This sub-section derives the estimates of TFP level of India's manufacturing sector, which are utilized for the second stage analysis. Moreover, the average TFP growth rates are computed and compared across the industries for two sub-periods. To begin with, TFP is computed for all the manufacturing industries using the estimated parameters of the production function as follows:

$$\ln\widehat{TFP}_{i,t} = \ln Y_{i,t} - \widehat{\alpha_1}\ln K_{i,t}^{\mathrm{N}} - \widehat{\alpha_2}\ln K_{i,t}^{\mathrm{I}} - \widehat{\alpha_3}\ln L_{i,t} \qquad [3\text{-}3]$$

where $\widehat{\alpha_1}$, $\widehat{\alpha_2}$ and $\widehat{\alpha_3}$ are the estimated coefficients of non-ICT capital, ICT capital and labor, respectively from the first stage analysis of production function. For this analysis, estimated coefficients are taken from the *FGLS* estimates of Model [3-2A].

The estimated average TFP growth rates by industry are shown in Table 3.3. The average TFP growth rates are also reported for two sub-periods, each divided into four years ranging from 2000-01 to 2003-04 and from 2004-05 to 2007-08, respectively. This helps to provide insight into two sub-periods and the overall sample period. The average TFP growth has been higher in the second sub-period (2004-05 to 2007-08) than the first one, except for five industries, namely, 'Tobacco', 'Coke and Refined Petroleum Products', 'Office, Accounting and Computing Machinery', 'Motor Vehicles', and 'Other Transport Equipment'. These estimates of TFP suggest that the overall performance of the manufacturing sector has been relatively better in the second sub-period. This trend of two sub-periods is similar to the results of Sharma and Sehgal (2010, 105) even though the division of two sub-periods is different. For the entire sample period, 'Coke and Refined Petroleum Products' has shown the highest average TFP growth, followed by 'Office, Accounting and Computing Machinery', 'Basic Metals', 'Motor Vehicles' and 'Other Non-Metallic Mineral Products'.

Table 3.3 Estimates of the Average TFP growth of the Industries, 2000-01 to 2007-08

Industry	Average TFP growth (2000-01 to 2003-04)	Average TFP growth (2004-05 to 2007-08)	Average TFP growth (2000-01 to 2007-08)
Food and Beverages	0.986	1.108	1.047
Tobacco	1.024	1.011	1.017
Textiles	1.017	1.091	1.054
Wearing Apparel	0.952	1.092	1.022
Leather	1.002	1.073	1.037
Wood and Products of Wood	1.050	1.095	1.072
Paper and Paper Products	1.017	1.130	1.073
Printing and Publishing	0.962	1.104	1.033

Coke and Refined Petroleum Products	1.314	1.115	1.215
Chemicals and Chemical Products	0.998	1.070	1.034
Rubber and Plastic Products	1.023	1.045	1.034
Other Non-Metallic Mineral Products	1.007	1.194	1.100
Basic Metals	1.101	1.148	1.125
Fabricated Metal Products	1.056	1.121	1.089
Machinery and Equipment n.e.c.	1.026	1.114	1.070
Office, Accounting and Computing Machinery	1.193	1.171	1.182
Electrical Machinery and Apparatus n.e.c.	1.033	1.167	1.100
Radio, Television and Communication Equipment	1.054	1.127	1.090
Medical, Precision and Optical Instruments	1.061	1.094	1.077
Motor Vehicles	1.141	1.076	1.109
Other Transport Equipment	1.124	1.068	1.096
Furniture; Manufacturing n.e.c.	0.969	1.092	1.030

Source: Author's estimates

3.4.3.2 Estimation of the Second-stage

The analysis is carried out following Sharma and Sehgal (2010, 108). ICT infrastructure, as has been specified earlier, is divided into three main components; namely, aggregate manufacturing ICT capital, access to telecommunications (sum of fixed-line and wireless telephones) and internet density. These components are regressed separately on the estimates of TFP of the manufacturing sector using *pooled OLS* technique. The estimates of TFP obtained from the second-stage analysis, using *FGLS* parameters of the production function, are utilized for the analysis. The functional form of the models to be estimated is as follows:

$$\ln\widehat{TFP}_{i,t} = \alpha + \beta\ln ICTCap_t + \theta_1\ln K_{i,t}^{\mathrm{N}} + \theta_2\ln L_{i,t} + \mu_{i,t} \qquad [3\text{-}4]$$

$$\ln\widehat{TFP}_{i,t} = \alpha + \beta\ln Tele_t + \theta_1\ln K_{i,t}^{\mathrm{N}} + \theta_2\ln L_{i,t} + \mu_{i,t} \qquad [3\text{-}5]$$

$$\ln\widehat{TFP}_{i,t} = \alpha + \beta Net_t + \theta_1\ln K_{i,t}^{\mathrm{N}} + \theta_2\ln L_{i,t} + \mu_{i,t} \qquad [3\text{-}6]$$

where $\widehat{TFP}_{i,t}$ is the estimate of TFP level derived for industry *i* for a period *t*, *ICTCap* is the aggregate manufacturing ICT capital stock, *Tele* is the access to telecommunications and *Net* is the internet density. ln indicates that the variables are in logarithmic form. All the ICT infrastructure variables are common across the industries. All the above three models are extended by including industry specific characteristics in terms of non-ICT capital and labor to the RHS variables of the models. It is important to distinguish the variables of ICT infrastructure in order to identify whether they are in stock form or in flow form. The stock assessment of ICT infrastructure is captured by including a series of aggregate manufacturing ICT capital stock into the analysis; however, the proxies used for 'access to telecommunications' and the 'internet density' are not expressed in the stock form in a strict sense. The proxies are the cumulative measurement of the number of telephones and the number of internet users per 100 people over a period of time. Hence, the stock and non-stock variables are regressed separately.

To check whether the individual series are stationary or not, panel unit root tests have been applied to individual series of the models. For the TFP, non-ICT capital and labor series, the Levin-Lin-Chu (LLC) panel unit root test and Im-Pesaran-Shin (IPS) panel unit root test have been applied. For the individual ICT infrastructure components, the Dickey-Fuller (DF) and Augmented Dickey-Fuller (ADF) time series unit root tests have been used. For a panel dataset, the LLC test may be viewed as a pooled DF test or an ADF test when lags are included, with the null hypothesis that of nonstationarity of the series (Levin, Lin, and Chu 2002, 2-3). The test assumes common auto-regressive (AR) (1) coefficients for each individual unit in the panel; however, the main advantage of using this test is that it can be employed on large-N, small-T panels such as the ones used in this study. On the other hand, the IPS test allows for heterogeneity of the panel and performs the test based on the mean of the individual DF t-statistics of each unit in the panel (Im, Pesaran, and Shin 2003, 54). The test assumes nonstationarity of all series under the null hypothesis. These two tests would increase the robustness of the analysis. The results of the tests are reported in Table 3.4.

Table 3.4 Unit Root Tests

Variables	DF	ADF	LLC	Augmented LLC	IPS	Augmented IPS
ICTCap	-2.181	-4.242***(1)				
Tele	3.394	3.664(1)				
Tele D1	-4.719****t*					
Net	1.203	1.126(1)				
Net D1	-2.084	-1.398(1)				
TFP			-8.895***	-16.544 ***(1)	-1.888**	-2.261***(1)
K^{N}			-5.204***	-4.551***(1)	-1.640	-2.652***(2)
L			-1.843	-5.190***(2)	-1.489	-2.167***(2)

Notes: *** denotes significance at 1%, ** at 5% and * at 10% critical level; lags are reported in parenthesis; t denotes trend.

Source: Author’s estimates

The results show that the estimates of TFP derived from the *FGLS model* are stationary in both the tests of LLC and IPS. The results of ADF test show that *ICTCap* is also stationary. The series of *Tele* is nonstationary at the level; however, the first differenced series is stationary around a trend. The series of *Net* is nonstationary at the level as well as at the first difference, but is stationary at the second difference. The series of K^{N} is stationary at the level in the LLC as well as IPS tests. In the case of *L* series, it is also stationary in both the tests. The results, although mixed, are robust in both the LLC and IPS tests. All the series are stationary either at the level or at the first difference, except for the *Net* series which is integrated of order 2 (*I* (2)).

The study applies co-integration test on the combinations of these series, as specified in the models [3-4], [3-5] and [3-6]. To test for co-integrating relationships of these models, the LLC and IPS tests on the estimated residuals of the three models are applied using Granger procedure (Gujarati and Porter 2009, 762-764). Both the tests are augmented by using lags (up to two as the optimum) of the estimated residuals of the models [3-4], [3-5] and [3-6]. The results of the tests are reported in Table 3.6, showing significance at 1 and 5 percent critical levels. It confirms that the variables of all the aforementioned three models have linear combinations, and are co-integrated. In the next, Table 3.5 reports the estimates of the Model [3-4], [3-5] and [3-6].

Table 3.5 ICT Infrastructure and TFP: Regression Analysis

Model [3-4]			Model [3-5]			Model [3-6]		
Variables	Model [3-4(A)]	Model [3-4(B)]	Variables	Model [3-5(A)]	Model [3-5(B)]	Variables	Model [3-6(A)]	Model [3-6(B)]
ln*ICTCap*	0.527* (0.300)	0.541* (0.304)	ln*Tele*	0.245*** (0.043)	0.255*** (0.044)	*Net*	0.157*** (0.028)	0.163*** (0.029)
$\ln K^{\mathrm{N}}$		0.033 (0.032)	$\ln K^{\mathrm{N}}$		0.035 (0.029)	$\ln K^{\mathrm{N}}$		0.035 (0.029)
$\ln L$		-0.079 (0.057)	$\ln L$		-0.100* (0.053)	$\ln L$		-0.099* (0.053)
constant	-7.978 (7.789)	-8.207 (7.946)	constant	1.255 (0.776)	1.392 (0.948)	constant	5.433*** (0.056)	5.740*** (0.646)
F value	3.09	1.47	F value	32.60	11.15	F value	31.59	10.92
Prob > F	0.081	0.224	Prob > F	0.000	0.000	Prob > F	0.000	0.000
R-sq.	0.014	0.029	R-sq.	0.136	0.160	R-sq.	0.130	0.153
Obs.	198	198	Obs.	198	198	Obs.	198	198

Notes: Dependent Variable: $\ln\widehat{TFP}$; *** denotes significance at 1%, ** at 5% and * at 10% critical level; Robust standard errors are reported in parenthesis.

Source: Author's estimates

Table 3.6 Co-integration Test Results

Variables	Residual (Model [3-4])	Residual (Model [3-5])	Residual (Model [3-6])
LLC	-8.745***	-8.708***	-8.709***
LLC (1)	-15.713***	-15.526***	-15.535***
LLC (2)	-27.042***	-25.923***	-25.968***
IPS	-1.875**	-1.873**	-1.873**
IPS (1)	-2.184***	-2.164***	-2.165***
IPS (2)	-2.263***	-2.193***	-2.196***

Notes: *** denotes significance at 1%, ** at 5% and * at 10% critical level; (1) denotes augmented by lag 1 and (2) denotes augmented by lags 2.
Source: Author's estimates

From the results of the above estimates, it has been found that the ICT infrastructure has a positive and significant effect on the manufacturing sector of India. Model [3-4] estimates the effect of aggregate ICT capital on the estimates of TFP of the manufacturing sector. The aggregate ICT capital is considered as a proxy for the availability of a sector wide network of IT and as a part of the ICT infrastructure. The model is estimated by the *pooled OLS* methodology, with and without industry characteristics. The estimated coefficients of aggregate ICT capital are positive and statistically significant in both the variants (Model [3-4(A)] and Model [3-4(B)]) of the model. These results give insight into the potential of externalities emerging out of ICT capital and affecting the manufacturing sector as a whole. There will be a 0.53 percent increase in the TFP with every 1 percent increase in the aggregate ICT capital stock across the manufacturing sector. However, the results need to be interpreted cautiously and cannot be overemphasized given the low explanatory power of Model [3-4(A)] and failing of goodness-of-fit in Model [3-4(B)].

The same steps as for Model [3-4] have been carried out for Model [3-5] and [3-6]. The results of Model [3-5] indicate that the access to telecommunications is critical in the development of the manufacturing sector. The reduction in transaction and communications costs, efficient ways of communication, and availability of information are some of the main advantages that emanate from the availability of telecommunications. The coefficients in both the variants of the model are positive and statistically significant (at 1 percent critical level). The result of *Tele* shows that there will be a 0.24 percent increase in the TFP with a 1 percent increase in the number of telephones. In the case of internet density, results from Model [3-6] also support the importance of access to the internet, which assists in accessing and sharing information, communications and in other functionalities such as e-commerce, and online recruitments. The coefficients of *Net* are positive and significant (at 1 percent critical level). This suggests that with an increase of 1 percent in the internet density, there will be a 0.16 percent increase in the TFP of the manufacturing sector.

Overall the results are significant and supportive of the rising importance of the ICT infrastructure — which is still in the early stage of its development — in the industrial performance and development of the manufacturing sector of India. In comparison to the results from Sharma and Sehgal (2010, 110-111), the ICT infrastructure elasticities from the estimation indicate relatively strong effects on the manufacturing sector through the indirect channel of TFP. However, the comparison may not be fully plausible due to differences in the dataset used in both the studies.

3.5 Conclusion

The study has used a two-stage analysis, in which first the production function approach has been used to account for the direct effect of ICT capital as a factor of production on India's manufacturing sector. After accounting for heteroscedasticity and autocorrelation, the results have shown a significant effect of ICT capital on the output of the sector. In a similar way, the impact of ICT capital per labor on labor productivity has also been positive and significant.

In the second stage, the indirect effect of ICT infrastructure on India's manufacturing sector has been analyzed. First, the estimates of TFP of the manufacturing sector were computed by applying estimated parameters of the production function. Next, in estimating the effect of ICT infrastructure, each element of the ICT infrastructure has been regressed against the estimates of TFP of the manufacturing sector. The unit root tests have been carried out on all the panels including those of the ICT infrastructure and TFP. After the regression analysis, co-integration tests on estimated residuals of the three models have been employed. The results of these tests confirm that the variables are co-integrated, and help to identify the relationship between ICT infrastructure and the estimates of TFP. The results from this analysis have shown that the ICT infrastructure, which includes aggregate manufacturing ICT capital, telecommunications and the internet, has a significant impact on the manufacturing sector of India.

The direct effect of ICT investment shows that ICT is critical for industrial development, since it works as a factor of production and affects the output and labor productivity positively. However, this depends on the intensity of ICT investment and is limited to industries that invest in ICT capital directly. On the other hand, externalities emerging from the ICT infrastructure— encompassing aggregate sector wide stock of ICT capital, access to telecommunications, and the availability of internet— is critical for the manufacturing sector, since it not only affects an individual firm but also helps to increase the performance of the overall sector. This indirect effect depends on the availability of ICT infrastructure and the sector wide stock of ICT capital.

The analyses and results of the study, within the given dataset, provide insights into the relationship between ICT investment and the performance of the manufacturing sector of India. From the production process point of view, investment in ICT capital, which consists of computers and software, improves how production and non-production activities are conducted and contributes to output and labor productivity. Moreover, the network effects and network externalities that characterize ICT infrastructure play an important role in adding value to the sector as the network increases. In a period of globalization and liberalization of trade regimes, competitiveness has become a necessity for survival. Under such circumstances, ICT infrastructure helps to increase competitiveness through its indirect effect on the manufacturing TFP. It also helps in opening up new business opportunities through various channels of communications and information dissemination.

Chapter 4 An Overview of the Inter-industry and Inter-temporal Effects of the Indian ICT Services Industry: An Input-Output Analysis

4.1 Introduction

In Chapter 4, the focus is on an analysis of the influence and adoption of ICT, particularly ICT services using an I-O framework. This chapter explains how the ICT services industry is interlinked with the rest of the Indian economy and its effect on other industries through I-O analysis. The inter-industry and inter-temporal analysis carried out in this chapter addresses the second research objective and corresponding research questions, 3, 4 and 5.

Chapter 3 discusses the direct and indirect effect of ICT investment on the Indian manufacturing sector. In particular the role of ICT as a factor input and an infrastructure is assessed through production function and productivity analysis. Although the analysis has been restricted to the manufacturing sector, it provided insights into the effects of ICT capital and ICT infrastructure on the Indian industry. It becomes imperative to understand the role of ICT services while assessing the impact of emerging ICT on Indian industry. The services sector grew exponentially in the 1990s and 2000s, and accounts for the largest share of Indian GDP (around 52 percent). In particular the importance of ICT services has increased in the last decade, as is reflected in the two-digit growth rate of these services in the past couple of decades. One of the reasons for the expansion of Indian ICT services sector lies in its export-intensive nature. In particular, exports of software and IT services have witnessed double digit growth in the past decade. Software and IT services exports in 2010-11 are estimated at USD 59 billion as compared to USD 50 in 2009-10, an 18 percent growth in dollar terms (Department of Information Technology (DIT) 2011a, 13). However, this study does not include the impact of ICT services exports into the analysis due to limitations of data; in particular the lack of firm-level data does not allow for this type of analysis. In addition, understanding exports performance and its impact requires various aspects to be considered such as entrepreneurial and managerial skills, firm-level strategies and capabilities, among others, which is not the focus of this study. The direct contribution of software and services exports such as contribution to foreign exchange and employment generation has been listed in various publications (see, for instance, NASSCOM n.a., 2009; Varma and Sasikumar 2004).

Hence, this chapter aims to find out the effect of ICT services[13] on the rest of the economy in the light of inter-industry and inter-temporal linkages using IOTT of India for 2003-04 and 2006-07. For this purpose, the I-O analytical framework is utilized since I-O transactions matrix is the best source of inter-industry relations of an economy. In order to estimate the influence of ICT services, I-O multipliers and elasticities are applied whereas the left causative matrix method— utilized to analyze inter-temporal development of ICT services and their industrial linkages— aims to highlight how emergence of ICT services affected the output of the economy over a period of time (given the contribution of other industries), as well as how the other industries influenced the contribution of ICT services industry to the output of the economy. As an extension of the inter-temporal analysis, an ICT services intensity of the other industries has been computed and compared for the two periods. In the beginning multipliers and elasticities are computed for the ICT services to evaluate the inter-industry linkages of the ICT services industry. This is followed by the inter-temporal analysis by applying the left causative matrix model and ICT services intensity to highlight

[13] ICT services, for this study, are composed of 'Computer & related activities' and 'Communication' sectors. The details of these two services sectors, which represent ICT services in the IOTT of India, are given in the Appendix D.

the evolution of the ICT services industry and its linkage with other industries over a period of time.

The remaining chapter is divided as follows. Section 4.2 reviews the previous literature briefly followed by methodology explanations in Section 4.3. Section 4.4 describes data used for the analysis. In Section 4.5, the results of the analysis are presented. The last section, Section 4.6 concludes the chapter.

4.2 Literature Review

According to Hansda (2001, 1), the contribution of the services sector to the overall GDP growth reached an all time high of 65.1 percent in the 1990s compared to 43.6 percent in the 1980s. Moreover, IT related services emerged strongly during the 1990s and continued to grow at a higher rate. According to Gordon and Gupta (2003, 12), business services was the fastest growing industry in the 1990s, with an average annual growth rate of nearly 20 percent followed by communication services, with an average annual growth rate of 14 percent. While the growth in business services was largely due to the fast growing IT services industry, it was telecommunications services which led the communication industry in the 1990s (Gordon and Gupta 2003, 12). This suggests the growing importance of the ICT related services in the Indian economy. It is, therefore, necessary to understand the influence of ICT services industry's evolution and its linkages with other industries while analyzing the effect of ICT on the Indian economy.

