Modern Communication Technology and its Economic Impact: A Survey of Research Findings

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Abstract: In the last two decades, explosive innovation in Information and Communications Technology (ICT) and rapid expansion of modern communications networks with fixed and mobile broadband access features are changing the way we access, store and transmit information bringing significant efficiency gains in all activities. In this paper we intend to identify the various channels through which ICT is influencing many activities that impact the economy. Empirical findings reviewed in this paper support the role of ICT as an important source of economic growth and productivity with asymmetric effects across industries and sectors. This analysis summarizes the different methodologies explored by various researchers to measure the impact of ICT on the economy by incorporating the spillover effects of ICT into the impact measurement. Impacts of the use of ICT capital and ICT infrastructure on structure of production and input demands are also discussed. This aspect is very important for understanding the consequences of ICT use on aggregate demand for labor, composition of labor skills and type of capital formation.

Key words: communications, ICT, broadband, infrastructure, marginal benefits, productivity.

In the modern era, Information and Communications technology (ICT) is an important source of economic growth and productivity improvement. Empirical evidence suggests a positive impact of ICT investment and its use on productivity at the firm, industry and national levels. In the last two decades, explosive innovation in ICT and rapid expansion of

(*) The views and opinions expressed in this paper are solely those of the authors, and are not endorsed or attributable to AT&T. Authors express their sincere thanks to Rebecca COFFMAN of AT&T Labs and Ramen N. NANDI, retired engineer from DEP-NY for many helpful suggestions.

modern communications networks with fixed and mobile broadband (BB) access features are changing the way we access, store and transmit information bringing significant efficiency gains. Improvements in means of communications facilitate the accessibility of existing knowledge and information which, in turn, induces further technological change in the economy. Rapid deployment and adoption of mobile communications also permit access and transmission of information and knowledge seamlessly from anywhere in the world. The communications connectivity through the internet and mobile phones is increasingly bringing market information, financial, health, and educational services to remote areas and thus, extending economic opportunities to both urban and rural populations, even with low levels of income and literacy. The ICT infrastructure also generates spillover and network externality effects among firms and various other economic units within and across countries, leading to enhanced economic growth and development. Finally, due to various uses of ICT capital and ICT services in the production process, the input requirements of many industries are significantly changing through substitution and complementary effects. These changes have an impact on factor demands and structure of production at the micro and macro economy level and are likely to affect the aggregate demand for labor, composition of labor skills and the type of physical capitals.

The focus of this paper will be on the following major channels through which ICT is influencing many activities that generate impacts on the economy:

- growth of knowledge capital through easy access to information and ideas within and across various countries;
- direct efficiency and productivity gains. Special attention is given to understand the role of the service sector in this respect;
- spillover and network externality effects of ICT;
- impact on factor demands and production structure.

Even though ICT is generating efficiency gains and network externality effects in both supply and demand side of the economy and bringing significant transformation in the structure of production and consumption, this paper primarily addresses the supply side effects. The study also focuses on analyzing the impacts from modern communications technology on the economy which is the major component of ICT.

The present paper is organized in the following manner. The next Section explains the role of ICT in the process of knowledge management which creates impact on economic growth. The following Section summarizes the findings of various studies regarding the impact of ICT on productivity growth and its spillover effects. The Section after provides the summary of the industry level estimates of benefits from communication infrastructure and BB penetration. This section also describes the impacts of communication infrastructure on input demands and structure of production. Concluding remarks are provided in the last section.

■ Knowledge capital, ICT and economic growth

In the field of modern macroeconomic growth theory, ROMER (1990), BARRO (1990), LUCAS (1988), MANKIW, ROMER & WEIL (1992) with their pioneer works have well established the role of knowledge capital in accelerating economic growth by inducing technical change in the growth process. These and other research findings suggest that efficient transfer of knowledge and information due to its complex spillover effects is the primary factor toward achieving high economic growth. Knowledge arises as a dynamic learning process that occurs between individuals, teams, organizations and communities. The modern communication system is facilitating such information flows and dynamic interactions. In the supply side of the economy, such knowledge capital helps in improving the quality of existing products, increasing the efficiency of production processes and supports innovation of new technologies that generate new products, services and processes. Thus, Knowledge capital together with availability of well-developed ICT system leads to higher economic growth and productivity gains.