The main components of IT usage in manufacturing include the use of Computer-Aided Design (CAD)/Computer-Aided Manufacturing (CAM)/Computer-Aided Engineering (CAE) software, data communication networks in enterprises, and the use of Enterprise Resource Planning (ERP) solutions among others (Asian Productivity Organization

(APO) 1998, 61). As far as CAD tools are concerned, the package solutions for 2D and 3D systems distributed and supported by multinational corporations in India find use in the automobile, aerospace and heavy engineering industries (Asian Productivity Organization (APO) 1998, 62). According to the aforementioned source, some of the ERP solutions were built for the process industry and discrete manufacturing.

As per the study of Guerrieri and Meliciani (2005, 493), it is argued that the structure of the manufacturing sector of a country can condition the rise of producer services, in particular financial, communication and business services (FCB). Their results show that specialized (market share) manufacturing industries and service industries that are high users of FCB are an important source of international competitiveness and specialization in producer services. These findings have an important bearing in interpreting the results of the left causative matrix model. Since the left causative matrix model tries to understand the inter-dependency of various industries and their influence upon each other over a period of time, it could be argued that in addition to service industries, the manufacturing industries that are internationally competitive and specialized can influence the ICT services industry's ability to affect the output multiplier of the economy.

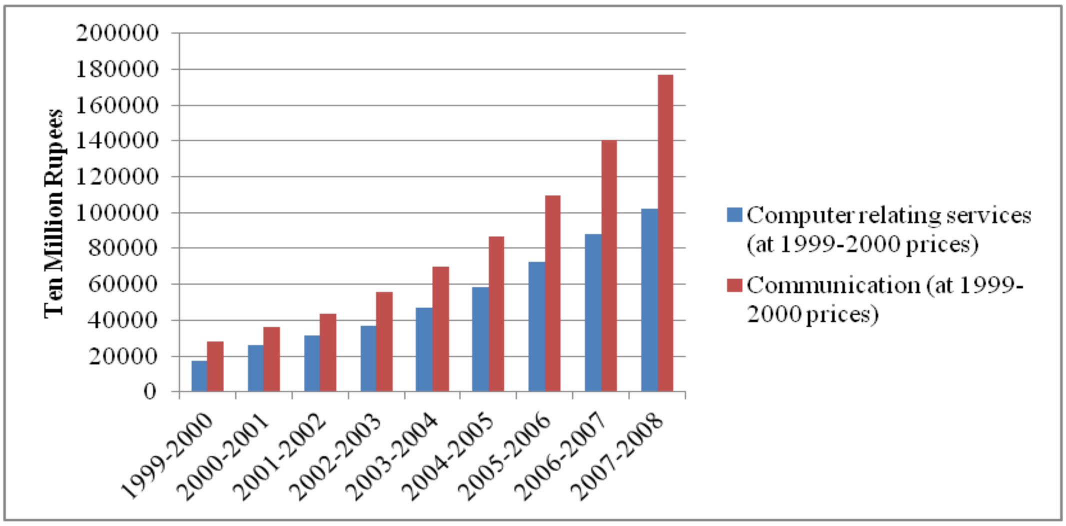
In addition, taking clues from a firm-level study of determinants of ICT adoption, it is argued that whether or not a firm operates in international markets can affect the firm's behavior with respect to ICT adoption (Bayo-Moriones and Lera-Lopez 2007, 354). According to that study, adoption could be linked to a firm's efforts to explore new markets and products. As far as ICT is concerned, a website development activity could be linked to attract prospective customers by showing a firm's specialization and activities more visibly. This suggests that firms that want to be active in international market or have high export sales are more likely to adopt ICT than others. Having applied the same logic to industries, it could be observed that industries operating in international markets through exports tend to be the high user of ICT services.

The conventional measures, such as backward and forward linkages as well as the output, income and employment multipliers, form the basis of inter-industry analysis under the I-O framework. These measures are complimentary to each other. Hence, this study will focus on backward and forward linkages, I-O multipliers, and elasticities in order to estimate the inter-industry linkages of the ICT services industry. While backward linkage of an industry measures the inducement to production in other industries whose goods are used as input to production to the former, forward linkage of an industry measures the extent to which the industry provides inputs for utilization by other industries (Hansda 2001, 10). I-O multipliers measure the response of the economy to an exogenous change in final demand (Ciobanu, Mattas, and Psaltopaulos 2004, 606). They permit the measure of overall impacts generated by injection of one additional unit of final demand, taking into account both the direct effects in the industry whose final demand has changed and indirect effects produced by backward linkages with the other industries (Miller and Blair 2009). Multipliers are not only used to estimate impacts, for example of a given policy, but also to quantify the degree of sector/industry interdependence of a given economy and to identify those sectors/industries (the so-called key sectors/industries) which might contribute significantly to economic growth (Bonfiglio 2005, 10). The conventional measures help identify 'key' or 'important' industries for the industrialization of an economy, and highlight industry interdependence.

For measuring inter-temporal changes of the ICT services industry and its effect on other industries over a period of time, this study adopts the left causative matrix model to analyze evolution of the ICT services and their contribution to the rest of the economy. According to Bonfiglio (2005, 18), the main advantage of the left causative matrix model is the possibility of analyzing the contribution of industries with respect to the total economy, taking account of the influences of each industry on each other industry. Roy *et al*. (2002), using left causative matrix model, examined the Indian information industry using IOTT for 1983-84 and 1989-90, representing the extent of informatization of the economy at the end of 1980s. Their study observed increased linkage of the information industry with the rest of the industries during the same period. However, the classification of information industry used in Roy *et al*. (2002) comprised of office computing, communication equipment, electronics equipment, communication, and education and research. Although this classification broadly defines information activities, it does not cover ICT related services activities, since the emergence and growth of these services took place post 1990. Hence, this study particularly focuses upon ICT services to evaluate its impact on the Indian economy. In addition to the left causative matrix, this chapter examines the ICT services intensities of other industries and a change in those intensities during the period of the analysis (that is, between 2003-04 and 2006-07).

Indian ICT services, led by ‘Computer & related activities’ and ‘Communication’ industries, are growing faster and continuing their growth momentum of the 1990s into the twenty-first century. Both the industries in real values are growing by two digits in recent years, with an average annual growth rate of 25.4 percent and 25.7 percent of ‘Computer & related activities’ and ‘Communication’ industries between 1999-2000 and 2007-2008, respectively at 1999-2000 prices. This suggests that the economic activities of these industries are increasing in the Indian economy.

Figure 4.1 Gross Domestic Product of the Indian ICT Services (at 1999-2000 prices)



Source: Author's compilation based on the data from Central Statistics Office (CSO) (2008) and (2009c).

The real GDP values (at 1999-2000 prices) of these two industries[14] for a period of nine years between 1999-2000 and 2007-2008 are given in Figure 4.1. As is shown in the figure, both the industries are showing growth in their annual GDP for the given period. As has been explained earlier, 'Computer & related activities' services industry is export-intensive in nature. Although increasing steadily, the domestic share of its total revenue is small compared to its exports share. The following figure explains the proportion of exports and domestic sales of the Indian software and services industry, as is commonly described.

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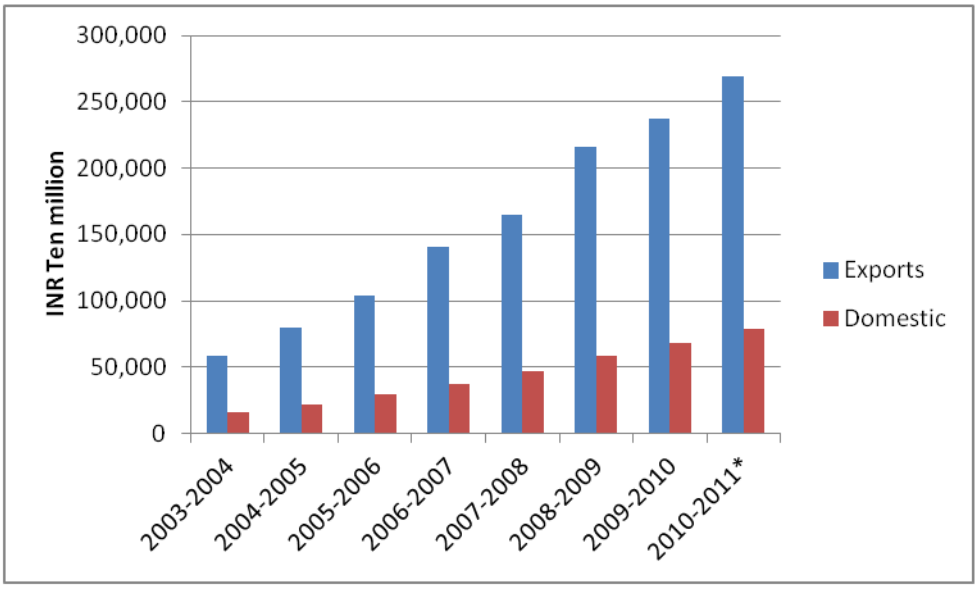
[14] The GDP values of 'Computer & related activities' between 1999-2000 and 2007-2008 mentioned in this section and the ones given in the national accounts (combined with other business services) differ marginally, since the national figures are net of 'Financial intermediation services indirectly measured'.

Figure 4.2 Exports and domestic market share of the Indian software and services industry



Note: * indicates estimates.

Source: Author's compilation based on the data from Department of Information Technology (DIT) (2009, 2010a, 2011a).

As is shown in Figure 4.2, the Indian software and services industry ('Computer & related activities' services) including ITES-Business Process Outsourcing (BPO) is dominated by high exports sales, which is estimated to reach INR 2696300 million (approximately USD 59607 million) in 2010-11. As compared to exports, revenue from the domestic sales is estimated at INR 787000 million (approximately USD 17398 million) in 2010-11, which is 22.6 percent of the total revenue of the same period. However, the revenue from the domestic market is increasing at a high rate, recording an average annual growth of 25.5 percent (24.9 percent for exports) during the period between 2003-04 and 2010-11. On the other hand, the 'Communication' services industry is dominated by domestic market sales. The proportion of exports of these services to the total production is very small. As per the data of IOTT of 2006-07, the share of exports of 'Communication' services is 4.9 percent of the total production. The study, however, focuses upon the domestic side of ICT services in order to understand the inter-industry dynamics of this industry and effect of ICT services adoption on the Indian industry.

4.3 Methodology

4.3.1 Input-Output Multipliers

This study estimates output and value added multipliers of the ICT services industry. Due to lack of employment related information, employment multiplier is not computed.

Output Multipliers

An output multiplier for industry j is defined as the total value of production in all industries of the economy that is necessary in order to satisfy a unit of final demand for industry j's output (Miller and Blair 2009, 245). It is estimated by summing each column of the Leontief's inverse matrix (total requirement matrix) (Ciobanu, Mattas, and Psaltopaulos 2004, 606) as follows:

$$M(O)_j = \sum_{i=1}^{n} l_{ij} \qquad \text{for } j = 1, 2, \ldots\ldots\ldots, n \qquad [4\text{-}1]$$

where $M(O)_j$ is the output multiplier of industry j and l_{ij} is the element of total requirement matrix.

Value added Multipliers

Value added multipliers measure the overall impact in terms of value added produced in all industries of the economy in order to satisfy a unit of final demand for industry j's output.

$$M(V)_j = \sum_{i=1}^{n} v'_{c,i}\, l_{ij} \qquad \text{for } j = 1, 2, \ldots\ldots\ldots, n \qquad [4\text{-}2]$$

where $M(V)_j$ is the value added multiplier of industry j, v'_c is the value added coefficient ($v'_{\mathrm{c}} = v'\hat{x}^{-1}$), and l_{ij} is the element of total requirement matrix.

4.3.2 Input-Output Elasticities

I-O elasticities measure the economy-wide response of changes in final demand, an indicator similar to that of I-O multipliers. However, I-O easticities, unlike multipliers, take relative size of an industry in the overall economy into account while estimating the impact of an exogenous shock. As a result, I-O elasticities represent a better measure than the multipliers of the impacts of industrial changes on the economy (Ciobanu, Mattas, and Psaltopaulos 2004, 607). Hence, this study estimates output and value added elasticities of ICT services industry within the I-O framework.

Output Elasticities

Output elasticities are the percentage change in total output of the economy due to percentage changes in the final demand of any industry. Output elasticities take the following form:

$$E(O)_j = \sum_{i=1}^{n} l_{ij}\, (f_j / \textstyle\sum_j x_j) \qquad \text{for } j = 1, 2, \ldots\ldots\ldots, n \qquad [4\text{-}3]$$

where $E(O)_j$ is the output elasticity of industry j, l_{ij} is the element of total requirement matrix, and $f_j / \sum_j x_j$ is the ratio of final demand to total output for industry j.

Value added Elasticities

Value added elasticities are the percentage change in value added of the economy due to percentage changes in the final demand of any industry, which take the following form:

$$E(V)_j = \sum_{i=1}^{n} v'_{c,i} \, l_{ij} \, (f_j / \sum_j x_j) \qquad \text{for } j = 1, 2, \ldots\ldots\ldots, n \qquad [4\text{-}4]$$

where $E(V)_j$ is the value added elasticity of industry j and v'_c is the value added coefficient.

4.3.3 Backward and Forward Linkages

The backward and forward linkages of ICT services industry are computed by taking relative size of the industry into consideration. Following Claus (2002, 7), the backward and forward linkages are weighted by the size of a respective industry's final demand in the total final demand of all the industries.

Backward Linkage

In its simplest form, the sum of column elements of the total requirement matrix is taken to be the indicator of backward linkage, as shown by $B_j = \sum_{i=1}^{n} l_{ij}$ where l_{ij} is the column element of the total requirement matrix. However, this measure is weighted by the relative size of final demand of industry j vis-à-vis other industries in the total final demand of all the industries to avoid possible bias which is discussed further below (Claus 2002, 7). This measure is computed as follows:

$$b_{ij}^{w} = b_{ij}\left(\frac{f_i}{\sum_{i=1}^{n} f_i}\right) \qquad [4\text{-}5]$$

where b_{ij}^{w} represents the elements of the total requirement matrix weighted by the final demand of industry i, b_{ij} denotes elements of the total requirement matrix before weights are applied, and f_i is the final demand for industry *i*'s output. Hence, the equation of backward linkage (weighted) becomes:

$$B_j^{w} = \sum_{i=1}^{n} b_{ij}^{w} \qquad [4\text{-}6]$$

where B_j^{w} is the sum of elements in column *j*, showing the input requirements for an additional unit increase in the final demand for industry *j*'s output, given each industry's share in the total final demand. This is an indicator of backward linkage.

Although this indicator appropriately measures the backward linkage of an industry with the rest of the economy weighted by its relative size, this alone falls short of providing sufficient insight about where a certain industry stands among others in respect of its backward linkage. Thus, an independent index of backward linkage is constructed for the ICT services industry in order to make inter-industry comparisons possible (Claus 2002, 7-8). The index of backward linkage is constructed as follows:

$$U_j^{w} = \frac{\left(\frac{1}{\mathrm{N}}\right) b_j^{w}}{\left(\frac{1}{\mathrm{N}^2}\right) \sum_{j=1}^{n} b_j^{w}} = \frac{b_j^{w}}{\left(\frac{1}{\mathrm{N}}\right) \sum_{j=1}^{n} b_j^{w}} \qquad [4\text{-}7]$$

where U_j^{w} is the index of backward linkage of industry *j*. The numerator in equation [4-7] measures the average stimulus to other industries, according to each industry's share in the total final demand, resulting from a unit increase in the final demand for industry *j*'s output.

On the other hand, the denominator measures the average stimulus to the whole economy resulting from a unit increase in the final demand for the output of all the industries.

Forward Linkage

As a counterpart of backward linkage, forward linkage is also computed by using the final demand weighted total requirement matrix as in equation [4-5]. The equation of forward linkage is as follows:

$$F_i^w = \sum_{j=1}^{n} b_{ij}^w \qquad [4\text{-}8]$$

where F_i^w is the sum of elements in row i, showing an increase in the output of industry *i* used as inputs to produce an additional unit of final demand for the output of industry *j*, given industry *i*'s share in the total final demand. Hence, forward linkage of industry *i* indicates the extent to which other industries does stimulate the output of industry i given exogenous change in the final demand of other industries, considering the extent to which direct and indirect requirements of the economy are met by intermediate inputs from industry *i*.

As has been mentioned in Claus (2002, 8), the assumption necessary in the case of conventional forward linkage (row sums of Leontief inverse matrix) — that demands for all industries uniformly increase by one unit — leads to bias measurement. Hence, it is necessary to apply weights to the total requirement matrix to measure unbiased backward and forward linkages.

Similar to the index of backward linkage, an index of forward linkage is constructed to enable comparison of the ICT services industry with other industries in terms of its forward linkage. The index of forward linkage is constructed as follows:

$$U_i^w = \frac{\left(\frac{1}{\mathrm{N}}\right) b_i^w}{\left(\frac{1}{\mathrm{N}^2}\right) \sum_{i=1}^{n} b_i^w} = \frac{b_i^w}{\left(\frac{1}{\mathrm{N}}\right) \sum_{i=1}^{n} b_i^w} \quad [4\text{-}9]$$

where U_i^w is the index of forward linkage of industry *i*. The numerator in equation [4-9] measures the average stimulus to industry *i*, according to its share in the total final demand, resulting from a unit increase in the final demand of other industries. On the other hand, the denominator measures the average stimulus to all the industries through their forward linkages, resulting from a unit increase in the final demand for the output of all the industries. Those industries having each of the indices greater than unity are identified as the key industries using the index of backward and forward linkages (Hansda 2001, 11).

The I-O measures such as I-O multipliers, I-O elasticities and backward and forward linkages and their indices, which are discussed in the above section, help identify key industries in terms of their influence on the output and value added of the economy, and estimate the inter-industry linkages of various industries based on the inter-industry and intra-industry transactions. These measures provide information about the interconnectedness among industries and the impact they can exert on the economy given exogenous change in demand takes place. However, the use of these measures has some merits and demerits, which are outlined in the table below.

Table 4.1 Merits and Demerits of the I-O Measures

Measures	Merits	Demerits
I-O multipliers	I-O multipliers, namely output and value added multipliers show the relative importance of industries in terms of their impact on the economy's output and value added, respectively.	I-O multipliers do not take relative size of the industries into account while analyzing their impact on the economy's output and value added.
I-O elasticities	I-O elastcities, namely output and value added elasticities, take the relative size of the industries into account while analyzing their impact on output and value added of the economy, respectively.	I-O elasticities do not provide any information on the forward linkage of an industry.
Backward and Forward Linkages	Provide information about interconnectedness of an industry, the extent a certain industry is dependent on inter-industry demand and/or supply.	Do not provide total linkage of an industry and ranking by inter-industry comparisons.
Indices of Backward and forward linkage	Inter-industry comparisons are made possible by using the indices. They provide insight into identifying key industries of an economy.	Since the indices are averages, they are sensitive to extreme values (Claus 2002, 8). In other words, industries with large index could be selling (buying) large amounts of output to (from) only a few industries.

Source: Author

4.3.4 Left Causative Matrix

Jackson *et al.* (1990) presented an extension to I-O analysis of the causative matrix model to evaluate the change between two matrices, which was originally used in Markov chain analysis (Ciobanu, Mattas, and Psaltopaulos 2004, 607). This method, using elements of causative matrix, helps explain changes between transition matrices at two different points in time. Following the previous literature mentioned earlier, the left causative matrix model is formulated as follows:

$$K_t = Z\widehat{M}^{-1} \qquad [4\text{-}10]$$

where K_t is a transition matrix for period *t*, Z is the Leontief inverse matrix of the same period, and $\widehat{M}$ is the diagonal matrix whose elements, M_{jj}, equal the sum of the *j*'th column of Z.

The elements of each column of the Leontief inverse are normalized by their respective column sums so that the column sums of transitional matrices are equal to 1. This process converts Leontief inverse matrix into standardized Leontief inverse, in other words, focusing the analysis upon relative influences of each industry on each other industry by standardizing changes in magnitudes of output multipliers.

Given the two time periods, *t* and *t*+1, the corresponding transition matrices are assumed to be linked by the following formula:

$$K_{t+1} = CK_{\mathrm{t}} \qquad [4\text{-}11]$$

where transition matrix K_{t+1} is calculated according to equation [4-10], and C is the causative matrix, which takes the following form:

$$C = K_{t+1}K_t^{-1} \qquad [4\text{-}12]$$

Causative matrix C transforms one transition matrix into the next using above formula. The elements of the transition matrix for the second (K_{t+1}) of the two time periods were identified as a function of the elements of the first transition matrix and the elements of the causative matrix (C) as given by

$$l_{ij}^{t+1} = c_{i1}l_{1j}^{t} + c_{i2}l_{2j}^{t} \dots \dots \dots + c_{in}l_{nj}^{t} \qquad [4\text{-}13]$$

Industry i's contribution to industry j's output multiplier in the next period is a linear function of all industries' previous contribution to industry j's output multiplier ($\sum l_{ij}^{t}$). In other words, transition probabilities for the second period are the weighted linear combinations of the transition probabilities of the first period, and the weights are elements of the causative matrix. A negative c_{ik} implies reduction in industry i's influence on output multiplier of industry j due to the presence of industry k. Element c_{ik}, therefore, is interpreted as industry k's influence on industry i's ability to contribute to output multipliers of other industries. All column sums of C equal 1. Row sums of each element of the causative matrix are conceived as final demand multiplier. Hence, a row sum greater than unity indicates greater contribution to output multipliers. This suggests that the corresponding industry experiences greater output impacts when final demands in other industries change (and vice versa in the case of row sums less than one).

The diagonal elements of the causative matrix are also interpretable. Negative deviations of the diagonal elements of corresponding industries from unity suggest decreased relative internalization of their own final demand output impacts (and vice versa in the case of positive deviations of the diagonal elements from one). The causative matrix method has an additional advantage of capturing both the direct changes in interactions and the relative changes due to the presence of other industries[15].

4.3.5 ICT services Intensity of the Indian Economy

In an attempt to analyze the effect of ICT services and its evolution using I-O framework, it is necessary to measure the intensity ICT services of various industries of the Indian economy and to identify industries with high intensity. In addition, this measure will also allow for observation of changes in ICT services intensity of various industries over the two sub-periods. Two types of ICT services intensity can be classified based on their usage. The first type measures the ratio of ICT services used per unit of output x. The second type measures direct and indirect use by accounting for usage of ICT services per unit of final output y (Roy, Das, and Chakraborty 2002, 113). Hence, the ICT services intensity is defined as follows:

$$\mathrm{H}'\mathrm{x} = I_{\mathrm{ind}} = \overline{\mathrm{H}}'\mathrm{y}$$

where H is a vector of direct productive ICT services requirements (I_{ind}) to produce one unit value of commodity. The vector $\overline{\mathrm{H}}$ represents direct plus indirect ICT services requirements

[15] The details of the left causative matrix model and the following elaborate explanation regarding interpretation of the model are mainly taken from Ciobanu (2004, 607) and Heng and Thangavelu (2006, 5-6).

to produce one unit value of commodity by each industry, delivered to final demand. I_{ind} is defined by $I_{\text{ind}} = \sum_{i=1}^{n} I_i$, suggesting ICT services use by all *n* industries in the economy. The ratio of ICT services per unit of output for industry *i* is defined by $H_i \equiv I_i/x_i$.

The vector $\overline{\mathrm{H}}$ can be derived from H using relationships[16]:

$$\mathrm{H}'\mathrm{x} = I_{\text{ind}} \tag{4-14}$$

$$\overline{\mathrm{H}}'\mathrm{y} = I_{\text{ind}} \tag{4-15}$$

The matrix form of output x is defined by

$$\mathrm{x} = (\mathrm{I} - \mathrm{A})^{-1}\mathrm{y} \tag{4-16}$$

Substituting equation [4-16] for x in [4-14] gives

$$\mathrm{H}'(\mathrm{I} - \mathrm{A})^{-1}\mathrm{y} = I_{\text{ind}} \tag{4-17}$$

Comparing [4-15] with [4-17] gives

$$\overline{\mathrm{H}}' = \mathrm{H}'(\mathrm{I} - \mathrm{A})^{-1} \tag{4-18}$$

The ICT services intensity is calculated for the two periods, using IOTT 2003-04 and 2006-07.

4.4 Data

Input output transactions tables (IOTTs) of India for the years 2003-04 and 2006-07 are used to carry out the above mentioned analysis. These tables are prepared and published by the CSO (2007a, 2009b), GoI[17]. The IOTT 2006-07 has been converted to constant prices

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[16] The explanation defining relationships of two vectors H and $\overline{\mathrm{H}}$, and deriving the matrix form of vector $\overline{\mathrm{H}}$ is taken from Roy *et al*. (2002, 113).

[17] For the year 2003-04, the 'Commodity-by-Commodity' matrix is used, which is made available by the CSO. The 2006-07 IOTT consists of 'Absorption' and 'Make' matrices. These matrices are used to construct 'Commodity-by-Commodity' matrix for 2006-07, which

(2003-04) with the help of price deflators of two types, namely WPI and implicit GDP deflators adjusted to the base of 2003-04, to suit corresponding industries[18]. The matrices are available at 130X130 industry classification for both the tables. Within the given industry classification of IOTTs two industries, namely ‘Communication’ (industry code: 115) and ‘Computer & related activities’ (industry code: 124), are identified as those that fall into the ICT services category. These two industries are analyzed separately in order to assess the influence and inter-industry linkages of ICT services.

4.5 Results

This section reports results of the analysis of the ICT services based on the aforementioned methodology. Results of the analysis of I-O multipliers, elasticities, backward and forward linkages, and their respective indices for the ‘Computer & related activities’ industry and ‘Communication’ industry are reported separately in Table 4.2. These measures indicate inter-industry linkages, and the influence of ICT services on the Indian economy in an I-O framework. The results are presented for two periods using IOTTs for 2003-04 and 2006-07 in order to understand the evolution of both the industries representing ICT services.

Those industries with index of backward linkage and forward linkage each greater than unity or the sum of the indices exceeding 2 are considered as the key industries of the economy (Hansda 2001, 11). As is shown in Table 4.2, both the indices of backward and forward linkage are greater than unity for ‘Computer & related activities’, whereas the ‘Index of Forward Linkage’ is greater than unity for ‘Communication’ but the ‘Index of Backward Linkage’ does not exceed unity.

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is utilized for the analysis.

[18] Explanation about type of deflator used for corresponding industry is summarized in Appendix E.

Table 4.2 I-O Indicators of ICT Services, for 2003-04 and 2006-07

Indicators	Computer & related activities		Communication	
	2003-04	2006-07	2003-04	2006-07
Backward Linkage	0.0390	0.0553	0.0104	0.0096
Forward Linkage	0.0292	0.0412	0.0216	0.0247
Index of Backward Linkage	2.6165	3.5829	0.6982	0.6210
Index of Forward Linkage	1.9604	2.6664	1.4528	1.6028
Output Multiplier	1.5198	1.5363	1.5823	1.5807
Value added Multiplier	1.1026	1.1083	1.2495	1.2409
Output Elasticity	0.0201	0.0276	0.0054	0.0048
Value added Elasticity	0.0146	0.0199	0.0042	0.0037

Source: Author's estimates

Nonetheless, the sum of both the indices for 'Communication' industry exceeds 2. Hence, both the industries representing ICT services of the Indian economy can be treated as the key industries for the industrial development of the Indian economy. The results of backward and forward linkage show that 'Computer & related activities' industry has larger backward linkage than its forward linkage. The result is counter-intuitive given the assumption that services tend to have large forward linkage compared to their backward linkage. The reason for ‘Computer & related services’ industry having larger backward linkage than its forward linkage lies with its high export-intensity. Since this industry is export-oriented, it requires domestic inputs to fulfill its export demand, increasing its backward linkage. On the contrary, ‘Communication’ services industry has larger forward linkage than its backward linkage due to its domestic market orientation.

Moreover, output and value added multipliers of both the industries suggest that the economy will benefit through increased output and value added in the case of an exogenous shock increasing final demand of these industries. An increase of a unit of final demand in ‘Computer & related activities’ will lead to an increase in the economy’s output and value added by 1.5363 and 1.1083 units, respectively, as per the calculation of 2006-07. Similarly, an increase of a unit of final demand for ‘Communication’ will generate 1.5807 and 1.2409 units of output and value added for the economy, respectively, for the same period. Further, the output and value added elasticities, by taking relative size of the industries into account, reveal the potential of ‘Computer & related activities’ and ‘Communication’ industries to influence the output and value added of the economy. In the case of ‘Computer & related activities’, a 10 percent increase in the final demand of this industry leads to 0.276 and 0.199 percent increase in the output and value added of the national economy, respectively for 2006-07. The output and value added elasticities of the ‘Communication’ industry are relatively small, indicating a 10 percent increase in the final demand of communication services leads to 0.048 and 0.037 percent increase in the national output and value added, respectively for the same period.

Further, a comparison of these indicators for two periods, that is, for 2003-04 and 2006-07, allows for an evaluation of the increasing or decreasing influence of ICT services on the Indian economy during the corresponding period of time. Although some indicators of

‘Communication’ services dropped during the given period, all the indicators of inter-industry linkages for ‘Computer & related activities’ services increased. In the case of ‘Computer & related activities’, all the indicators including output and value added multipliers and elasticities, backward and forward linkages, and their indices, increased during the period of the study indicating the growing influence and inter-industry linkage of this industry. On the other hand, except for forward linkage and its index, all the other indicators for ‘Communication’ decreased marginally during the same period. This suggests that the Indian industry is relying on ‘Computer & related activities’ services more than on ‘Communication’ services. It is also indicative of the Indian industries’ gradual shift from communication services to IT and IT enabled services that have high potential to add value.

In the next section, the results of the analysis of inter-temporal linkages of ICT services and their evolution are reported in Table 4.3 and Table 4.4 using the left causative matrix model. Table 4.3 presents the results of ‘Computer & related activities’ industry, while the results of ‘Communication’ industry are reported in Table 4.4.

Table 4.3 Analysis of 'Computer & related activities' industry under the Left Causative Matrix Model

No	Commodity	Causative elements	No	Commodity	Causative elements	No	Commodity	Causative elements
1	Computer & related activities	0.9689	9	Paints, varnishes and lacquers	0.0036	17	Organic heavy chemicals	0.0027
2	Silk textiles	0.0078	10	Leather footwear	0.0033	18	Readymade garments	0.0026
3	Air transport	0.0076	11	Tractors and agri. implements	0.0031	19	Inorganic heavy chemicals	0.0022
4	Tobacco products	0.0068	12	Water transport	0.0030	20	Plastic products	0.0022
5	Khadi, cotton textiles(handlooms)	0.0056	13	Other chemicals	0.0029	21	Ships and boats	0.0021
6	Miscellaneous textile products	0.0048	14	Supporting and auxiliary transportation activities	0.0028	22	Miscellaneous manufacturing	0.0019
7	Aircraft & spacecraft	0.0045	15	Industrial machinery(others)	0.0027	23	Machine tools	0.0019
8	Electrical wires & cables	0.0045	16	Carpet weaving	0.0027	24	Art silk, synthetic fiber textiles	0.0018

25	Jute, hemp, mesta textiles	0.0017	33	Leather and leather products	0.0012	41	Miscellaneous food products	0.0008
26	Hand tools, hardware	0.0016	34	Forestry and logging	0.0011	42	Other metallic minerals	0.0008
27	Other non-metallic mineral prods.	0.0016	35	Motor vehicles	0.0011	43	Pesticides	0.0008
28	Electrical industrial Machinery	0.0016	36	Iron ore	0.0009	44	Fertilizers	0.0007
29	Beverages	0.0016	37	Gems & jewellery	0.0009	45	Rail equipments	0.0007
30	Other electrical Machinery	0.0014	38	Business services	0.0008			
31	Furniture and fixtures-wooden	0.0014	39	Miscellaneous metal products	0.0008			
32	Woolen textiles	0.0014	40	Wood and wood products	0.0008			

Note: Figures in parenthesis indicate negative values.

Source: Author’s estimates

Table 4.4 Analysis of 'Communication' industry under the Left Causative Matrix Model

No	Commodity	Causative elements	No	Commodity	Causative elements	No	Commodity	Causative elements
1	Communication	1.1218	11	Other metallic minerals	0.0086	21	Land transportation including via pipeline	0.0053
2	Communication equipments	0.0226	12	Non-ferrous basic metals	0.0082	22	Structural clay products	0.0052
3	Batteries	0.0189	13	Other services	0.0079	23	Trade	0.0051
4	Iron ore	0.0173	14	Bauxite	0.0079	24	Electrical wires & cables	0.0048
5	Gems & jewellery	0.0159	15	Other transport equipments	0.0072	25	Copper ore	0.0046
6	Supporting and auxiliary transportation activities	0.0150	16	Other electrical Machinery	0.0071	26	Cement	0.0040
7	Electronic equipments(incl.TV)	0.0135	17	Insurance	0.0069	27	Miscellaneous metal products	0.0038
8	Real estate activities	0.0127	18	Other non-electrical machinery	0.0065	28	Coal tar products	0.0038
9	Electrical industrial Machinery	0.0095	19	Computer & related activities	0.0056	29	Legal services	0.0037
10	Business services	0.0091	20	Motor cycles and scooters	0.0054	30	Machine tools	0.0036

31	Industrial machinery(F & T)	0.0036	38	Bicycles, cycle-rickshaw	0.0030	45	Iron and steel foundries	0.0027
32	Furniture and fixtures-wooden	0.0034	39	Manganese ore	0.0030			
33	Tractors and agri. implements	0.0034	40	Water supply	0.0030			
34	Motor vehicles	0.0034	41	Electrical appliances	0.0029			
35	Industrial machinery(others)	0.0031	42	Iron, steel and ferro alloys	0.0028			
36	Medical and health	0.0031	43	Air transport	0.0028			
37	Water transport	0.0030	44	Iron and steel casting & forging	0.0028			

Note: Figures in parenthesis indicate negative values.

Source: Author’s estimates

The figures reported in Table 4.3 and Table 4.4 are the row elements of the 'Computer & related activities' and 'Communication' industries of the left causative matrix, respectively. The industries are reported in descending order, starting from the highest value to the lowest one for up to 45 industries. 'Computer & related activities' and 'Communication' industries are analyzed separately.

The diagonal element of 'Computer & related services' (0.9689) from the left causative matrix, which is recorded as the first industry in Table 4.3, falls short of unity. This implies that, relative to the impact on other industries, the final demand of the 'Computer & related activities' industry stimulated a reduced output impact on the 'Computer & related activities' industry itself during the period 2003-04 to 2006-07. In other words, the impact of the 'Computer & related activities' industry's final demand, relative to others, has been increasingly externalized. Examining the row elements recorded in Table 4.3, it is found that industries, including 'Silk Textiles', 'Air Transport', 'Tobacco Products', 'Khadi, Cotton Textiles (Handlooms)', 'Miscellaneous Textile Products', 'Aircraft & Spacecraft', and 'Electrical wires & cables' among others, have an increasing proportionate importance in stimulating 'Computer & related activities' output, either directly or relative to the importance of final demand deliveries of other industries. At the aggregate level these industries fall into 'Textiles', 'Transport', 'Beverages Tobacco and Tobacco products' and 'Electrical Machinery' categories, except for 'Aircraft & Spacecraft'. With the exception of a few industries, final demand of other industries also generated an increased output of 'Computer & related activities' industry. As has been discussed earlier in the literature review, international competitiveness and specialization, and export-orientation could be among the parameters of ICT services adoption (Guerrieri and Meliciani 2005; Bayo-Moriones and Lera-Lopez 2007), though the study does not explicitly establish a correlation between them. From the export-orientation viewpoint, it is interesting to note that some of the manufacturing industries with a high propensity to stimulate the output of ‘Computer & related activities’ directly and indirectly are into international market through export sales such as ‘Silk Textiles’, ‘Khadi, Cotton Textiles (Handlooms)’, ‘Miscellaneous Textile Products’, and ‘Aircraft & Spacecraft’ among others. The exports to total output ratio for these industries for 2006-07 is 49.9, 18.3, 13.7, and 42.1 respectively (calculated from the IOTT 2006-07). The share of ‘Textiles’ industry’s exports in the total exports of principle commodities from India in 2008-09 is 10.5 percent (Office of the Economic Adviser n.a.). However, the ‘Tobacco Products’ industry does not export, indicating that there are other factors as well that drive the demand of ICT services. Nonetheless, India is placed among the top 15 producers of ‘Tobacco Products’ in the world in 2005, and its operating surplus (34 percent) is higher than some of the developing countries and other Indian manufacturing industries in the year 2003 as per the Industrial Statistics 2007 (UNIDO 2007). From this observation, it can be pointed that competitive pressure (Bayo-Moriones and Lera-Lopez 2007, 353) due to higher domestic demand is at work, which could be one of the reasons this industry is affecting the output of ‘Computer & related activities’ industry through intermediate demand. In addition to the aforementioned manufacturing industries, ‘Air Transport’ is the service industry that has increased its service delivery through online services such as internet booking, for which it requires higher content of computer related services.

As is shown from the results of Table 4.3, row sum corresponding to ‘Computer & related activities’ industry is larger than one. This implies that the final demand in other industries has generated an increased impact on the output of the ‘Computer & related activities’ industry during the period between 2003-04 and 2006-07. This suggests that the ‘Computer & related activities’ industry has become a competitive supplier of ICT services catering to the total (direct and indirect) requirements of other industries during the same period.

In the case of ‘Communication’ industry, the dominant diagonal element of this industry from the left causative matrix exceeds unity (1.1218) as is recorded in the first industry in Table 4.4. This implies that the final demand impact of this industry, relative to other industries, is increasingly internalized within the industry. In other words, the final demand of the ‘Communication’ industry stimulated an increased output impact on the ‘Communication’ industry itself during the period 2003-04 to 2006-07, in contrast to the ‘Computer & related activities’ industry. The row elements recorded in Table 4.4 indicate that the industries at the aggregate level that have increasing proportionate ability in stimulating ‘Communication’ industry’s output (and hence, its ability to contribute to the output multipliers of other industries) include ‘Communication equipments’, ‘Batteries’, ‘Iron ore’, ‘Gems & jewellery’, ‘Supporting and auxiliary transportation activities’ ‘Electronic equipments(incl.TV)’, and ‘Real estate activities’ among others. At the aggregate level these industries fall into ‘Electrical Machinery’, ‘Mining & Quarrying’, and ‘Transport’, except for ‘Gems & jewellery’ and ‘Real estate activities’. With the exception of three industries, final demand of other industries also generated an increased output of ‘Communication’ industry. Similar to the case of ‘Computer & related activities’, some of the manufacturing industries with high influence on the ‘Communication’ industry through intermediate demand have high export sales such as ‘Communication equipments’, ‘Iron ore’, and ‘Gems and jewellery’. The share of ‘Gems and jewellery’ in the total Indian export of principle commodities in 2008-09 is 15.2 percent, which is very high. The ratio of exports to the total output for ‘Communication equipments’ and ‘Iron ore’ is 23.1 and 56.9 percent, respectively. There are also service industries such as ‘Supporting and auxiliary transportation activities’ and ‘Real estate activities' that had high demand for telecommunication services during 2003-04 and 2006-07. This could be to improve the delivery of their services using telecommunication and the internet.