In a recent paper, WILDER & FERRIS (2006) explained the possible impact of evolving communication technology over time on the process of knowledge acquisition and knowledge sharing. In the age of oral cultures of communication, information were memorized by individuals and predominantly transmitted via one-to-one connectivity. Later, the advent of the written word helped to mitigate such limitations. The invention of printing had far reaching effects on knowledge formation and technological innovation processes. The accessibility of knowledge was further enhanced in the latter half of the 20th century by revolutionary innovations in the field of ICT. Information flow is no longer bounded by physical restriction of printed texts or limited by geographic or temporal boundaries. The spread of computer, digital technology and cyber space have extended immensely possibilities for storage, transmission and access to information. Thus, these changes in options for knowledge creation and transmission process are empowered to have significant impact on inducement of further technological change which leads to higher economic growth and a better quality of life. LOPES, MARTIN & NUNES (2005) in their paper on "Knowledge Economy" mentioned the role of knowledge capital as an important corporate asset. Their data analysis supports the concept that by providing an efficient network platform, knowledge can be captured and transferred to individuals, groups and organizations in more efficient and effective ways. Based on empirical models and data from OECD countries for the period 1991-2000, these authors showed the supremacy of knowledge capital over fixed capital as a contributing factor toward improved GDP in some developed countries.

■ Impact of ICT on productivity and its spillovers

Investment in ICT has increased significantly since 1980's in many countries. Its contribution toward productivity and growth of the economy is now well documented around the world. However, in the post 1970 period, when spending on ICT capital was increasing rapidly in the US, researchers could not readily substantiate the contribution of ICT capital to productivity growth. The evidence showed that while computer power was increasing over time, the measured productivity growth remained slow or stagnant for the entire U.S. economy. This observed phenomenon was characterized as "productivity paradox" (BRYNJOLFSSON, 1993) in the context of U.S. economy, and later referred as Solow's computer paradox in reference to growth theorist Robert SOLOW's 1987 statement, "You can see the computer age everywhere but in the productivity statistics" (SOLOW, 1987). This paradox was resolved by several subsequent studies (BRYNJOLFSSON & HITT, 1993; STIROH, 2002) which established empirically the linkage between ICT capital and productivity growth at the micro and macro economy levels. These studies identified measurement deficiencies and methodological weakness as primary explanations behind the observed paradox. The lag between ICT investment and realization of its benefits also was addressed as another possible explanation (BASU & FERNALD, 2006). Since the mid-1990s, further research has clearly established the strong relationship between ICT capital and productivity gains and has identified its sizeable spillover effects in the economy. In the following sections, we review several such studies conducted both at the aggregate and disaggregate levels.

Aggregate level analysis

Empirical evidence reveals that ICT affects the productivity and economic growth through direct and indirect paths. There are different roles through which ICT can contribute toward high productivity growth of aggregate economy. First, investment in ICT capital leads to capital deepening and thus increases labor productivity. Secondly, due to rapid technological progress and strong demand, the efficiency in producing ICT goods and services improves which increases the total productivity of ICT sector. The most important role is the use of ICT in non-ICT sectors and its impact on productivity. Accumulated ICT capital also builds the ICT infrastructure at the national level which generates network externalities and spillover effects across all firms and industries and thereby enhances the productivity in the aggregate economy. Evidence also supports that such spillover effects cross the national boundaries of individual countries.

A group of studies (using OECD data) examined the impact of ICT at the macroeconomic level (such as COLECCHIA & SCHREYER, 2002; van ARK, *et al.*, 2003). These studies show that ICT investments have a capital deepening effect, which increased productivity and growth in most of the OECD countries in the 1990s with wide variations across countries. With a relatively higher ICT diffusion rate, the United States and Australia experienced a higher impact of ICT-use on productivity growth than other European countries.