Similar to 'Computer & related activities' industry, row sum corresponding to 'Communication' industry is larger than one. This implies that the final demand in other industries has generated an increased impact on the output of the 'Communication' industry during the period between 2003-04 and 2006-07. This suggests that the 'Communication' industry has also become a competitive supplier of total requirements of other industries.

In order to assess potential gains from the increased ability of the domestic ICT services industry to cater to the needs of the domestic market, a hypothetical import endogenization of ICT services is tested by using the left causative matrix model. This hypothetical model will provide insights into how the improvements in capabilities of the domestic ICT services industry to serve other industries of the economy will lead to increased benefits to the overall economy. The effect of import endogenization is analyzed only for 'Computer & related activities' industry since it has higher potential to grow and serve the domestic market by substituting imports in future. The model explained in Section 4.3.4 is extended for hypothetical import endogenization. Results are presented in Table 4.5.

Table 4.5 'Computer & related activities' industry under the Left Causative Matrix Model: The Case of Import Endogenization

No	Commodity	Causative elements	No	Commodity	Causative elements	No	Commodity	Causative elements
1	Computer & related activities	0.9281	11	Ships and boats	0.0069	21	Supporting and auxiliary transportation activities	0.0045
2	Aircraft & spacecraft	0.0264	12	Leather footwear	0.0068	22	Organic heavy chemicals	0.0043
3	Silk textiles	0.0136	13	Watches and clocks	0.0060	23	Hand tools, hardware	0.0042
4	Tobacco products	0.0125	14	Paints, varnishes and lacquers	0.0058	24	Bicycles, cycle-rickshaw	0.0042
5	Air transport	0.0114	15	Tractors and agri. implements	0.0055	25	Woolen textiles	0.0041
6	Khadi, cotton textiles(handlooms)	0.0104	16	Machine tools	0.0053	26	Fishing	0.0038
7	Water transport	0.0086	17	Miscellaneous manufacturing	0.0051	27	Inorganic heavy chemicals	0.0038
8	Industrial machinery(others)	0.0082	18	Readymade garments	0.0051	28	Plastic products	0.0036
9	Miscellaneous textile products	0.0080	19	Carpet weaving	0.0046	29	Electrical industrial Machinery	0.0036
10	Electrical wires & cables	0.0080	20	Other chemicals	0.0046	30	Jute, hemp, mesta	0.0032

							textiles	
31	Art silk, synthetic fiber textiles	0.0032	37	Leather and leather products	0.0023	43	Fertilizers	0.0021
32	Other electrical Machinery	0.0031	38	Furniture and fixtures-wooden	0.0023	44	Non-ferrous basic metals	0.0020
33	Iron and steel casting & forging	0.0030	39	Other non-electrical machinery	0.0023	45	Rail equipments	0.0019
34	Beverages	0.0030	40	Motor vehicles	0.0022			
35	Other non-metallic mineral prods.	0.0027	41	Forestry and logging	0.0022			
36	Business services	0.0027	42	Printing and publishing	0.0021			

Note: Figures in parenthesis indicate negative values.

Source: Author’s estimates

Similar to the models without import endogenization, Table 4.5 reports row elements of the left causative matrix of import endogenization corresponding to the ‘Computer & related activities’ industry. The industries are in descending order, starting with the highest value of row elements. The diagonal element of ‘Computer & related activities’ is less than unity, showing that the final demand impacts of this industry are externalized during the period. The externalization of final demand’s impact of ‘Computer & related activities’ has increased in the case of import endogenization, as shown by a decrease in the diagonal element’s value compared to that without endogenization (0.9689>0.9281). This implies that the influence of the ‘Computer & related activities’ industry on other industries’ output has increased between 2003-04 and 2006-07 under the hypothetical situation. The other row elements also suggest some improvements, in that the industries affecting the ‘Computer & related activities’ industry’s ability to contribute to output multipliers of other industries negatively also decreased. The industries that are affecting the ‘Computer & related activities’ industry negatively are the ones with less probabilities to import ICT related services, including ‘Ownership of dwellings’, ‘Other services’ and ‘Storage and warehousing’.

The row sum, being larger than unity, also suggests that the final demand in other industries has generated an increased impact on the output of the ‘Computer & related activities’ industry during the same period. The row sum is larger than that without import endogenization (1.2063>1.0771), indicating that the industry will increase its competitiveness as a supplier of intermediate inputs to the requirements of other industries of the economy. Referring to the typological division based on left causative matrix method given in Roy S., Das T., and D. (2002, 112), the results of the left causative matrix analysis are summarized in Table 4.6.

Table 4.6 A Typological Division of ICT services under the Left Causative Matrix Method

	$\sum_{k\neq i} C_{ik} < 0.0$ Decreased output impacts simulated by other industries' final demand	$\sum_{k\neq i} C_{ik} > 0.0$ Increased output impacts stimulated by other industries' final demand
$C_{ii} > 1.0$ Increased relative endogenization of impacts	IV	I Communication ↓ (C_{ii}=1.1218; $\sum_{k\neq i} C_{ik}$=1.4788 -1=0.4788)
$C_{ii} < 1.0$ Decreased relative endogenization of impacts	III	II Computer & related activities ↓ (C_{ii}=0.9689; $\sum_{k\neq i} C_{ik}$= 1.0771-1=0.0771) Computer & related activities (import endogenization case)

Source: Author's estimates

The results from Table 4.3, Table 4.4, Table 4.5 and Table 4.6 suggest that the 'Computer & related activities and 'Communication' industries have an increased contribution to output multipliers of other industries, and have become a competitive supplier of intermediate inputs during the period 2003-04 to 2006-07. The output multipliers (Table 4.2) reveal that the final demand of these industries generates increased total output impacts, whereas the row sums of the left causative matrix corresponding to these industries reveal that the final demand in other industries generates increased output impacts for these industries. The 'Computer & related activities' industry falls in type II of Table 4.6, implying that it is not only being influenced by other industries' final demand but is also influencing other industries' output. On the other hand, the 'Communication' industry belongs to type I of Table 4.6, suggests that it has become a competitive supplier of inputs but has also increased internalization of its final demand impacts relative to other industries. Hence, the ICT services industry has become more interactive with the rest of the economy, resulting in higher potential for other industries to benefit from technological advancements and innovations of ICT, as well as providing opportunities for the ICT services industry to grow.

Since ICT services industry is becoming competitive as a supplier of intermediate inputs to other industries, it becomes imperative to estimate the ICT services intensity of various industries of the economy, and corresponding changes in intensity over the period. The results of the ICT services intensity, represented by the intensities of 'Computer & related activities' and 'Communication' industries together, are reported in Table 4.7.

Table 4.7 ICT Services Intensity of the Indian Economy, for 2003-04 and 2006-07

No	Commodity	ICT Intensity for 2003-04	Commodity	ICT Intensity for 2006-07
1	Communication equipments	0.1805	Communication equipments	0.2316
2	Electronic equipments(incl.TV)	0.1095	Electronic equipments(incl.TV)	0.1426
3	Supporting and auxiliary transportation activities	0.0889	Supporting and auxiliary transportation activities	0.1204
4	Aircraft & spacecraft	0.0877	Gems & jewellery	0.0970
5	ICT services	0.0687	Aircraft & spacecraft	0.0965
6	Batteries	0.0666	Batteries	0.0951
7	Gems & jewellery	0.0595	ICT services	0.0912
8	Insurance	0.0579	Real estate activities	0.0785
9	Real estate activities	0.0558	Business services	0.0745
10	Business services	0.0516	Electrical industrial Machinery	0.0722
11	Other transport equipments	0.0481	Iron ore	0.0706
12	Electrical industrial Machinery	0.0465	Ships and boats	0.0697
13	Watches and clocks	0.0454	Insurance	0.0669
14	Ships and boats	0.0444	Electrical wires & cables	0.0665
15	Motor cycles and scooters	0.0439	Other transport equipments	0.0633
16	Other services	0.0436	Other electrical Machinery	0.0633
17	Other electrical Machinery	0.0410	Other services	0.0578
18	Industrial machinery(others)	0.0385	Motor cycles and scooters	0.0575
19	Electrical wires & cables	0.0378	Air transport	0.0542
20	Air transport	0.0366	Industrial machinery(others)	0.0536
21	Bicycles, cycle-rickshaw	0.0364	Other non-electrical machinery	0.0535
22	Other non-electrical	0.0359	Non-ferrous basic metals	0.0534

	machinery			
23	Machine tools	0.0339	Watches and clocks	0.0523
24	Tractors and agri. implements	0.0338	Tractors and agri. implements	0.0509
25	Land transportation including via pipeline	0.0324	Bicycles, cycle-rickshaw	0.0499
26	Electrical appliances	0.0321	Machine tools	0.0486
27	Industrial machinery(F & T)	0.0315	Silk textiles	0.0456
28	Non-ferrous basic metals	0.0314	Land transportation including via pipeline	0.0453
29	Silk textiles	0.0314	Bauxite	0.0449
30	Banking	0.0302	Electrical appliances	0.0427
31	Medical, precision& optical instruments	0.0302	Industrial machinery(F & T)	0.0427
32	Woolen textiles	0.0298	Miscellaneous manufacturing	0.0413
33	Readymade garments	0.0296	Motor vehicles	0.0407
34	Motor vehicles	0.0279	Medical, precision & optical instruments	0.0402
35	Miscellaneous manufacturing	0.0276	Miscellaneous metal products	0.0396
36	Water transport	0.0259	Readymade garments	0.0390
37	Bauxite	0.0255	Water transport	0.0382
38	Hand tools, hardware	0.0252	Other metallic minerals	0.0372
39	Miscellaneous metal products	0.0251	Woolen textiles	0.0368
40	Miscellaneous textile products	0.0248	Iron and steel foundries	0.0365
41	Tobacco products	0.0244	Tobacco products	0.0363
42	Storage and warehousing	0.0243	Banking	0.0356
43	Iron and steel foundries	0.0237	Miscellaneous textile products	0.0353

44	Printing and publishing	0.0235	Hand tools, hardware	0.0351
45	Rail equipments	0.0225	Iron and steel casting & forging	0.0345

Source: Author's estimates

The ICT services intensity in the form of combined intensities of 'Computer & related activities' and 'Communication' of various industries for 2003-04 and 2006-07 are reported in Table 4.7. The industries are arranged in descending order, starting from an industry with the highest value up to 45 industries. All the industries have increased their ICT services intensity during the period except for 'Storage and warehousing', 'Sugarcane' and 'Cotton' when all the 129 industries are considered.

The total (direct plus indirect) ICT services intensity varied from 18.05 percent for 'Communication equipments' to 0.07 percent for 'Ownership of dwellings' and 0.00 percent for 'Public administration in 2003-04. During 2006-07, it varied from 23.16 percent for 'Communication equipments' to 0.09 percent for 'Ownership of dwellings' and 0.00 percent for 'Public administration'. Other industries with high ICT services intensity include 'Electronic equipments (incl. TV)', 'Supporting and auxiliary transportation activities', 'Gems and jewellery', 'Aircraft and spacecraft', 'Batteries', 'ICT services', 'Real estate activities', 'Business services' and 'Electrical industrial machinery' among others for 2006-07. The average ICT services intensity during the period 2003-04 to 2006-07 increased from 2.23 percent to 3.23 percent.

The industries with high ICT services intensity such as 'Communication equipments', 'Electronic equipments (incl. TV)', and 'Aircraft and spacecraft' are some of the high-tech industries using embedded software in their products. Electronics has been considered by the government as a strategic industry for the dissemination of information technology among people. It is also intuitive to have services industries with high ICT services intensity such as 'Supporting and auxiliary transportation activities', 'Real estate activities', and 'Business services' other than the ICT services industry itself. Since these industries have services as their output, they increase the quality of their services by introducing ICT. In addition, ICT also works as an interface between the customers and the providers of those services by introducing online access to some of the services. One of the reasons behind the high ICT services intensity of 'Batteries' and 'Electrical industrial machinery' industries is its capital intensive nature. In addition, the cost of input materials and utilities (as a percentage of output) of 'Batteries' in 2003 is relatively low compared to that of other traditional industries. The cost is 71.8 (as a percentage of output) which is also relatively competitive compared to some of the developing economies (UNIDO 2007, 145). The value added per employee (8.5 thousand USD) of the 'Batteries' industry is more than four times larger than its wages and salaries per employee (2.0 thousand USD) for 2003 (UNIDO 2007, 145). These figures partially indicate the competitiveness of this industry and a probable reason behind its high ICT services intensity. As for 'Gems and jewellery', it is one of the export competitive industries of India. The high ICT services intensity of this industry partially suggests that ICT services provide a competitive advantage when competing in the world economy.

4.6 Conclusion

ICT services, being one of the fastest growing industries, are considered a catalyst of economic growth. The Indian economy experienced a surge in the growth of the services sector, driven by ICT related services among others in the 1990s. Hence, it becomes imperative to analyze the effects and inter-industry relations of ICT services, as a part of an evaluation of the economic effects of ICT on the Indian industry.

This chapter examined the second research objective that focuses upon the inter-industry and inter-temporal linkages of ICT services in order to analyze the effect of ICT services on the Indian industry. I-O structure of the Indian industry provides the rich data set and basic framework for the analysis of ICT services. ICT services under the I-O framework are represented by the 'Computer & related activities' and 'Communication' industries. Hence, these two industries are examined to assess the inter-industry and inter-temporal relations of ICT services using I-O framework. For the analysis purpose, IOTTs of India for 2003-04 and 2006-07 are utilized.

In the beginning, conventional measures of I-O analysis that include I-O multipliers, I-O elastcities, backward and forward linkages and their indices are applied in order to understand the influence and inter-industry relations of ICT services. These measures are computed for 2003-04 and 2006-07 for comparison purposes. The findings of multipliers and elasticies analysis for 'Computer & related activities' industry reveal that exogenous shock to these services in terms of final demand increase have high potential to increase the total output and value added of the Indian economy. Similarly, final demand impact of the 'Communication' industry also generates increased output and value added contribution to the national economy. Although the output and value added multipliers of the 'Communication' industry are larger than those of 'Computer & related activities' industry, I-O elasticities, by taking relative size of the industry into account, suggest that the 'Computer & related activities' industry provides larger gains to the economy. Moreover, 'Computer & related activities' can impact the output of other industries due to its high value of backward linkage which falls among the top ten industries for 2006-07. It also has high value of forward linkage ranking eleventh among all the industries for the same period. The 'Communication' industry has a lower value of backward and forward linkages than the 'Computer & related activities' industry. However, both the indices of backward and forward linkage indicated that these two industries are ‘key’ industries for industrial development. Comparisons for two time periods indicated that all the indicators for ‘Computer & related activities’ increased during the period, whereas, except for forward linkage and its index, there was a marginal decline in those for ‘Communication’ industry. It suggests that the relative influence of the ‘Computer & related activities’ industry has increased during the period of the analysis compared to that of the ‘Communication’ industry.

The inter-temporal analysis of ICT services is carried out using the left causative matrix model and ICT services intensity comparisons for 2003-04 and 2006-07. The results of the left causative matrix model implied that the ICT services industry, represented by the ‘Computer & related activities’ and Communication’ industries, has become a competitive supplier of total requirements of other industries and increased its interaction with other industries. Both the industries are not only influenced by the final demand impacts of other industries, but are also influencing other industries’ output. The hypothetical stimulation using import endogenization of the economy gave increased impacts and interactions of the ‘Computer & related activities’ industry and reduced the number of industries affecting its ability to contribute to others industries negatively. This suggests that the ICT services industry can benefit by delivering the domestic needs of the economy and that other industries can also benefit by the increased interaction with ICT services.

In addition, the comparison of ICT services intensity of various industries between 2003-04 and 2006-07 shows that the adoption of ICT services for productive purposes, both directly and indirectly, has increased with the exception of three industries. This also substantiates the earlier findings that the ICT services industry has become a competitive supplier of total requirements of other industries. Since the ICT services, particularly

‘Computer & related activities’ services, have high potential to generate increased output and value added impacts, this increased interaction and adoption of these services will benefit other industries of the economy. Some of the industries with high ICT services intensity include those manufacturing industries with high electrical and electronics content such as ‘Communication equipments’, ‘Electronic equipments (incl. TV)’, and ‘Electrical industrial machinery’ as well as high-tech industries such as ‘Aircraft and spacecraft’. There are also some services industries with high intensity that include ‘Business services’, ‘Real estate activities’ and ‘Insurance’ other than the ‘Computer & related activities’ and ‘Communication’ industries themselves.

In a nut shell, Indian ICT services industry, particularly ‘Computer & related activities’ services, has increased its influence and inter-industry relations over a period of time. This industry has also evolved as a competitive supplier of inputs and hence, increased its contribution to other industries.

Chapter 5 ICT services and price-responsiveness of the Indian Industry: Simulation using a VIO method

5.1 Introduction

After having established the influence and impact of ICT services through inter-industry and inter-temporal analysis, this chapter extends the analysis seeking to evaluate the effect of changing relative prices of ICT services on other industries of the economy. As the previous literature has pointed out, technological developments and innovations in ICT producing industries worldwide lead to a fall in relative prices of these goods and services while the quality of the same improves. The falling prices of ICT capital, for instance, are supposed to benefit the ICT services industry by reducing its cost structure, since ICT capital is assumed to consist of a larger share of the ICT services industry's capital structure. This will result in falling relative prices of these services, which are used by other industries as intermediate inputs. Hence, this chapter analyzes the potential benefits of a decrease in relative prices of ICT services to other industries of the economy. A variable input output (VIO) model, which evaluates price-responsiveness of the economy, is utilized for this purpose.

The remaining chapter is organized as follows. Section 5.2 discusses empirical literature followed by the price change of Indian ICT services in the recent past. The data and methodology is discussed in Section 5.3. This is followed by a discussion of empirical results in Section 5.4. The concluding remarks are given in Section 5.5.

5.2 Empirical literature and Indian ICT services

5.2.1 Empirical literature review

The empirical evidence on separate analysis of the impact of ICT services in an inter-industry setting is mainly limited to advanced and newly industrialized economies. Klein (2003) in his work estimated the impact of IT services, as an important intermediate input used in the production process, on the productivity of the U.S.'s automotive industry using various I-O tables. The findings of that study indicate a positive influence of IT services as an intermediate input on the automotive industry. In another study on the impact of IT at the industry-level, Gill *et al*. (1997) found a positive influence of IT capital and labor on the productivity of U.S. industries. In particular, the findings from their study reveal positive output elasticities with respect to IT equipment for two-thirds of the industries, while significant and high marginal returns to IT equipment for 10 of the 58 industries analyzed. However, this chapter particularly deals with Indian ICT services, focusing upon their effect on other industries as a result of price decreases of these services.