Several researchers (BEBEE & GILLING, 1976; HARDY, 1980; DHALAKIA & HARLM, 1994; CRONIN *et al.*, 1991) investigated the relationship between the telecommunications infrastructure (a major component of ICT infrastructure) and economic growth and established the linkage between the two. CHAKRABORTY & NANDI (2003) used the panel data from 12 Asian countries for the periods 1975-2000. They noted the existence of a long run relationship between per capita GDP and the tele-density. By grouping these countries based on privatization, they also found that causality is bi-directional for countries with a relatively higher degree of privatization but causality runs only from tele-density to per capita GPD in countries with low degrees of privatization. In the later study, CHAKRABORTY & NANDI (2011) extended the previous study by using data from 93 developing countries for the period 1985-2007. These countries span the four continents of Asia, Africa, Europe and Latin America. The countries were sub-divided into three groups based on their development level: less developed, emerging and more developed. They found that growth effects of increased telecommunications infrastructure investment appeared to be stronger for less developed and emerging countries than for relatively more developed countries. Results also show that for the less developed countries, mainline tele-density and per capita GDP reinforce each other both in the short run and in the long-run, suggesting a high return on telecommunications investment.

Similarly, FARHADI & FOOLADI (2001), using data from 159 countries, estimated the impact of ICT use on economic growth and reported that ICT-use has positive impact on GDP growth and is statistically significant. For further analysis, they categorized 159 countries into four groups based on their income levels. Results show that for all groups except the low income group, ICT-use has a positive and significant effect on economic growth and the estimated impact is positively correlated with the country's income level.

Disaggregate level analysis

Even though aggregate level studies have established the positive impact of ICT use on economic performance, to understand fully the various mechanism through which ICT is contributing, it is important to analyze the data at a more disaggregate level. For example, at the firm level, the effective use of ICT may help the firm to gain market share through higher productivity in comparison to their competitors and may help the firm to innovate. In addition, ICT may help in reducing inefficiency in the use of capital and labor. Firm level studies also reveal clearly that the use of ICT accompanied by other complementary factors help in increasing the economic performance. There is also some lag time in ICT adoption. Disaggregate level studies are likely to shed more light in these respects.

While a host of studies, including JORGENSON & STIROH (1999, 2000) and OLINER & SICHEL (2000), provide evidence in support of a substantial contribution of production and use of ICT toward aggregate productivity revival, studies at the micro level are relatively scarce in the literature. STIROH (2001) adds to such findings by arguing that with broad-based productivity gains in the late 1990s, industries that were intensive in the use of ICT capital accounted for a major share of productivity growth at the macro level. These studies, however, ignored the network externality effects of accumulated ICT capital on productivity growth. On the other hand, utilizing an input-output framework, CRONIN *et al.* (1997) reported that, though heterogeneous across industries, investment in ICT infrastructure generates substantial consumption and production externalities. Employing an econometric framework that incorporates ICT infrastructure (together with public infrastructure) as an integral input in the industry production process, NADIRI & NANDI (2001) calculated the network externality effects and showed a strong link between access to such infrastructure and productivity gain at the disaggregate level.

Direct and indirect impacts of ICT on productivity

Although our understanding about the impact of ICT on productivity growth has been enhanced by the above mentioned studies, due to the complex role of ICT, questions may be raised regarding proper treatment of ICT capital in a firm or industry level production function. At the micro level, use of ICT capital equipment has the same role as traditional inputs and affects output growth directly. However, at the aggregate level, accumulated stocks of ICT capital refer to the national level of ICT infrastructure service which is available to all industries irrespective of their specific production process. These two roles of ICT capital can be defined as "ICT intensity" and "ICT infrastructure" impacts respectively. In a later study, NADIRI, NANDI & CHAKRABORTY (2009) incorporated this dual role of ICT capital by introducing industry specific ICT-capital and national level ICT [1] infrastructure as two separate inputs in the industry level production function. The cost function derived from such production function is used to estimate the cost savings due to incremental increase communications infrastructure capital and is defined as "Marginal Benefits" from communication infrastructure.

This study covers 42 U.S. industries in the private sector over the period of 1977-1999. In this study, ICT capital consists of computers, communications equipment and software. At the industry level, the ICT capital intensity index is formulated by taking ratio of ICT capital to non-ICT capital. The mean values of such intensity measures are estimated for the entire sample period as well as for the pre and post 1987 periods. Estimation shows that the mean value of the capital intensity index is relatively high as expected in Communications, Wholesale trade, Business services, Insurance, Motion Pictures, Bank and Securities and other services

[1] See NADIRI, NANDI & CHAKROBORTY (2009) for details. In this study, authors decided to focus only on the telecommunications segment of ICT infrastructure to avoid the complication of measuring benefits.

industries. Moreover, the growth rates in the ICT index over the two periods indicate that the intensity of the use of ICT capital increased significantly for many industries in the post 1987 period.