In order to estimate the impact of the IT industry (which consists of more than one industry) on other industries of the Korean economy, Kim and Oh (2004) utilized VIO model, which was originally developed by Liew and Liew (Liew and Liew 1979, 1988). The benefit of this model is that it allows for assessing the impact of cost/price change while using the conventional I-O framework. However, the Kim and Oh (2004) study analyzed the effect of 1 percent reduction in capital costs of the Korean IT industry on the output of other industries and found less satisfactory results. Out of the 31 industries at the aggregate level, only 3 industries, including the IT industry itself, show positive increases in production (substitution effect) due to a fall in the prices of IT goods and services. On the other hand, the total effect (combining substitution and income effect) of the same indicate as many as 18 and 13 industries increased production in 1995 and 1998, respectively. In another similar study, Kim (2008) estimated the impact of a fall in prices in the Korean IT industry through technological innovations on the output elasticities of other industries using VIO model. The results of that study also show a less satisfactory impact—about one-tenths, i.e. 3 out of 31 industries, were positively affected— of the Korean IT industry on other industries between 1995 and 2000. The aforementioned studies on the Korean economy define IT industry in a broader way that encompasses hardware commodities such as electric appliances, video/audio & communication devices, computer & office devices, and software services such as communications, broadcasting, and computer services. In another study, Heng and Thangavelu (2006, 16-21) estimated the elasticity of industrial GDP to falling prices of information goods and services for the Singaporean economy, by estimating the ratio of expenditure on information input to nominal GDP of the industry. Their results find most of the industries benefiting from the price decrease, with the industries experiencing the largest impact doing so as a result of 10 percent decrease in the prices of information input include 'information sector', 'electrical appliances and equipments', and 'business services' among others.

There are studies which deal with macroeconometric models of price change and respective impact on demand and supply conditions of individual industries, as well as on the welfare of an economy. On the other hand, there are also various studies which deal with price change using the theory of general equilibrium. However, as far as the inter-connectedness of industries is concerned, the I-O framework provides a foundation to analyze the effect of price changes of an industry or a set of industries. Under the I-O framework of interconnectedness of industries, Leontief's IO price model (both demand-pull and cost-push) provides the basis to evaluate the effect of price increase or decrease in any particular industry or group of industries (Miller and Blair 2009, 41-46). Using the extended models of Leontief's IO price model, some studies have analyzed the effect of exogenous price change on the price level of other industries (see, for instance, Bazzazan and Batey 2003; Tunali and Aydogus 2007). However, the extended models of price change rely on the fixed technical coefficient assumption of Leontief's production function.

In order to evaluate the impact of changing ICT services prices not only on the price structure of other industries, but also on their production as a result of increasing demand for ICT services, an extended model of price change in the form of VIO model is useful. Based on I-O characteristics of interconnectedness of industries, this model assists in tracing the effect on production of price change by treating primary input costs exogenous and variable. In other words, a VIO model, based on profit maximization and cost saving behavior of firms, utilizes the price transmission system of I-O framework and provides insights into production change of other industries which respond to price changes in a certain industry. Since ICT services are increasingly playing an important part in economic activities of various industries, this study tries to evaluate the effect of these services industries and their potential to influence other industries.

The left causative matrix model in the previous chapter assesses the effect of the ICT services industry on other industries' output multipliers. However, as a result of technological improvements and innovations worldwide, the prices of ICT goods and services in real terms are decreasing. This relative fall in the prices of ICT services, for instance, provides ground for assessing impact of price change in the ICT services industry of India. Hence, in replying to the third research question of the study, VIO model of price change is applied. As has been discussed earlier, ICT services constitute an important part of the broader ICT industry and require separate assessment while understanding the economic effect of emerging ICT on the Indian industry. Hence, this chapter extends the analysis of ICT services in the previous chapter to evaluate the price effect of the ICT services industry on the other industries of the economy.

The effect of price cuts of ICT services is highly relevant for the Indian industry as a whole, since Indian industries are suffering from high input material and utility costs and a resulting small operating surplus. Although many of the Indian industries have competitive labor costs compared to other emerging and developing countries, high input material costs put Indian industries at a competitive disadvantage since they cannot exploit economies of scale with higher material costs and a lower operating surplus. According to the International Yearbook of Industrial Statistics 2007, only ten industries at three/four-digit level enjoy an operating surplus of 20 percent or more (UNIDO 2007). Hence, the falling ICT services prices will reduce the burden of input and material costs by increasing demand for these services and substituting for other inputs. This depends on the price and output elasticity of various industries to changing ICT services prices. Since, this is based on the principle of profit maximization and cost saving behavior of firms, the VIO model is appropriate in the sense that it is based on the same principle.

5.2.2 Price change of Indian ICT services

Since the focus of this chapter is to estimate the price-responsiveness of the Indian industry by simulating price decreases in the ICT services industry, this section explains the rationale behind the price decrease simulations. The main reasons for price decreases are explained separately for the 'Computer & related activities' industry and 'Communication' industry.

The Government of India had signed the IT Agreement (ITA) of the World Trade Organization (WTO) in early 1997, which set the target that 'concomitant' to phasing out the duties on the finished products as identified in the ITA list, duties on input raw material, including that on dual usage items, would also be phased out to nil prior to the terminal year i.e., 2005 (Department of Information Technology (DIT) 2006). The products covered under the ITA list broadly include computer hardware and peripherals, telecommunications equipment, computer software, semiconductor manufacturing equipment, analytical instruments, and semiconductors and other electronic components. It was only in 2005 that the challenge for ICT producers in a zero-duty regime was addressed by the government by permitting imports of non-IT inputs, raw material and dual-usage items at nil customs duty under end-use-certification (Department of Information Technology (DIT) 2006). In the budget of 2006-07, additional customs duty of 6 percent or 7 percent levied on computers was withdrawn (Ministry of Finance 2006). As a consequence, customs duty on 217 tariff lines covered under the ITA-1 of WTO is zero percent, and all goods required in the manufacture of ITA-1 items have been exempted from customs duty subject to actual user condition (Department of Information Technology (DIT) 2011a). Thus, customs duty on specified raw materials /inputs used for manufacture of electronic components became zero percent. In addition, customs duty on specified capital goods used for manufacture of electronic goods is also zero percent. In general, the peak rate of basic duties on imported items was also reduced to 12.5 percent in 2006-07 from 15 percent in 2005-06.

As a result of this deregulation of import tariffs on ICT related products by the Indian government following the WTO ITA, the cost of imports of ICT related products was reduced and became available at undistorted world market prices. As a consequence, the exogenous technological innovations and progress in information and communications technology worldwide became available at a world market price through imports of ICT related products, both as a final product and as an intermediate input. In addition, this trade liberalization also put competitive pressure on the domestic ICT manufacturing industry to compete with the imported products. Overall, it put downward pressure on ICT products such as computers and peripherals, telecommunications equipment, and other electronic items.

To promote the domestic usage of ICT related products including packaged software, the government also rationalized the excise duty regime for these products. The domestic ICT products industry that was under pressure due to constant lowering of customs duties, was adversely affected when computers were exempted from excise duty of 8 percent in the budget of 2004-05 without reducing excise duty on accessories used as inputs and subassemblies. This led to overflow of central excise duties and disruption of business (Department of Information Technology (DIT) 2006). However, this adverse duty structure was addressed in the budget of 2006-07 with the introduction of a 12 percent excise duty on computers (Ministry of Finance 2006). Due to the reduction in customs and excise tariffs on ICT products over the years, the local grey market for computers has been adversely affected, the proportion of which has come down to 37 percent in 2005-06 as compared to over 60 percent in 2003-04 (Department of Information Technology (DIT) 2006). This led to increased output of the organized computers industry and reduced the gap between computers offered at a price by the organized industry against that by the grey market.

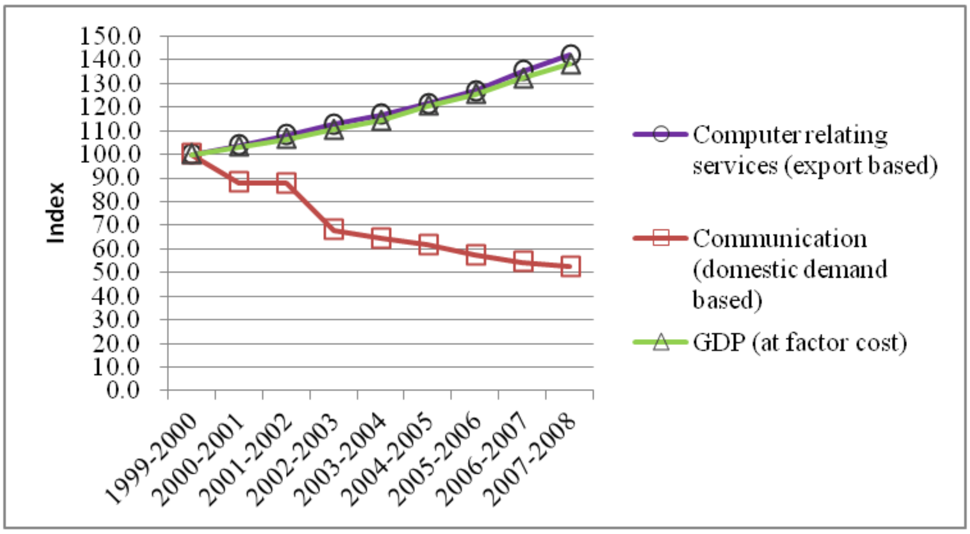
To boost the domestic telecom electronics and equipment manufacturing industry, the government also exempted infrastructure telecom equipment from customs duties and made the import of all capital goods for manufacturing telecom equipment and the manufacturing of telecom equipment itself license free (Department of Information Technology (DIT) 2010b). Hence, the lowering of first the customs duties and subsequently in 2001-02 the excise duties has enabled the organized sector to offer mobile products to consumers at the same price as that of the grey market. The grey market in mobile phones, once over 90 percent, is now totally eradicated.

As a result of deregulation of import duties and rationalization of the excise duty structure related to a broad range of ICT products, the domestic ICT manufacturing industry came under competitive pressure. The availability of imported ICT goods at a fair market price put downward pressure on the prices of these products in the Indian market. In addition, the rapid technological innovations related to ICT, especially from the advanced economies, also made the ICT products relatively cheaper and affordable. Hence, domestic prices of ICT capital goods decreased in the recent past partly due to deregulation of imports and resulting competitive pressure on the domestic ICT manufacturing industry. One of the industries that are supposed to intensively use ICT capital goods and benefit from a downward pressure on the prices of ICT capital goods is the ICT services industry.

Hence, this chapter estimates the effect of the fall in the prices of ICT services by simulating a decrease in the capital costs of the ICT services industry, that include both the 'Computer & related activities' and 'Communication' services industries. However, due to high costs of human resources in the ICT services industry, particularly in 'Computer & related activities' industry, the capital costs advantage is assumed to be partly offset. Nonetheless, the net effect of decreases in ICT capital costs is simulated based on three different scenarios. The first scenario does not consider relative prices of other commodities, whereas the other two scenarios do. The third scenario is to explore the direction of effect of price changes compared to the earlier ones and compare the magnitude of change in production with the earlier scenarios. The deregulation of imports of ICT products and increasing competitive pressure on the domestic ICT manufacturing industry provides technological dissemination and a healthy and fair market price structure for these commodities. The ICT services, in particular ‘Computer & related activities’ services, which are growing mainly due to their high exports will become relatively cheaper in the domestic market as a result of decrease in their ICT capital costs. The usage of ICT services is assumed to increase competitiveness and reduce intermediate input costs in various industries, resulting in a higher production and operating surplus. Hence, the analysis focuses on the effect of price changes in ICT services on production in other Indian industries. Two important policy implications can be made from the findings. First, the introduction of ICT services at an affordable price can reduce the burden of intermediate input costs in many industries as a result of substitution effect, suggesting that the usage of ICT services help other industries to grow and become competitive. The implication is that ICT services are important for industrial development, and hence should be made available by improving ICT infrastructure as well as its diffusion across a country. Second, the human resources development should be the priority area for the Indian labor force to utilize ICT goods and services, and adapt to changing ICT technologies.

The comparison between ‘Computer & related activities’ and ‘Communication’ indicates that the latter is bigger in size in real terms. However, when compared at current prices, the GDP of ‘Computer & related activities’ exceeds that of ‘Communication’ from the year 2002-2003. This indicates that the price of ‘Computer & related activities’ services is growing faster than that of ‘Communication’ services. The implicit price indices of both the industries during 1999-2000 and 2007-2008 and their comparison with the implicit national GDP (at factor cost) price index are reported in Figure 5.1.

Figure 5.1 Comparison of Price change through Implicit GDP Deflators (at 1999-2000 prices)



Source: Author's compilation based on the data from Central Statistics Office (CSO) (2008) and (2009c).

As is shown in Figure 5.1, the implicit annual price indices of 'Computer & related activities', 'Communication' and national GDP (at factor cost) at the base of 1999-2000[19] are compared against each other for the given period. The comparison indicates that the annual price of 'Computer & related activities' services increased during the period a little over that of the national average. On the other hand, the implicit price index of 'Communication' falls substantially below the national average. This observation suggests the prices of 'Communication' services are more competitive than that of 'Computer & related activities' services.

In an inflationary economy such as India, the prices of goods and services produced in that economy are assumed to rise as is indicated by the price index of 'Computer & related activities'. The high prices of 'Computer & related activities' compared to 'Communication'

[19] These implicit price indices (deflators) are derived by using the ratio of GDP at current prices and at 1999-2000 prices for corresponding sectors.

services in India needs to be seen mainly in light of its export-intensive nature. Due to high exports in the 'Computer & related activities' industry, the labor costs in this industry are very high compared to other industries. Besides, these services involve skilled labor that adds up to be their high primary input cost. As far as the domestic market is concerned, the industry does not enjoy economies of scale because the market is not yet fully matured and requires product differentiation to successfully cater to the domestic needs. As a result, 'Computer & related activities' services entail high prices, which hinder the adoption of these services among other industries and mitigate benefits of technological advancements in ICT. Moreover, the introduction of 'Computer & related' services additionally requires firms to invest in their human capital and organizational structure, which increases the actual cost of these services. In contrast, 'Communication' services have a huge domestic market that allows them to enjoy economies of scale. In addition, the introduction of telecommunication services requires less additional costs. Hence, the fall in 'Communication' services prices is due to intense competition in the industry to capture the fast growing domestic demand for communication services as well as the benefits of scale economies. However, as explained earlier, due to the liberalized imports of ICT products and intense competition in the ICT manufacturing industry, 'Computer & related activities' are also assumed to be affected positively, making them more affordable than before.

Since ICT services are assumed to play an important role as intermediate inputs, this analysis focuses upon the price responsiveness of other industries of the economy on hypothetical falling prices of ICT services. As has been indicated in the previous literature, the prices of ICT goods and services are assumed to fall due to world-wide technological improvements and innovations in ICT producing industries, which will make these goods and services more competitive. Hence, the price responsiveness of the economy in terms of changing production of other industries is assessed by simulations based on a hypothetical decrease in the prices of ‘Computer & related activities’ and ‘Communication’ services. However, in the analysis to be followed, this price decrease is assumed only for the domestic market and not for its exports. This is due to the fact that the prices of ICT services, which are used as an intermediate input in the domestic market, are assumed to change as a result of a fall in ICT capital costs. This ICT capital is assumed exogenous and consequently, the change in its costs are a result of exogenous shock. This whole process is captured only for ICT usage in the domestic market because exports are treated as a part of total final demand in the I-O analysis, the component which is treated as exogenous. In addition, cost competitiveness is one of the advantages ICT services exports have enjoyed in the past where price competitiveness in the international market initially increased the exports of ICT services. The higher income elasticity of ICT services in the international market brought increased demand for cost competitive ICT services from India, leading to increases in its prices as a feedback effect. However, in the analysis of domestic market scenarios, one of the limitations is that such feedback effect is not observed. Moreover, the capital cost-cut is observed through ICT services industry only and not through the ICT manufacturing industry as computer and peripherals manufacturing is not available separately in the Indian IOTT.

5.3 Data and Methodology

5.3.1 Data

The dataset used for the analysis in this chapter relies on IOTTs of the Indian economy for 2003-04 and 2006-2007, similar to the previous chapter. Further, for the analytical purpose the 130 industries of the IOTTs are aggregated into 45 industries for both the years. The aggregation is based on Indian industrial classification. Those industries which do not fall into any aggregation are treated as is. ‘Computer & related activities’ and ‘Communication’ industries are also not aggregated and treated separately as they are the main industries of interest. The deflators of 2006-2007 derived from implicit GDP deflators as well as WPI are used. The deflators are derived from the same source as given in Chapter 4.

5.3.2 Methodology

Since the analysis requires information on the detailed inter-industrial structure of the economy, the methodology relies on I-O framework of the Indian economy. A VIO model, an extension and modified model of existing “Leontief Price Model (Cost-push)”, is used to analyze how falling relative prices of ICT services stimulate production of other industries of the economy. The main advantage of the VIO model is that it is a price-responsive model based on a firm’s profit maximization theory (Liew and Liew 1988, 65). Under the conventional Leontief’s input-output model, industrial outputs are determined by final demand and input-output ratios are assumed to be fixed, that is, there is zero elasticity of substitution between inputs in the production function. However, under the VIO model, industrial outputs are not only determined by final demand but also by the primary input prices, and thus, technical coefficients are made endogenous to input prices (Liew and Liew 1988, 65). Hence, the VIO model permits the prediction of changes in production in other industries due to the changes in input cost of a certain specific industry.

Under the Leontief’s price model (Cost push), price equation of the input side is determined by

$$\tilde{p} = (I - A')^{-1} v_c \quad \text{for} \quad v_c = v_j / x_j$$

where prices of all commodities $\tilde{p}$ are determined by the exogenous values (costs) of primary inputs v_c (Miller and Blair 2009, 44). On the other hand, output is determined by the output side equation:

$$x = (I - A)^{-1}f$$

where output of all commodities x is determined by the final demand f in terms of change in household consumption, government expenditure, private investment and net exports. The above equations indicate that the Leontief's price equation is independent of its output equation, i.e. a dichotomy exists between the two equations due to the assumption of fixed technical coefficient, α_{ij}, of the matrix A (Liew and Liew 1988, 65-67). Hence, the conventional I-O price model does not allow tracing any change in the outputs of other industries to the change of primary input costs in a specific industry. On the other hand, the VIO model does so by allowing technical coefficients to respond to changing relative prices due to change in primary input costs of a certain industry. Following Kim and Oh (2004), the theoretical background of the VIO model is explained as follows.

Model

The VIO model is originally derived by transforming a Cobb Douglass' production function into a log-linear one and by including intermediate inputs and primary inputs on the RHS of the model. The primary inputs such as employee pay, business surplus, depreciation of fixed capital, and indirect tax form value added items of the I-O table.

$$\ln x_j = \alpha_{0j} + \sum_i \alpha_{ij} \ln x_{ij} + \sum_k \beta_{kj} \ln L_{kj} \qquad [5\text{-}1]$$

where x_j is the output of industry j, x_{ij} is the commodity (intermediate input) of industry i purchased by industry j, L_{kj} is the amount of primary inputs k (labor and capital) employed in industry j as value added, and $\sum_i \alpha_{ij} + \sum_k \beta_{kj} = 1$ satisfies the condition of linear homogeneity.

$$p_j x_j - \sum_i p_i x_{ij} - \sum_k w_{kj} L_{kj} = 0 \qquad [5\text{-}2]$$

where p_j is the commodity price of industry j, p_i is the commodity price of industry i, w_{kj} is the unit price of primary production factors k purchased by industry j.