All industries are first ranked based on estimated mean values of marginal benefits derived from communication infrastructure capital (MBS1) for the entire sample period. The list of top 15 industries is presented in Table 1.

Table 1 - Top 15 industries for the period 1977-1999

Rank of the Industry	*Industry Number*	*Industry Title*	*MBS1*
			1977-1999
1	31	Real Estate	0.0306
2	28	Retail trade	0.0292
3	27	Wholesale trade	0.0225
4	39	Health services	0.0191
5	3	Construction	0.0186
6	29	Bank & Security	0.0184
7	11	Transportation equipment	0.0167
8	14	Food and Kindred products	0.0165
9	24	Transportation services	0.0162
10	34	Business Services	0.0157
11	42	Other services (social svc, museum etc.)	0.0158
12	9	Industrial machinery & equipment	0.0141
13	20	Chemicals and allied products	0.0136
14	10	Electronic ans other electric equipment	0.0127
15	26	Electric, gas & sanitary service	0.0124

Note: Ranking is based on Mean's Values of Marginal Benefits from Telecommunications Infrastructures (MBS1).

As evident from this table, the majority of the industries listed in this group are service industries with few exceptions. Results reveal that all the above listed industries are benefiting from the use of telecommunication services in many different ways. If we focus on analyzing the benefit opportunities from telecommunications for the top five industries in the list, we see that the use of communication service allows the Retail and Wholesale trade sectors [2] to improve their efficiency in handling products and managing inventories whereas in Real Estate business, use of such

[2] See GORDON (2004) and KASK, KLEMAN & FRIEDMAN (2002).

service allows better collaboration and communications with prospective buyers. On the other hand, the Construction industry operates primarily as a system of sub-contracts and key success factors in such a process are communication and collaboration which ICT facilitates. Thus, even though the Construction industry does not belong to service industries group, we observe higher productivity gains through increased use of telecommunication services. These observations are similar to those reported in CRONIN *et al.* (1997), NADIRI & NANDI (2001) and SHAPIRO & MATHUR (2011).

NADIRI, NANDI & CHAKRABORTY (2009) also ranked the industries based on mean values of ICT-intensity and its growth over two defined sub-periods. Comparison of all three types of rankings suggests that 11 out of 15 top industries with highest marginal benefits from communication infrastructure are either already high in ICT-intensity or increasing their ICT-intensity at relatively rapid rates over time in comparison to others. Thus, this analysis captured both the impact of industry specific ICT intensity and spillover effects of ICT infrastructure on industry level productivity growth.

Since service industries are benefitting most from ICT and the service sector is now a major contributor of world economy, we would like to understand the role of ICT in influencing economic performance through enhancing innovation, growth and productivity of industries in this sector. A number of researchers (BARRAS, 1990; MILES, 2000) have identified the relationship between innovation and growth in services. Recently, using data from Norway service industries, KOSON (2007) explored the relationship between the innovation activities and economic performance of firms under service industries and results show that the higher the share of ICT in R&D expenditure, the higher the economic performance of firms in the service sector. This observation illustrates the role of ICT intensity in R&D for leading greater economic performance of service industries and thereby for the aggregate economy.

ICT and ITS spillover effect

The study done by NADIRI, NANDI & CHAKRABORTY (2009) indirectly captured the spillover effects of ICT on productivity through the introduction of ICT infrastructures as separate input into industry level production function. Several other researchers also put special focus on estimating the spillover effects on productivity. BASU & FERNALD (2006) conducted a study using U.S. industry level data for the period 1987-2004. They highlighted the fact that in standard neo-classical theory, the use of ICT throughout the economy leads to capital deepening, which increases the labor productivity in the ICT-using sector but does not change their total factor productivity (TFP). On the other hand, BASU & FERNALD (2006) interpreted ICT as general purpose technology (GPT) which thus can contribute toward TFP growth of ICT-using industries. They noted that, ICT-using firms respond to faster and more powerful computer and software by re-organizing and accumulating 'intangible capital' in the form of acquired knowledge. In addition, firms that do not use computers intensely might also benefit due to spillover of 'intangible capital'. Thus, technological change in ICT with GPT characteristics affects industries beyond the ICT-Sector. However, firms require making complementary investments in order to extract full benefits from the use of general purpose ICT. Using U.S. industry data, they find that ICT capital growth is associated with industry level TFP growth in U.S. with long lags of 5 to 15 years and show that acceleration in productivity in U.S. after mid-1990s was broad based and located primarily in ICT-using industries rather than ICT-producing industry.