Based on the equation [5-1] as a constraint condition and profit equation of [5-2], Langrangian function of profit maximization model is derived as:

$$Max\prod = \sum_j (p_j x_j - \sum_i p_i x_{ij} - \sum_k w_{kj} L_{kj}) + \sum_j \lambda\,(\ln x_j - \alpha_{oj} - \sum_i \alpha_{ij} \ln x_{ij} - \sum_k \beta_{kj} \ln L_{kj})$$

From the first order condition, the optimal levels of intermediate inputs x_{ij} and primary inputs L_{kj} to be applied are derived as follows.

$$x_{ij} = \alpha_{ij} p_j x_j / p_i, \; L_{kj} = \beta_{kj} p_j x_j / w_{kj} \qquad [5\text{-}3]$$

These optimal levels of intermediate inputs and primary inputs in equation [5-3] are substituted in equation [5-1] in order to obtain a following price function.

$$\ln p = (I - A')^{-1} [\sum_k \beta_k \ln w_k] \qquad [5\text{-}4]$$

where p is the price of commodities, β_k is the value added coefficient indicating primary input (k) usage of various commodities, and w_k is the price of primary input (k).

This equation indicates that the price (p) is determined by the price of primary input k (w_k). Here, the price of commodities affected by the change (increase/decrease) in primary input costs will affect the output, since the change in relative price ratios will influence the technical coefficient in matrix A, which in turn will change the output of other industries (x). Hence, there does not exist the dichotomy between the input and output equations under the VIO model.

In addition, the application of x_{ij} in equation [5-3] into the basic I-O identity will yield $x_i = \sum_j x_{ij} + \mathrm{F}_i$, where x_{ij} indicates optimal level of intermediate inputs applied through the change in production method $(p_j/p_i)\alpha_{ij}$ which is in turn affected by change in relative prices of commodities. This procedure transforms a production equality on output side into the matrix form, as:

$$x = (I - h)^{-1}F, \quad h = \alpha_{ij}\left(\frac{p_j}{p_i}\right) = p^{-1}Ap \qquad [5\text{-}5]$$

where p is a diagonal matrix, and h is a newly derived technical coefficient matrix.

The change in output under the VIO model is measured by differentiating[20] the equation [5-5], as:

$$\mathrm{d}x = (I - h)^{-1}\mathrm{d}hx + (I - h)^{-1}\mathrm{d}F \qquad [5\text{-}6]$$

This equation estimates price-responsiveness in terms of output elasticities of total

[20] For the details of differentiation, please refer to Kim and Oh (2004, 184).

industries to changes in the cost (w_k) of primary inputs of a certain industry, an exogenous variable in the price equation. The RHS of the above equation consists of two terms. The first term, $(I-h)^{-1}\mathrm{d}hx$, is an input substitution effect[21] through changes of production techniques (that is, technical coefficients) and the latter term, $(I-h)^{-1}\mathrm{d}F$, is an income effect through changes of final demand. If there is no price change in commodities of a certain industry influencing matrix h, the equation for change in output ($\mathrm{d}x$) will become $\mathrm{d}x = (I-A)^{-1}\mathrm{d}F$. It is nothing but the conventional Leontief's I-O model, showing that the change in output is determined only by final demand.

Since the analysis focuses on intermediate demand change due to change in prices in a certain industry, the second term $\mathrm{d}F$ (= 0), which is an income effect, is not considered in the analysis. In other words, the changes in output of all industries resulting from the decrease in the costs of primary production factor (w_k) in 'Computer & related activities' and 'Communication' industries are derived using the VIO model.

In order to evaluate the effect of price reductions in the 'Computer & related activities' and 'Communication' industries on the production of other industries of the economy, hypothetical scenarios are created. Based on these scenarios of price change, an impact of decreasing prices of ICT services is simulated on all the industries of the economy. To begin with, it is assumed that the 'Computer & related activities' and 'Communication' industries each experience 1 percent reduction of capital cost due to technological development in these industries as is the case in Kim and Oh (2004, 185) for the Korean IT industry. Although the primary production factors include capital and labor which form value added items in the I-O table, only the cost of capital input is assumed to be reduced due to

[21] The substitution effect explains change in production by the ratio changes of production techniques whereas Hick's substitution effect refers to the replacement of factors with a fixed output, hence, they are not in accord with each other (Kim and Oh 2004, 184).

technological developments and innovations in ICT, producing a net decrease by 1 percent in the cost of primary inputs in ‘Computer & related activities’ and ‘Communication’ industries that represent ICT services under the I-O framework. The change in output is derived for 2003-04 and 2006-07 using IOTTs of the two periods. The first scenario underscores that the exogenous change in primary input costs in the ICT services industry leads to change in its own prices as well as that of other industries. Hence, this price transmission affects the output of other industries including the ICT services industry itself.

The analysis of price change effect is further extended beyond the first scenario of 1 percent reduction of capital cost by factoring in real situations of price changes in the Indian economy during the period of the study. Since the Indian economy has been on an inflationary path during 2003-04 and 2006-07, it is necessary to factor in this inflation while assuming price decreases of ICT services and their effect on other industries. Hence, two new hypothetical scenarios are developed considering the real price changes of various industries of the economy in the year 2006-07 at 2003-04 constant prices. After deflating the value added items of each industry that reflects the relative prices of various industries based on their 2006-07 prices, the simulation is tested based on a hypothetical price decrease of ‘Computer & related activities’ and ‘Communication’ services. The details of the hypothetical scenarios to be analyzed are summarized below in Table 5.1.

Using equations [5-4], [5-5] and [5-6], the scenarios of price changes in ‘Computer & related activities’ and ‘Communication’ industries given in Table 5.1 are tested and the effect of relative price changes on the output of other industries is analyzed.

Table 5.1 Price-change Scenarios of ICT services

Scenario No	Name	Description	Change in the prices
Scenario 1	1% capital cost reduction of ICT services industry	Due to fall in the capital cost of ICT services industry, the relative prices of ICT services decrease.	For ICT services: $dlnp = (I - A')^{-1}\beta_k * (1 - 0.01)$ For other industries: $dlnp = (I - A')^{-1}\beta_k * 1$
Baseline	GVA is deflated as per the 2006-07 prices	Due to a fall in the total primary inputs costs as per the 2006-07 deflators, the relative prices of commodities change.	For ICT services: $dlnp = (I - A')^{-1}\beta_k * \left(\frac{1}{1.16}\right)$ For other industries: $dlnp = (I - A')^{-1}\beta_k * \left(\frac{1}{P_{06/07}}\right)$ where $P_{06/07}$ is 2006-07 price of corresponding industry
Scenario 2	10% decrease in the 2006-07 prices of the ICT services industry	10% decrease in the total primary inputs cost (through GVA) affects the relative prices of the ICT services industry vis-à-vis other industries.	For ICT services: $dlnp =$ $(I - A')^{-1}\beta_k * \left(\frac{1}{1.16*(1+0.1)}\right)$ For other industries: $dlnp = (I - A')^{-1}\beta_k * \left(\frac{1}{P_{06/07}}\right)$
Scenario 3	20% decrease in the 2006-07 prices of the ICT services industry	20% decrease in the total primary inputs cost (through GVA) affects the relative prices of the ICT services industry vis-à-vis other industries.	For ICT services: $dlnp =$ $(I - A')^{-1}\beta_k * \left(\frac{1}{1.16*(1+0.2)}\right)$ For other industries: $dlnp = (I - A')^{-1}\beta_k * \left(\frac{1}{P_{06/07}}\right)$

Source: Author

While Scenario 1 assists in understanding the effect of price decreases of ICT services, it does so by normalizing the prices of other commodities. In order to incorporate the relative prices of other industries including the ICT services industry, value added items of all the industries are deflated by their 2006-07 prices[22] and a baseline scenario is developed as is shown in the figure above. Once the relative prices are factored in, Scenario 2 and 3 are developed to simulate 10 percent and 20 percent decreases in primary input costs of the ICT services industry. The difference in the results of Scenario 2 and 3 and that of the baseline scenario is measured to derive the change in output of other industries due to decreases in the prices of ICT services.

These scenarios are important to understand how affordable ICT services can affect outputs of other industries through the price transmission system and interconnectedness of industries under the I-O framework. For instance, Scenario 1 considers the responsiveness of other industries to ICT services becoming more affordable than their current price level. Equally, Scenarios 2 and 3 find out the change in output of other industries when the magnitude of affordability of ICT services increases with the fall in primary input costs by 1 percent, 10 percent and 20 percent respectively. This shows the mechanism of price change under the real situation of the Indian economy.

5.4 Results

The results of the change in production of various industries, due to a fall in relative prices of the 'Computer & related activities' and 'Communication' services industries based on the aforementioned scenarios are given below.

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[22] The price index based on 2006-07 prices for all the 45 industries is provided in Appendix F.

Table 5.2 Results of Scenario 1: for 2006-07

No	The case of 'Computer & related activities' industry	Change in Production (%) for 2006-07	The case of 'Communication' industry	Change in Production (%) for 2006-07
1	Business services	0.1216	Mining & quarrying	0.1490
2	Miscellaneous manufacturing	0.0627	Ships and boats	0.1292
3	Ships and boats	0.0475	Communication	0.1250
4	Computer & related activities	0.0436	Miscellaneous manufacturing	0.0919
5	Banking	0.0410	Basic Metals Alloys & Metals Products	0.0775
6	Mining & quarrying	0.0367	Coal tar products	0.0696
7	Communication	0.0325	Business services	0.0653
8	Hotels and restaurants	0.0246	Electrical Machinery	0.0643
9	Paper & Paper Products	0.0225	Electricity, gas & water supply	0.0611
10	Coal tar products	0.0222	Paper & Paper Products	0.0519
11	Insurance	0.0206	Wood & Wood Products	0.0473
12	Electricity, gas & water supply	0.0201	Petroleum products	0.0463
13	Basic Metals Alloys & Metals Products	0.0194	Gems & jewellery	0.0451
14	Legal services	0.0176	Rubber & Plastic Products	0.0442
15	Electrical Machinery	0.0175	Banking	0.0433
16	Wood & Wood Products	0.0162	Insurance	0.0421
17	Aircraft & spacecraft	0.0156	Chemicals & Chemical Products	0.0408
18	Chemicals & Chemical Products	0.0144	Legal services	0.0403

19	Rubber & Plastic Products	0.0122	Renting of machinery & equipment	0.0361
20	Medical and health	0.0118	Non-Mettallic Mineral Products	0.0330
21	O.com, social & personal services	0.0115	Storage and warehousing	0.0316
22	Renting of machinery & equipment	0.0114	Non-Electrical Machinery & Parts	0.0307
23	Petroleum products	0.0114	Aircraft & spacecraft	0.0276
24	Non-Mettallic Mineral Products	0.0112	O.com, social & personal services	0.0268
25	Transport Equipment & Parts	0.0108	transport	0.0238
26	Medical, precision & optical instruments	0.0102	Medical, precision & optical instruments	0.0233
27	Real estate activities	0.0097	Trade	0.0219
28	Storage and warehousing	0.0087	Other services	0.0216
29	Education and research	0.0085	Forestry and logging	0.0177
30	Non-Electrical Machinery & Parts	0.0083	Real estate activities	0.0153
31	transport	0.0082	Transport Equipment & Parts	0.0146
32	Trade	0.0077	Leather & Leather Products	0.0106
33	Forestry and logging	0.0070	Hotels and restaurants	0.0097
34	Construction	0.0067	Construction	0.0087
35	Other services	0.0060	Textiles	0.0071
36	Gems & jewellery	0.0053	Agriculture	0.0069
37	Watches and clocks	0.0051	Computer & related activities	0.0063
38	Leather & Leather Products	0.0045	Watches and clocks	0.0046

39	Textiles	0.0040	Food Products	0.0043
40	Agriculture	0.0037	Beverages Tobacco & Tobacco Products	0.0028
41	Food Products	0.0033	Fishing	0.0021
42	Beverages Tobacco & Tobacco Products	0.0027	Medical and health	0.0012
43	Fishing	0.0009	Education and research	0.0003
44	Ownership of dwellings	0.0000	Ownership of dwellings	0.0000
45	Public administration	0.0000	Public administration	0.0000

Source: Author's estimates

The industries reported in Table 5.2 are in descending order, starting from the industry with the highest value of percentage change in output due to a 1 percent reduction in the primary input costs of 'Computer & related activities' and 'Communication' industries. This change in output is a result of substitution effect, that is, change in the coefficient of production techniques resulting from increasing demand for ICT services— represented by 'Computer & related activities' and 'Communication' services industries— as an intermediate input by the virtue of a fall in its prices against other intermediate inputs, reducing their application ratios in the production method. The values indicate substitution effect by the percentage change in production (output) of other industries for 2006-07[23].

As is seen from the results of Table 5.2, the industries which have potential to benefit the most due to falling prices of computer and related services include 'Business services', 'Miscellaneous manufacturing', 'Ships and boats', 'Computer & related activities', and 'Banking' among others for 2006-07. The 'Business services' industry holds the largest potential for an increase in output at 0.12 percent, due to cheaper 'Computer & related

[23] The results of Scenario 1 for the period 2003-04 are provided in Appendix G.

activities' services. This is followed by 'Miscellaneous manufacturing' with a 0.06 percent increase in output for the same period. All other industries also changed their production method by increasing application ratios of computer and related services, leading to an increase in output, except for 'Ownership of dwellings' and 'Public administration'. The results of the simulation indicate that all the industries (other than few exceptions) are price-sensitive, resulting in more demand for computer and related services with the fall in relative prices of these services. This substitution by changing intermediate input application ratios (and, thus the production technique) produces increases in output.

Further, as is shown in Table 5.2, the industries which could benefit the most due to decreases in the 'Communication' services industry's prices include 'Mining & quarrying', 'Ships and boats', 'Communication', 'Miscellaneous manufacturing', and 'Basic Metals Alloys & Metals Products' among others. The 'Mining & quarrying' industry poses the largest gains by a 0.15 percent increase in output in 2006-07. This is followed by the 'Ships and boats' industry with a 0.13 percent increase in production for the same period of time. In addition, industries such as 'Business services' and 'Electrical machinery' also pose to gain from a decrease in the prices of communication services. Similar to the case of 'Computer & related activities', other industries also benefit from the communication price fall, with the exception of 'Ownership of dwellings' and 'Public administration'.

These results provide inferences as to how price decreases in ICT services can induce industries to change their production techniques by substituting ICT services for other inputs and thus reduce costs. This in turn will increase the production of the industries as per their output elasticity to changing prices. The results of Scenario 2 and Scenario 3 are presented in the tables below.

Table 5.3 Results of Scenario 2: Relative price change

No	The case of 'Computer & related activities' industry	Change in Production (percentage point) for 2006-07	The case of 'Communication' industry	Change in Production (percentage point) for 2006-07
1	Business services	1.500	Mining & quarrying	3.856
2	Ships and boats	0.960	Ships and boats	3.392
3	Miscellaneous manufacturing	0.812	Communication	1.859
4	Mining & quarrying	0.730	Miscellaneous manufacturing	1.742
5	Banking	0.523	Basic Metals Alloys & Metals Products	1.720
6	Computer & related activities	0.503	Coal tar products	1.635
7	Communication	0.415	Electricity ,gas & water supply	1.382
8	Coal tar products	0.384	Business services	1.311
9	Basic Metals Alloys & Metals Products	0.332	Electrical Machinery	1.035
10	Electricity, gas & water supply	0.328	Wood & Wood Products	1.006
11	Paper & Paper Products	0.317	Petroleum products	1.003
12	Hotels and restaurants	0.290	Paper & Paper Products	0.991
13	Insurance	0.279	Chemicals & Chemical Products	0.928
14	Legal services	0.273	Banking	0.911
15	Wood & Wood Products	0.258	Rubber & Plastic Products	0.907
16	Chemicals & Chemical	0.239	Legal services	0.877

	Products			
17	Aircraft & spacecraft	0.233	Insurance	0.835
18	Electrical Machinery	0.229	Gems & jewellery	0.769
19	Petroleum products	0.194	Storage and warehousing	0.764
20	Rubber & Plastic Products	0.192	Renting of machinery & equipment	0.745
21	Non-Mettallic Mineral Products	0.180	Non-Mettallic Mineral Products	0.704
22	Renting of machinery & equipment	0.175	Non-Electrical Machinery & Parts	0.673
23	O.com, social & personal services	0.162	Aircraft & spacecraft	0.596
24	Storage and warehousing	0.161	Other services	0.546
25	Medical, precision & optical instruments	0.151	O.com, social & personal services	0.527
26	Real estate activities	0.140	Transport	0.514
27	Non-Electrical Machinery & Parts	0.138	Trade	0.478
28	Transport Equipment & Parts	0.138	Medical, precision & optical instruments	0.470
29	Medical and health	0.135	Forestry and logging	0.390
30	transport	0.128	Real estate activities	0.288
31	Trade	0.122	Transport Equipment & Parts	0.283
32	Forestry and logging	0.112	Leather & Leather Products	0.203
33	Other services	0.112	Hotels and restaurants	0.172
34	Education and research	0.097	Construction	0.171
35	Construction	0.087	Agriculture	0.135
36	Gems & jewellery	0.075	Textiles	0.122
37	Watches and clocks	0.061	Computer & related activities	0.119

38	Leather & Leather Products	0.060	Watches and clocks	0.088
39	Agriculture	0.054	Food Products	0.082
40	Textiles	0.048	Beverages Tobacco & Tobacco Products	0.054
41	Food Products	0.046	Fishing	0.038
42	Beverages Tobacco & Tobacco Products	0.037	Medical and health	0.019
43	Fishing	0.013	Education and research	0.005
44	Ownership of dwellings	0.000	Ownership of dwellings	0.000
45	Public administration	0.000	Public administration	0.000

Source: Author's estimates

Table 5.4 Results of Scenario 3: Relative price change

No	The case of 'Computer & related activities' industry	Change in Production (percentage point) for 2006-07	The case of 'Communication' industry	Change in Production (percentage point) for 2006-07
1	Business services	2.928	Mining & quarrying	7.187
2	Ships and boats	1.810	Ships and boats	6.326
3	Miscellaneous manufacturing	1.573	Communication	3.581
4	Mining & quarrying	1.381	Miscellaneous manufacturing	3.273
5	Banking	1.015	Basic Metals Alloys & Metals Products	3.219
6	Computer & related activities	0.986	Coal tar products	3.047
7	Communication	0.802	Electricity, gas &	2.589

			water supply	
8	Coal tar products	0.734	Business services	2.450
9	Basic Metals Alloys & Metals Products	0.630	Electrical Machinery	1.975
10	Electricity, gas & water supply	0.625	Wood & Wood Products	1.878
11	Paper & Paper Products	0.607	Petroleum products	1.870
12	Hotels and restaurants	0.567	Paper & Paper Products	1.863
13	Insurance	0.537	Chemicals & Chemical Products	1.729
14	Legal services	0.523	Banking	1.700
15	Wood & Wood Products	0.491	Rubber & Plastic Products	1.693
16	Chemicals & Chemical Products	0.450	Legal services	1.640
17	Aircraft & spacecraft	0.447	Insurance	1.559
18	Electrical Machinery	0.442	Gems & jewellery	1.429
19	Petroleum products	0.367	Storage and warehousing	1.421
20	Rubber & Plastic Products	0.364	Renting of machinery & equipment	1.393
21	Non-Mettallic Mineral Products	0.345	Non-Mettallic Mineral Products	1.311
22	Renting of machinery & equipment	0.334	Non-Electrical Machinery & Parts	1.258
23	O.com, social & personal services	0.312	Aircraft & spacecraft	1.116
24	Storage and warehousing	0.307	Other services	1.017
25	Medical, precision & optical instruments	0.290	O.com, social & personal services	0.983
26	Real estate activities	0.272	transport	0.961
27	Transport Equipment & Parts	0.267	Trade	0.892

28	Medical and health	0.265	Medical, precision & optical instruments	0.878
29	Non-Electrical Machinery & Parts	0.261	Forestry and logging	0.729
30	Transport	0.244	Real estate activities	0.535
31	Trade	0.232	Transport Equipment & Parts	0.527
32	Forestry and logging	0.213	Leather & Leather Products	0.378
33	Other services	0.211	Hotels and restaurants	0.323
34	Education and research	0.190	Construction	0.322
35	Construction	0.169	Agriculture	0.250
36	Gems & jewellery	0.142	Textiles	0.226
37	Watches and clocks	0.113	Computer & related activities	0.223
38	Leather & Leather Products	0.113	Watches and clocks	0.164
39	Agriculture	0.103	Food Products	0.152
40	Textiles	0.091	Beverages Tobacco & Tobacco Products	0.101
41	Food Products	0.089	Fishing	0.070
42	Beverages Tobacco & Tobacco Products	0.071	Medical and health	0.037
43	Fishing	0.024	Education and research	0.009
44	Ownership of dwellings	0.000	Ownership of dwellings	0.000
45	Public administration	0.000	Public administration	0.000

Source: Author’s estimates

From the results of Scenario 2 as are reported in Table 5.3, it is found that a decrease in the commodity prices of the ‘Computer & related activities’ services industry in relative terms, in addition to the price changes as per 2006-07 prices of various commodities, leads to increases in the production of other industries. The industries which benefit the most from the 10 percent decrease in the primary inputs costs of ‘Computer & related activities’ industry include ‘Business services’, ‘Ships and boats’, ‘Miscellaneous manufacturing’, ‘Mining and quarrying’, ‘Banking’, ‘Computer & related activities’, and ‘Communication’ among others. These findings substantiate the results of Scenario 1 related to the ‘Computer & related activities’ industry. The industries which fall in the top seven in Scenario 1 and Scenario 2 are the same ones with, nonetheless, a slight difference in their rankings and a higher magnitude of output change in the case of Scenario 2. All other industries also gain from the decreasing prices of computer and related services, given the effect of each other’s price of 2006-07 on each other.