Recently several other studies (MARRANO *et al.*, 2009; BALDWIN *et al.,* 2012; CHUN & NADIRI, 2015, and others) identified a significant contribution from intangible assets on productivity gains and its implication on financial markets where intangible assets primarily consist of R&D, computer related information and various firm specific human and organizational resources. CHUN & NADIRI (2015) estimated a sizeable contribution from intangible assets toward growth of labor productivity in the Korean economy accounting for about 60% of growth in average labor productivity during 1981-2008. Availability of high quality ICT equipment and services facilitate the use of intangible assets further and enhance the productivity gain and its spillover effects in the economy.

Another study on the spillover effect of ICT was done by LEEUWEN & WEIL (2003). Even though there was an unprecedented growth of ICT capital per employee, growth accounting studies (STIROH, 2002; VAN DER WEIL, 2001) indicated moderate growth in labor productivity in the last decades. Using the firm level data from Netherlands, LEEUWEN & WEIL attempted to examine the direct and indirect contribution of ICT toward labor productivity. They argued that growth accounting studies are not sufficient to account for indirect contribution of ICT on labor productivity. They introduced ICT spillover capital stock as a separate input in production function in addition to ICT-capital, non-ICT capital and labor. They constructed

ICT-spillover capital stock at the industry level as well as firm level. The firm level ICT-spillover capital stock was computed by subtracting a firm's own ICT capital stock from industry level aggregate stock. Results show that the elasticity of labor productivity with respect to ICT capital is considerably lower when using the model that includes the ICT spillover capital stock as additional input in production process than that without it. This result illustrates that a considerable part of the labor productivity growth is channeled through TFP which captures the ICT spillover effects. The estimated contribution of ICT spillover to labor productivity growth is approximately 1.5% which appears to be quite high at firm level. However, the result is consistent with the results obtained by MUN & NADIRI (2002) which analyzed the impact of ICT spillover effects at the industry level using inter-industry commodity flow.

The concept of ICT spillover effects can be generalized to the international level as well. ICT can improve the standard of living in less developed countries not only through the production of ICT goods and services but through easy access of information across national boundaries around the world. MOSHIRI & NIKPPOR (2010) investigated the possible ICT spillover effects on productivity of 69 countries including both developed and developing countries. Their results show that the ICT spillovers, measured by a bi-lateral trade index, exert significant positive impact on output per worker across countries with much larger effects for OECD countries than the non-OECD countries.

■ Communications infrastructure, broadband technology and productivity

Broadband (high speed) accessibility of internet is another revolutionary phenomenon of ICT. This technology, together with high capacity computers, allows faster diffusion of existing knowledge, by increasing the speed and quality of information transfer. With increasing adoption of BB technology in various countries, several researchers around the world are continuously exploring various methodologies to assess the role of BB technology toward economic growth. In the early stage of BB penetration, studies done by CRANDALL & JACKSON (2001), CRANDALL, LEHR & LITAN (2007) are important. In later stages, important studies were conducted by CRANDALL *et al.* (2007) using U.S. data, KOUTROUMPIS (2009), WAVERMAN *et al.* (2009), KATZ *et al.* (2009), QIANG *et al.* (2009)

of World Bank and SCOTT (2012) using data from countries with different incomes and by CZERNICH *et al.* (2011) using OECD data. Most of these studies found a positive impact of BB penetration on GDP growth. Estimated incremental growth rate in these studies ranges from 0.9% to 1.5% in response to a 10% increase in BB penetration rate (number of BB subscribers per 100 inhabitants) and varies across countries with different income levels. Regarding the productivity gain, the WAVERMAN *et al.*, (2009) study found that 1% increase in BB penetration rate will contribute 0.13% gain in productivity.

In a recent study, NADIRI, NANDI & AKOZ (2015) examined the impact of modern communications infrastructure and the incremental spillover effects of high speed BB connection on productivity gains of various U.S. industries and for the aggregate economy. They also analyzed the impact of communication infrastructure use on factor demands and structure of production which are not addressed by most of the existing studies.