‘Communication’ services also affect outputs of other industries positively given the decrease in their prices as per Scenario 2. As is observed from the results in Table 5.3, industries which are positively affected include ‘Mining and quarrying’, ‘Ships and boats’, ‘Communication’, ‘Miscellaneous manufacturing’, ‘Basic Metals Alloys & Metals Products’, ‘Coal tar products’, and ‘Electricity, gas & water supply’ among others. These results also corroborate the findings of Scenario 1 related to the ‘Communication’ industry, given the similar ranking of the first few industries. The results of the simulations, in particular some of the industries that seem to benefit the most, for instance, ‘Business services’, ‘Banking’, ‘Computer & related activities’, ‘Communication’, ‘Electrical machinery’, and ‘Petroleum products’, are comparable with the case of Singapore (Heng and Thangavelu 2006) and to some extent South Korea (Kim and Oh 2004).

Further, the results of the simulation based on Scenario 3 are also comparable to that of Scenario 2 in the case of both the industries, ‘Computer & related activities’ and

‘Communication’. Their ranking, based on the corresponding magnitude of production change in industries, reported in Table 5.5, are more or less similar to that of Scenario 2. However, the effect of price changes on production change is larger in the case of Scenario 3, corresponding to 20 percent cost reduction in the ICT services industry compared to 10 percent of the same for Scenario 2. The results also indicate that some of the industries do not benefit from the price-cuts in ‘Communication’ services as much as those in ‘Computer & related activities’ services such as ‘Hotels and restaurants’ and ‘Insurance’ industries. The reason for this difference is that these industries rely heavily on the database of customers and online provision of their services, which requires computer and related services more than communication services. Similarly, some of the industries gain more from ‘Communication’ services price-cuts such as ‘Mining and quarrying’, ‘Basic Metals Alloys & Metals Products’, ‘Coal tar products’, and ‘Petroleum products’. These industries are in general far from their market place and scattered geographically, which requires higher utilization of telecommunications services to reduce logistics and transportation cost. All the findings from the three scenarios are comparable and substantiate the view that the falling relative prices of ICT services, through ‘Computer & related activities’ and ‘Communication’ industries, affect other industries of the economy positively.

5.5 Conclusion

This chapter sought to analyze the price effect of ICT services on other industries of the economy. Using a VIO model, this chapter evaluated the effect of falling relative prices of ICT services, hypothetically observed in three different scenarios. The first simulation, based on the related previous literature, assessed the effect of a 1 percent decrease in the capital costs in the ICT services industry on the production of other industries. The subsequent scenarios 2 and 3 are the extension of the analysis in the 1st scenario, in which the effect of falling prices of ICT services is observed after factoring in changing prices of other industries based on the 2006-07 implicit GDP deflators. This modification allowed for estimating price effects of ICT services not only in isolation but also considering relative price change of other commodities as per the real economic situation of 2006-07. The falling prices of ICT services which are used in the aforementioned scenarios are assumed to be the result of innovations and technological developments in ICT producing industries worldwide, making ICT goods and services cheaper. The VIO model, used to empirically analyze the effect of price change, is not a macroeconomic price model, but an extension of Leontief's I-O price model that is interconnected with inter-industry linkages such as backward and forward linkage, and exogenous change in technological innovations.

As has been shown by the simulation results of Scenario 1, a percent reduction in the capital costs of 'Computer & related activities' services industry resulted in an increase in the output of many industries due to falling relative prices of these services as intermediate inputs. Not only services industries such as 'Business services' and 'Banking', but also manufacturing industries such as 'Miscellaneous manufacturing' and 'Ships and boats' among others hold the potential to gain from the price decrease. In addition, cheaper 'Communication' services also exerted a positive influence on other industries. In the case of communication services, manufacturing industries such as 'Ships and boats' and 'Miscellaneous manufacturing', as well as 'Mining and quarrying' and the 'Communication' industry itself benefited the most. As has been shown by the other simulations in Scenario 2 and 3, the percentage points of output change are positive and show higher values as the decrease in relative prices of these services widens. These findings corroborate the positive effect of ICT services as intermediate inputs on the Indian industry as a whole, given exogenous decreases in the relative prices of these services as a result of ICT related technological improvements and innovations.

In a nutshell, the role of ICT services as a competitive supplier of intermediate inputs and the resulting positive effect of adoption of these services on the Indian economy would be larger, given the decrease in its relative prices.

Chapter 6 Conclusion and Policy Recommendations

6.1 Introduction

This chapter concludes the findings of the analyses carried out in this study, and discusses policy implications in line with those findings. In particular, this chapter synthesizes the findings at the various levels of investigation pertaining to each research objective and question so as to provide a comprehensive view and necessary policy implications of the study.

This study attempted to investigate the role of ICT as an 'enabling technology' and its relevance in the industrial development of India. In the context of the pervasiveness of this technology and its network effect, this study assessed the channels through which ICT affects performance of the Indian industry. The economic effect of ICT on the Indian industry is estimated based on the usage of ICT capital and ICT services, since they embody technological advances of ICT. ICT capital is constituted of computers (including software), whereas ICT services are constituted of 'Computer & related activities' (including software) and 'Communication' (mainly telecommunication) services. Moreover, the ICT infrastructure is also factored in to understand the effect of externalities. The network and provision of ICT infrastructure in the economy is believed to have a positive relationship with the economic performance of an industry in principle just as other public infrastructure is assumed to augment the private output of an economy. However, network externalities of ICT infrastructure differentiate this infrastructure from others in that it affects the economic performance of an economy more indirectly. ICT infrastructure including aggregate manufacturing ICT capital stock and the ICT services sector, including 'Computer & related activities' and 'Communication' industries, serve as complements to each other. The provision of ICT infrastructure and its sector-wide availability including the stock of aggregate ICT capital attracts higher adoption of ICT services. Thus, ICT capital and ICT services are related as complements to each other in this study.

The structure of the Indian economy suggests that the services sector has grown tremendously in recent years to the extent that it accounts for over 50 percent of the national GDP. In particular, software and IT services as well as telecommunication services led the growth of this sector in recent years. However, the GDP share of secondary sectors including the manufacturing sector remains relatively small compared to other industrialized economies. Although the share of manufacturing in the total export sales of the economy is very high (around 70 percent in value terms), it is adversely affected by many supply side constraints. The competitive advantage of this sector is deteriorating due to high input material and utility costs and low labor productivity of many industries, among others, compared to that of other countries. Hence, it becomes relevant to investigate the importance of ICT in increasing the competitiveness of Indian industry in general, and the manufacturing sector in particular.

The framework of the study in terms of motivation, research objectives and questions, methodology, significance, and limitations are discussed in the first chapter. After having discussed the contours of the thesis in the first chapter, the second chapter gave an account of government policies affecting ICT in India that shaped the evolution and development of the IT and telecommunication industry, and the dissemination of ICT infrastructure. The policy framework is broadly divided into two periods, the pre-reform and post-reform periods characterized by a heavily regulated and protective policy environment prior to 1990-91 and a steady liberalization and privatization phase of post-1991. There are some landmark policy initiatives in the history of IT as well as telecommunications that need to be touched upon in order to understand the overall ICT development of India such as the 1986 Policy on computer software exports and software development, and the New Telecom Policy of 1994 along with de-regulation and privatization initiatives of 1991 and 1992. These policies highlighted the steps taken by the government to promote the development of these industries through liberalization and the opening up of the private sector. These initiatives also impacted the technological dissemination and overall development of ICT such as access to telecommunications and the internet density. The chapter also provided a brief overview of ICT development of India in comparison to the rest of the world. Different indicators of ICT infrastructure in India in comparison with other countries showed that ICT development is at an emerging stage in India and requires further stimulus measures.

6.2 A Synthesis of the findings and Policy Recommendations

As a part of the empirical analysis of the economic effects of ICT on Indian industry, Chapter 3 investigated the channels through which investment in ICT affects the performance of the manufacturing sector. The direct channel included investment in computer hardware as a factor of production that positively affects output and labor productivity in the manufacturing sector. This analysis tried to find out the output and labor productivity elasticity of ICT capital vis-à-vis other factor inputs of the manufacturing sector as a whole. The findings of the production function approach showed that ICT capital works as a factor of production for the manufacturing sector, with statistically significant coefficients; however, the output elasticity of ICT capital is smaller than that of the non-ICT capital. This also suggested that while ICT capital is an important source affecting output and labor productivity, it requires other complimentary factors such as human capital and organizational change to fully exploit its benefits. The findings also implied that the manufacturing sector, which is facing lower value added per output and lower labor productivity, can benefit from investment in ICT capital and adoption of this technology to improve its production process.

Another important channel through which investment in ICT can influence the economic performance of industries and sectors pertains to its infrastructure nature and externalities that emerge from its network effects. ICT infrastructure and its network externalities led to increases in the competitiveness of industries by affecting their TFP performance. The aggregate manufacturing ICT capital stock is considered one of the main components of ICT infrastructure other than access to telecommunications and the internet density. The reason for explicitly considering aggregate manufacturing ICT capital stock is that it provides a measure of the network of sector-wide availability of ICT, the network which provides a common platform for industries to perform their economic activities more efficiently and productively. Moreover, this indicator is a stock assessment of ICT infrastructure whereas the access to telecommunications and internet density are not the measures of stock. The findings of the regression analysis indicated that there is a positive correlation between all the three indicators of ICT infrastructure and the TFP levels of the manufacturing sector. The results of the co-integration test also implied that there is long-run relationship between the variables of ICT infrastructure and manufacturing TFP. Hence, it could be argued that ICT infrastructure exerts positive externalities and that it affects the productivity of the manufacturing sector in the long-run. The results have important bearings in improving the competitiveness of the manufacturing sector.

The findings of Chapter 3, which investigated the economic effects of ICT investment on the Indian manufacturing sector in a two stage analysis, are interpreted in totality as:

- ICT capital, as a factor of production, is an important source of output (gross value added) and labor productivity of the manufacturing sector as a whole. This, however, shows its direct effect on the manufacturing sector and captures only part of its full potential. The ICT capital that embodies new technology and that differentiates itself with non-ICT capital in respect of externalities suggest that the benefits of ICT capital need to be interpreted not only as a factor input just as other non-ICT capital, but also as a network that increases with every addition to the aggregate manufacturing ICT capital stock.

- This network of ICT capital is incorporated into the analysis of ICT infrastructure and productivity. The aggregate stock of ICT capital augments the benefits of ICT capital of an industry and the way other factors of production are utilized. Hence, the aggregate stock of ICT capital serves as an infrastructure for the manufacturing sector and affects its TFP. In totality, the results indicate that ICT capital as a factor of production affects output and labor productivity positively, and adds up to the aggregate stock of ICT capital. This aggregate stock of ICT capital in turn improves the overall efficiency and utilization of ICT capital and other factor inputs. Hence, the findings from the second step analysis of a positive and significant relationship between the ICT infrastructure variables including aggregate ICT capital stock, access to telecommunications, internet density, and the manufacturing TFP substantiates the aforementioned viewpoint.

As has been mentioned earlier, ICT services also impart the information and communications technology and necessitate a separate analysis to understand the comprehensive effect of ICT on the Indian industry. Chapter 4 provided a deeper analysis of ICT services in the context of inter-industry and inter-temporal linkages. ICT services industry provides a measure to broaden the understanding of effects of ICT on the Indian industry at large. Indian ICT services are broadly divided into two types as per their structure in the IOTT as 'Computer & related activities' and 'Communication' services. These two industries are analyzed separately due to differences in their dynamics, for instance, one is led by export sales while the other by the domestic market, respectively. The methodology used in this chapter relied on I-O analysis due to the inter-industry nature of the study.

To begin with, the inter-industry linkage of the ICT services industry and its influence on the Indian economy are estimated using I-O multipliers and elasticities, and its integration into the economic system is investigated using backward and forward linkages, and their indices. The indices of backward and forward linkage showed that ‘Computer & related activities’ and ‘Communication’ services industries are ‘key’ industries in the economic growth of India, inducing output of other industries with their backward linkages as well as are induced to produce more and supply intermediate inputs with their forward linkages. The higher backward linkage of ‘Computer & related activities’ compared to its forward linkage underlined the fact that ‘Computer & related activities’ is an export-oriented industry, the growth of which induces output of domestic industries. Nevertheless, the forward linkage of ‘Computer & related activities’ increased between 2003-04 and 2006-07, implying increased adoption of these services by domestic industries as intermediate inputs. On the contrary, the ‘Communication’ industry showed a higher forward linkage, indicating its domestic-market orientation. The forward linkage of the ‘Communication’ industry increased between 2003-04 and 2006-07, while its backward linkage decreased marginally during the same period. This implies that demand for ‘Communication’ services as intermediate inputs increased during the period, while its ability to induce output of other industries declined.

The results of I-O multipliers and elasticities provided indications regarding the influence of the ICT services industry on the Indian economy. The multipliers analysis showed both industries have higher output and value added multipliers, suggesting that an exogenous increase in the final demand for these services can provide higher stimulus for the economy. The I-O elasticities of both the industries, by taking relative size into account, provided the percentage change in output and value added of the economy with a percentage change in final demand of this industry. Although smaller than multipliers, the results of elasticities of both the industries need to be interpreted as the potential of these services to affect the output and value added of the Indian economy, as these services grow in size. Overall the results using I-O measures established that ‘Computer & related activities’ and ‘Communication’ services have strong inter-industry linkages through which this industry can induce output and value added of the economy.

Since ICT services exhibited higher potential as intermediate input through its forward linkage, the I-O analysis is further carried out to deepen the understanding about its usage as intermediate input between two time periods. The inter-temporal analysis is carried out to understand the evolution of ICT services industry as a supplier of intermediate inputs and how it fares in the presence of other intermediate inputs. The left causative matrix model is used as an inter-temporal extension of the forward linkage analysis of the ICT services industry. The findings revealed that both ‘Computer & related activities’ and ‘Communication’ industries have evolved as a competitive supplier of intermediate inputs between 2003-04 and 2006-07. The row sum of the left causative matrix greater than unity for both the industries indicated that, when there is an exogenous increase in the final demand of other industries, the output of ICT services is stimulated as a result of increasing demand for these services, directly and indirectly. As is explained in the literature, one of the determinants of ICT adoption is international competitiveness and the structure of the manufacturing sector of a country. Some of the industries that had a larger impact on the output of ‘Computer & related activities’ services over the period of 2003-04 and 2006-07 are active in international markets through exports, and are export-competitive. These industries included sub-industries of ‘Textiles’ such as ‘Silk Textiles’, ‘Khadi, Cotton Textiles (Handlooms)’, ‘Miscellaneous

Textile Products'; and 'Aircraft and Spacecraft'. In the case of 'Communication' services, industries that exhibited larger impact such as 'Communication equipments', 'Iron ore' and 'Gems and jewellery' are the ones with high export sales. Besides manufacturing and mining industries, there are service industries that held a higher share of the pie of ICT services' adoption such as 'Air Transport', 'Supporting and auxiliary transportation activities' and 'Real estate activities'.

In addition, the analysis provided the ICT services intensity of various industries in 2006-07. It explained the requirement of ICT services directly and indirectly to produce one unit of output. The industries with higher ICT services intensity included 'Communication equipments', 'Electronic equipments (incl. TV)', 'Supporting and auxiliary transportation activities', 'Gems and jewellery', 'Aircraft and spacecraft', 'Batteries', 'ICT services', 'Real estate activities', 'Business services' and 'Electrical industrial machinery' among others. These industries are more or less similar to those that appear in the left causative matrix analysis. Besides service industries, there are manufacturing industries with higher ICT services intensity that are high-tech and capital intensive in nature. Moreover, the average ICT services intensity of the economy increased between 2003-04 and 2006-07. The findings of inter-temporal analysis shed light on two important aspects of ICT services, as follows.

- The ICT services industry including 'Computer & related activities' and 'Communication' services have emerged as a competitive supplier of intermediate inputs over a period of time.
- The industries that adopt ICT services as intermediate inputs and consumed a larger share of these services during the period of analysis included not only competitive service industries but also some of the manufacturing and mining industries. These industries are high-tech and capital intensive, and are also internationally competitive through exports.

The findings of Chapter 4, however, did not explicitly explain the gains of ICT adoption and change in production technology. In Chapter 5, the effect of ICT adoption as an intermediate input and the resulting change in production technology of various industries of the Indian economy is explored. It is evident that some of the ICT services have become affordable and cheaper due to technological improvements related to this technology, and the phasing out import duties on ICT goods seemed to intensify competition in the domestic market and put downward pressure on prices related to ICT goods and services, particularly in the case of India. This scenario is explored while investigating the effect of ICT services on price-responsiveness of various industries and resulting change in their production. However, due to a lack of data, the aspects of human capital and wage-inflation of the ICT services industry are not incorporated into the current analysis, and left for further exploration in the future. A simulation approach is utilized using the VIO model, which is an extension of the I-O price model. The effect of a price-cut in ICT services, both for 'Computer & related activities' and 'Communication' services is investigated based on three scenarios. It is assumed that falling relative prices in ICT services will induce demand for these services as intermediate inputs, the so called substitution effect. The change in production technology as a result of changing technical coefficients will make Indian industries reduce their costs of input materials and utilities as well as gain from the introduction of new technology. The price decrease in ICT services industry takes place through capital cost reduction.