In formulating an econometric model, NADIRI, NANDI & AKOZ realized that available communication capital stock data needs to be adjusted for quality improvement which is the outcome of ongoing technological progress. Moreover, to identify the contribution of broadband capital stock, it is necessary to separate this broadband capital stock from other communications capital stocks. However, due to data limitation and data complexity, none of these is an easy job. In addition to that it is a general consensus that BB technology is helping to increase efficiency in so many ways that the impact of it can be reflected through a shift in production function like other general purpose technology. Thus, NADIRI, NANDI & AKOZ extended the previous cost model (NADIRI & NANDI, 2001) by modifying the underlying production function as follows:

$$Y = F(L, K, M, G(S_1^{\theta} S_2^{1-\theta}))\ e^{T+\lambda BB}$$

where Y represents output quantity and L, K and M are the quantity of labor, capital and material. S1 and S2 represent communications infrastructure capital and public infrastructure capital respectively with G(.) function as the binding relationship between the two infrastructure capitals. The shift factor in the production function incorporates the impacts of general technological progress (T) and broadband penetration rate (BB) on productivity. The model is estimated using data for 41 U.S. industries (excluding communications industry) for the period 1987-2008.

In order to estimate the productivity effect at the industry level, they first estimated the cost elasticity with respect to communication infrastructure capital stock S_1 for each industry based on estimates of model parameters. Marginal benefit estimates derived from cost elasticities are positive for all industries. Estimated marginal benefits or cost savings from BB penetration are also positive for all industries. In both these cases, the magnitudes of marginal benefits are high for service industries and the top five industries are: Other Service (42), Health and Social Assistance (39), Bank, Fund and Security (30), Construction (4) and Retail Trade (24). *The scope of increasing the productivity in health services, banking and related financial service industries appears to be significantly higher than other industries*. They also studied the trend in productivity gains in various industries by comparing the mean values of estimated marginal benefits in pre and post 2005 period. It is noted that even though cost savings from use of communications infrastructure service is positive for all industries, the magnitudes have declined in the post 2005 period. However, the mean values of marginal benefits from BB penetration have increased for many industries in the post 2005 period. Top 5 among them are: bank, fund and security (30), health and social assistance (39), real estate (32), scientific & technical services (35) and other services (42).

At the aggregate economy level, they found that, the combined estimate of cost savings for a 1% increase in use of communications infrastructure capital together with a 1% increase in BB penetration rate is about 0.0216%. They also found that estimated net social rate of return (27%) from communication infrastructure investment is quite high and indicates the high potential spillover effect from communications infrastructure capital.

Impact on factor demands

NADIRI, NANDI & AKOZ (2015) also investigated the impact of communications infrastructure use on the demand for factors of production and on production structure. The use of communications infrastructure capital can influence the demand for primary inputs in two ways. The first effect is the substitution between infrastructure capital and other factors of production with a fixed level of output. It may increase or decrease the demand for other factors of production. The direction and magnitude of this effect depends on the substitution or complementarily between infrastructure and other inputs. The second effect is known as the 'output expansion effect' which is derived from cost savings effects of an increase in communications infrastructure. The net effect on factor demand depends on the combined effect of the above two effects. Based on their results, communications infrastructure service appears to be labor and material savings and capital using. Below is the detail discussion of the estimated impact on labor demand as that could be of interest for formatting policy decisions.

Communications infrastructure service appears to provide labor savings for all industries with variation across industries. The estimated substitution affects range from -0.31% to -1.65% with relatively higher negative impacts on labor demand for industries in the service sector. Industries are organized into 3 groups of equal size based on ranking of industries by the absolute magnitude of substitution effect. Industries in Group-1 are associated with relatively higher magnitude of substitution effect on labor demand (average effect is about -1.53%) and are primarily service industries. Group-2 industries are associated with moderate substitution effect on labor demand (average effect is about -1.36%) and consists of both manufacturing and service industries. In group-3 industries are associated with relatively lower substitution effect on labor demand (average effect is about -0.98%) and these are primarily manufacturing industries. When they estimated the output expansion effect of communications infrastructure, they found that for the sub-section of industries in each of the 3 groups, the positive output expansion effect exceeds negative substitution effect which depends on the strength of substitution effect and output growth rate of the specific industry. These sub-sections of industries primarily belong to the service sector with few exceptions [3] (KOLKO, 2011). The list of these industries is shown in Table 2.

For rest of the industries, negative substitution effect is stronger than positive output expansion effects and these industries experienced net loss of labor demand due to increase in the use of communications infrastructure service. By summarizing the results across all industries in the private sector (excluding the communications industry itself), NADIRI, NANDI & AKOZ found that an increase of 1% use of communications infrastructure service accounts for a 0.023% loss of demand for labor. All these results are summarized in Table 3.

[3] KOLKO'S analysis (2011) of zip code level data for U.S. found that employment effects tends to be stronger in industries where information technology service represents a large share of an industry's input.

Table 2 - Industries with net effect of communications infrastructure on labor demand is positive

Group	*Industry ID*	*Industry Name*
1	39	Health and Social Assistance
1	24	Retail trade
1	35	Technical Services
1	23	Wholesale trade
2	37	Administrative and waste management services
2	30	Bank, funds, Security
2	4	Construction
2	36	Management
2	25	Transportation and warehousing Services
3	21	Chemicals
3	32	Real estate
3	33	Rental and leasing services
3	3	Utilities

Table 3 - Net effects of communication infrastructure use on demand for labor

Group of Industries	*Type of Industries*	*Substitution Effects*	*Output Expansion Effect*	*Net*
Effect				
Group-1a	Primarily Service (*)	-0.01493	0.01502	0.00008
Group-1b	Primarily Service (**)	-0.01551	0.01503	-0.00048
Group-2a	Manufacturing & Service (*)	-0.01407	0.01414	0.00007
Group-2b	Manufacturing & Service (**)	-0.01359	0.01319	-0.00039
Group-3a	Primarily Manufacturing(*)	-0.00713	0.00743	0.00030
Group-3b	Primarily Manufacturing (**)	-0.01100	0.01063	-0.00037
Total		**-0.01299**	**0.01275**	**-0.00023**

(*) Expansion effect > Substitution effect, (**) Expansion effect <Substitution effect

Thus, analysis shows that except for a few growing service industries, negative substitution effects of communication infrastructure service exceed the positive output expansion effects derived from productivity gains and thereby generate net savings of labor costs by reducing the net demand for labor in the private sector (which excludes communication industry). [4] Many other researchers (KOLKO, 2011; WIECK & MIGUEL, 2010; SUMMERS, 2013) expressed their concerns about such net negative effect or zero effect of modern communication infrastructure use on labor demand. Possible

4 Communication industry cost function is not estimated to avoid the endogeneity issue.

solutions to avoid such net negative effect on labor demand [5] could be to adopt appropriate policies to encourage the production and output growth of existing industries, growth of new industries which deploy more labor intensive technologies in production, and to upgrade the skills of the labor force to be compatible with evolving technologies. [6]

Conclusion

Available empirical evidence strongly supports the view that, in the modern era, Information and Communication Technology (ICT) is an important source of economic growth and higher productivity. Reviewing previous studies and findings from our own study, we identify the various channels through which ICT can impact the economy and the best way to measure such impacts. The primary contribution of our own research is to identify the roles of ICT as industry specific capital and accumulated ICT capital as national ICT infrastructure in the production process. Recognition of this infrastructure role in the production process allows us to capture the network externality effects of ICT on productivity. In our recent study, we also examined the impact of modern communications infrastructure with its BB feature on productivity of U.S. industries and analyzed the influence of the communications infrastructure service on input demands and on the structure of production. This aspect is not discussed much in the existing literature. However, it can be a very important issue for understanding the impact of ICT on labor market and on capital market behaviors.

All these findings may provide new policy insights in order to exploit further the potential of the communication technology for growth and changing production structure in various industries and the economies. They may also help in formulating policies to address possible consequences with changes in factor market behavior such as employment level and capital formation.

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5 SUMMER (2013) explained that due to changing innovation of today's technology and more specifically innovation in ICT, capital can be put to one of the two uses in production: one is conventional use where capital complements labor and another use is to substitute labor.

6 Based on our model parameters, about 1% additional boost in overall growth in output will absorb all the surplus labor created by ICT infrastructure service.

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