The findings of the simulation analysis using the VIO model provided insights into the potential of this technology. The results of the simulation exhibited a positive effect of ICT services on the production of other industries. The capital cost reduction of one percent in both the services industries resulted in an increase of less than one percent in production in other industries. Additionally, different scenarios of price-cuts are explored by taking relative price changes in other commodities into account. The results from those simulations supported the findings of the first scenario as they are in the same direction. The magnitude of the production increase is larger in the case of 10 percent and 20 percent capital cost reduction. Some of the industries that benefited the most from this price decrease included service industries such as ‘Business services’, ‘Banking’, and ‘Computer & related activities’ and ‘Communication’ itself among others. The other manufacturing and mining industries that showed higher increases in production included ‘Miscellaneous manufacturing’, ‘Ships and boats’, ‘Mining & quarrying’, and ‘Basic Metals Alloys & Metals Products’ among others. The results explained that these industries have higher potential to reduce the cost of input materials and utilities by adopting relatively cheaper ICT services, which will increase production over their current level. The results are also comparable to a number of previous studies. Another important aspect of this analysis is that some of the traditional industries such as ‘Wood & Wood products’, ‘Rubber & Plastic products’ are also found to have benefited, given the price reduction of ICT services. This implies that India can progress towards a New Economy as those of the newly industrialized economies, where ICT will have a larger role to play and the economy as a whole will be more productive and competitive, benefiting from the introduction and adaptation of ICT.

The policy implications from the findings of the study are multi-fold. For the manufacturing sector to be competitive, private investment in ICT needs to be promoted with the help of financial concessions. As the analyses and results in this study pointed out, the adoption of ICT is beneficial to various industries including manufacturing and services. However, the high cost and scarcity of finance is one of the deterrents of ICT adoptions for non-ICT industries, especially for the SMB sector of India. Hence, this study suggests incentivizing adoption of ICT through financial support. Firstly, it is recommended to create a dedicated fund to promote ICT adoption in the SMB sector as has been advocated in the Eleventh Five Year Plan - Information Technology Sector 2007-12 (Department of Information Technology (DIT) 2006, 73, 86, 99). This requires banks to prioritize loans for ICT procurements in line with other priorities such as infrastructure loans. Secondly, a provision of loans for ICT procurements at a low interest rate targeted at the SMB sector will reduce the financial cost burden and attract more enterprises to invest in ICT. These measures will induce more and more industries to avail the benefits of ICT.

To take the advantage of externalities emerging from ICT investment including ICT capital and other components of ICT infrastructure, it is necessary to increase the access to and availability of ICT infrastructure in general, and telecommunications and the internet in particular. For this purpose, a policy focusing on the provision of high speed data communication (HSDC) at a concessional rate for non-ICT industries, mainly for the SMB sector, needs to be formulated and implemented. This may lead to the establishment of common ICT infrastructure facility centers for the manufacturing sector in line with STPI centers available for the Indian IT and ITES industry. As has been underlined in the IT annual report of 2010-11 (Department of Information Technology (DIT) 2011a, 69), the STPI scheme provides data communication services including value added services to be one of the main services. As per the report, SoftNet, the state-of-the-art HSDC network, designed and developed by STPI is available to software exporters who are registered under the scheme at competitive prices. This facility allows for international data communications and internet access on a shared and dedicated basis. On similar lines, it is recommended to provide ICT infrastructure to the SMB sector, located in clusters across the country. This provision will enable the formation of a network of enterprises and increase the utilization of ICT capital. The availability of ICT infrastructure will also increase the adoption of ICT services among different industries since it works as a complement factor for ICT services.

Under the National e-Governance Plan (NeGP), which was approved in 2006, the government initiated various schemes and programs to promote e-governance among various government departments and related agencies as per the annual report of 2010-11 (Department of Information Technology (DIT) 2011a, 16). This initiative aimed at providing public services at affordable cost and encouraging rural entrepreneurship. The government needs to replicate some of its projects, for instance, ‘Chanderi Integrated ICT for development programme (CIIDP)’ and ‘Establishment of Chanderi weavers ICT resource centre’ to encourage industrial adoption of ICT and attract domestic IT and ITES industry to develop products and services including software in accordance with the needs of local entrepreneurs. The ICT resource centre for Chanderi (a handloom fabric named after a town called Chanderi in India) weavers aims at providing various livelihood and soft skills through ICT based empowerment and facilitation of textile weavers in Chanderi community by focusing on digital preservation, ICT based training and marketing as per the annual report of 2010-11 (Department of Information Technology (DIT) 2011a, 32). Under these schemes, CAD software tool has been deployed to digitalize and preserve traditional weaving designs as well as to train designers. In addition, as described in the annual report of 2011-12, new embroidery and weaving designs are created to improve productivity, strengthen old design concepts, and generate variety of employment and trade (Department of Information Technology (DIT) 2012, 33). This study recommends schemes and projects on a similar basis targeting different industries so that there will be increased awareness of ICT usage and of its benefits.

There is also pressing need to upgrade the quality of manufacturing workers by providing technical training, including computer and software related training. This will enhance the absorption of new technology and improve the capacity utilization of ICT capital. In the case of ICT industry, in order to provide high quality human resource for the ICT industry, different initiatives have been put in place under the human resource development activities of the Department of Information Technology (DIT). For instance, a 'scheme for manpower development for the software export industry', which is being implemented by DIT, covers such things as the training of the trainer's program, enhancement of quality of IT education in colleges, virtualization of technical education, and conducting specialized short-term courses in IT-ITES industries as specified in the IT annual report of 2011-12 (Department of Information Technology (DIT) 2012, 47). In addition, as described in the Report of the Working Group on Information Technology Sector- Twelfth Five Year Plan (2012-17), a 'working group on human resource development in information technology' was set up to evolve long term human resource strategies aiming to increase the number of well-trained professionals for various electronics, ICT and related areas in line with economic projections (Department of Information Technology (DIT) 2011b, 58). According to the same report, under the 'National Skill Development Policy', which was announced in 2009, a target of 10 million manpower to be skilled by 2022 was assigned to DIT (Department of Information Technology (DIT) 2011b, 59). These schemes and initiatives underline the policy direction to create a pool of high quality human resource to be utilized by the Indian ICT industry. As a result, the Indian ICT industry can tap into the supply of skilled human resource, which is central to the high performance in terms of output and productivity of the industry.

Moreover, there are a number of government initiatives that focus on training to industries and organizations; for instance, the Indian Institute of Quality Management provides training to industries and organizations in various areas including Information Security Management System and IT service Management, as per the IT annual report of

2011-12 (Department of Information Technology (DIT) 2012, 55). In order to increase the employability and reduce the skill gap, the private sector has evolved with a large number of training centers and programs that cater to the needs of the Indian ICT industry. According to NASSCOM, any graduate who is hired in the industry, irrespective of his/her education institute and skill level, is required to undergo the entry-level training at the time of induction (NASSCOM 2009, 102). This in-house training, mainly conducted by large firms at their training centers, includes a range of areas from soft skills such as communication and cultural sensitization to analytical and technical skills specific to the company requirements (NASSCOM 2009, 104). There are a number of private training institutes that complement these efforts by providing expertise in learning content development and training delivery. Hence, aforementioned IT education and various training initiatives among others enable the ICT industry to capitalize on the technological advancements in ICT and gain productivity improvements.

In contrast, the Indian manufacturing sector is facing a shortage of skill-sets that can be utilized for enhanced labor productivity and technological adoption. As has been specified in the report on Occupational-Educational Pattern of Employees in India, 2003, only 10.5 percent of production and related workers (craftsmen and other skilled workers) were found to hold a degree or diploma in engineering/technology or certificate in engineering trade, whereas 69.3 percent of them had another type of educational and technical qualifications (Directorate General of Employment and Training 2008, 38). The same report indicates that 75.9 percent of the total workforce in manufacturing has been in the category of ‘production and related workers, transport equipment operators and laborers’ in 2003 (Directorate General of Employment and Training 2008, 42). One of the constraints in technology adoption in the manufacturing sector pertains to deficiency in skills of the labor force with the exception of some of the hi-tech sectors. This suggests that the manufacturing labor force requires training facilities that can enhance their skills and increase capacity. The human capital aspect is not investigated in this study due to limited dataset; however, it is an important aspect that can increase the technological adoption and productivity of the manufacturing sector. Hence, this study suggests that there needs to be policy initiatives that focus on capacity building and skill up-gradation of the manufacturing labor force through various e-learning and training programs. The policy interventions on similar lines to those for the ICT industry, including encouraging private sector participation in the training programs, are required to take the advantage of ICT adoption and become competitive through higher productivity.

The findings from Chapter 4 and Chapter 5 provided insights regarding the relevance of ICT services for industrial development in India. It also highlighted the economic integrity of the ICT services industry, in which the ICT services industry grows as a competitive supplier of intermediate inputs, and also induces the output of other industries. The benefits of adoption of ICT services are not restricted to the service industries but are imparted to some of the manufacturing and mining industries, given the falling relative prices of ICT services. Hence, the growth of the ICT services industry will benefit the rest of the economy, particularly the domestic manufacturing and mining industries. However, product differentiation and innovation that caters to the requirements of domestic industries will encourage the adoption of these services. In addition, policies that promote competition in the domestic market and eliminate price irregularities by phasing out import duties should contribute to increases in the adoption of new technology, ICT in this case. The adoption of ICT services also hinges upon the provision of ICT infrastructure.

In addition to promoting domestic ICT investment and demand for ICT goods and services, there is a need to address the supply side constraints of the Indian ICT industry.

Since ICT infrastructure provides externalities that are important to achieve competitiveness and improve productivity, the ICT infrastructure network needs to be broadened by improving access to telecommunications and increasing internet access. Public investment in large scale projects of national interest, such as development of satellites and other telecom infrastructure, will also attract private investment. Moreover, ICT infrastructure also serves as a complement and encourages the adoption of ICT services that are critical in businesses. Hence, public policies that focus on the telecommunications and internet proliferation are necessary. According to the Report of the Working Group on Information Technology Sector- Twelfth Five Year Plan (2012-17) (Department of Information Technology (DIT) 2011b, 10), the Common Service Centre (CSC) scheme was approved by the government in 2006 for setting up hundred thousand plus internet enabled centers in rural areas under the NeGP. The CSCs are proposed to be the delivery points for public, private and social sector services to rural parts of India. Moreover, to enhance the interest of ICT services providers, in particular those of SMEs, it is suggested to decentralize the industry beyond existing hubs by developing new townships and hubs, and to ensure that SMEs can continue to leverage the benefits offered under the STP/SEZ (special economic zone) scheme without constraint on their location (Department of Information Technology (DIT) 2006, 72-73). As has been observed in Chapter 5, price sensitivity of the Indian industry in general suggests that cost-efficient India specific products are required to be developed, including software and contents in various Indian languages.

This study provided an overview of and evidence for the importance of ICT in industrial development in India, the introduction and adoption of which can assist in increasing industrial productivity and competitiveness. Hence, this study emphasized that a comprehensive approach is required to understand the role of ICT in industrial development and suggested a range of policies that can enhance the contribution of ICT in India.

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Appendix

Appendix A: Classification of the 'registered manufacturing sector'

Coverage of the Annual Survey of Industries extends to the entire Factory Sector comprising industrial units (called factories) registered under the Sections 2(m)(i) and 2(m)(ii) of the Factories Act, 1948. The sections 2m (i) and 2m (ii) refer to any premises including the precincts thereof (a) whereon ten or more workers are working, or were working on any day of the preceding twelve months, and in any part of which a manufacturing process is being carried on with the aid of power, or is ordinarily so carried on or (b) whereon twenty or more workers are working or were working on any day of the preceding twelve months and in any part of which a manufacturing process is being carried on without the aid of power, or is ordinarily so carried on (Central Statistics Office (CSO) 2011b).

This classification of coverage of the ASI implies that the 'registered manufacturing sector' is the one that includes factories registered under the Factories Act, 1948 as specified above.

Appendix B: Hausman Specification Test, Model [2A]

hausman fixed random

Coefficients	(b) fixed	(B) random	(b-B) Difference	sqrt(diag(V_b-V_B)) S.E.
K^{N}	0.603	0.566	0.038	0.127
K^{I}	-0.060	-0.036	-0.023	0.017
L	0.718	0.414	0.304	0.050
T	0.055	0.068	-0.013	0.001

b = consistent under Ho and Ha; obtained from xtreg

B = inconsistent under Ha, efficient under Ho; obtained from xtreg

Test: Ho: difference in coefficients not systematic

chi2(4) = (b-B)'[(V_b-V_B)^(-1)](b-B)

= 5.93

Prob>chi2 = 0.2048

(V_b-V_B is not positive definite)

Appendix C: Hausman Specification Test, Model [2B]

hausman fixed random, sigmaless

Coefficients	(b) fixed	(B) random	(b-B) Difference	sqrt(diag(V_b-V_B)) S.E.
k^{N}	0.482	0.574	-0.092	0.113
k^{I}	-0.070	-0.035	-0.035	0.019
T	0.065	0.066	-0.001	0.002

b = consistent under Ho and Ha; obtained from xtreg

B = inconsistent under Ha, efficient under Ho; obtained from xtreg

Test: Ho: difference in coefficients not systematic

chi2(3) = (b-B)'[(V_b-V_B)^(-1)](b-B)

= 6.03

Prob>chi2 = 0.1100

Appendix D: Details of 'Computer & related activities' and 'Communication' industries

'Computer & related activities' (Industry 124):

According to National Accounts Statistics- Sources and Methods 2012 (Central Statistics Office (CSO) 2012, 171), the activities covered under this category include hardware consultancy; software publishing, consultancy and supply; data processing; database activities and distribution of electronic content; maintenance and repair of office, accounting and computing machinery; and other computer related activities.

'Communication' (Industry 115):

According to IOTT 2003-04 (Central Statistics Office (CSO) 2007a, 16), this industry comprises of services rendered by public and private communication organizations/enterprises. The activities of Department of Posts relating to 'Post Office Saving Bank' and 'Postal Life Insurance' are excluded from communication as the same are included in banking and insurance industries, respectively.

According to National Accounts Statistics- Sources and Methods 2007 (Central Statistics Office (CSO) 2007b, 9-10), the economic activities covered under this industry are (i) courier activities, (ii) activities of the cable operators, and (iii) other communication. The activities that come under 'Other communication' include the activities of cellular and basic telecom services, and the activities of public call offices (PCOs). The economic activities of internet, cyber cafes et al also fall under this category.

Appendix E: Concordance of price deflators and corresponding industries

Sectors/Industries	WPI	Implicit GDP deflator
Agriculture (primary commodities)	Industry 1~Industry 21, 23, 24	
Animal services (agricultural)		Industry 22
Forestry and logging, Fishing		Industry 25, 26
Mining & Quarrying, Manufacturing	Industry 27, Industry 29~Industry 105	
Natural gas		Industry 28
Construction		Industry 106
Electricity	Industry 107	
Services		Industry 108~Industry 130

Note: Implicit GDP deflators are derived from various publications of National Accounts Statistics (with the base 1999-2000) and the base is adjusted to 2003-04.

Appendix F: Price Index based on 2006-07 prices (Base 2003-04=100)

Industry	Value
Agriculture	119.31
Forestry and logging	113.31
Fishing	116.71
Mining & quarrying	134.42
Food Products	109.48
Beverages Tobacco & Tobacco Products	118.43
Textiles	100.53
Wood & Wood Products	114.99
Paper & Paper Products	110.04
Leather & Leather Products	108.58
Rubber & Plastic Products	109.78
Petroleum products	117.27
Coal tar products	184.07
Chemicals & Chemical Products	109.42
Non-Mettallic Mineral Products	129.27
Basic Metals Alloys & Metals Products	139.03
Non-Electrical Machinery & Parts	119.86
Electrical Machinery	114.77
Ships and boats	114.38
Transport Equipment & Parts	110.18
Watches and clocks	114.38
Medical, precision & optical instruments	114.38
Gems & jewellery	114.38
Aircraft & spacecraft	114.38
Miscellaneous manufacturing	114.38
Construction	135.07
Electricity ,gas & water supply	104.17
Transport	111.58
Storage and warehousing	117.30
Communication	84.53
Trade	124.99
Hotels and restaurants	122.47
Banking	88.90

Insurance	86.12
Ownership of dwellings	116.63
Education and research	108.60
Medical and health	115.39
Business services	115.36
Computer & related activities	115.81
Legal services	115.61
Real estate activities	115.59
Renting of machinery & equipment	115.52
O.com, social & personal services	115.70
Other services	112.69
Public administration	116.26
National GDP (at factor cost)	115.88

Source: Author's estimates

Appendix G Results of Scenario 1: for 2003-04

No	The case of 'Computer & related activities' industry	Change in Production (%) for 2006-07	The case of 'Communication' industry	Change in Production (%) for 2006-07
1	Business services	0.0822	Mining & quarrying	0.1328
2	Miscellaneous manufacturing	0.0465	Ships and boats	0.0888
3	Computer & related activities	0.0450	Electrical Machinery	0.0765
4	Ships and boats	0.0304	Communication	0.0761
5	Mining & quarrying	0.0258	Miscellaneous manufacturing	0.0743
6	Banking	0.0256	Basic Metals Alloys & Metals Products	0.0629
7	Communication	0.0226	Electricity, gas & water supply	0.0549
8	Hotels and restaurants	0.0199	Coal tar products	0.0442

9	Legal services	0.0172	Business services	0.0436
10	Electrical Machinery	0.0152	Petroleum products	0.0430
11	Paper & Paper Products	0.0151	Paper & Paper Products	0.0418
12	Insurance	0.0144	Gems & jewellery	0.0359
13	Real estate activities	0.0140	Rubber & Plastic Products	0.0358
14	Electricity, gas & water supply	0.0140	Insurance	0.0344
15	Basic Metals Alloys & Metals Products	0.0132	Banking	0.0343
16	Aircraft & spacecraft	0.0128	Wood & Wood Products	0.0339
17	Medical and health	0.0116	Legal services	0.0331
18	Coal tar products	0.0115	Chemicals & Chemical Products	0.0313
19	Wood & Wood Products	0.0099	Aircraft & spacecraft	0.0298
20	Transport Equipment & Parts	0.0093	Renting of machinery & equipment	0.0272
21	Chemicals & Chemical Products	0.0089	Storage and warehousing	0.0271
22	Petroleum products	0.0083	Non-Electrical Machinery & Parts	0.0265
23	Rubber & Plastic Products	0.0080	Non-Mettallic Mineral Products	0.0226
24	Renting of machinery & equipment	0.0076	Real estate activities	0.0197
25	O.com, social & personal services	0.0072	transport	0.0196
26	Non-Mettallic Mineral Products	0.0061	Trade	0.0189
27	Storage and warehousing	0.0060	O.com, social&personal services	0.0187
28	Non-Electrical Machinery & Parts	0.0060	Transport Equipment & Parts	0.0160
29	Transport	0.0059	Other services	0.0149

30	Trade	0.0053	Medical, precision & optical instruments	0.0141
31	Education and research	0.0053	Forestry and logging	0.0130
32	Medical, precision &optical instruments	0.0049	Hotels and restaurants	0.0105
33	Construction	0.0046	Leather & Leather Products	0.0068
34	Forestry and logging	0.0043	Construction	0.0063
35	Gems & jewellery	0.0033	Textiles	0.0061
36	Watches and clocks	0.0032	Agriculture	0.0060
37	Other services	0.0030	Computer & related activities	0.0051
38	Textiles	0.0023	Food Products	0.0032
39	Agriculture	0.0023	Beverages Tobacco & Tobacco Products	0.0026
40	Leather & Leather Products	0.0022	Watches and clocks	0.0024
41	Beverages Tobacco & Tobacco Products	0.0020	Fishing	0.0017
42	Food Products	0.0018	Medical and health	0.0010
43	Fishing	0.0004	Education and research	0.0002
44	Ownership of dwellings	0.0000	Ownership of dwellings	0.0000
45	Public administration	0.0000	Public administration	0.0000

Source: Author’s estimates