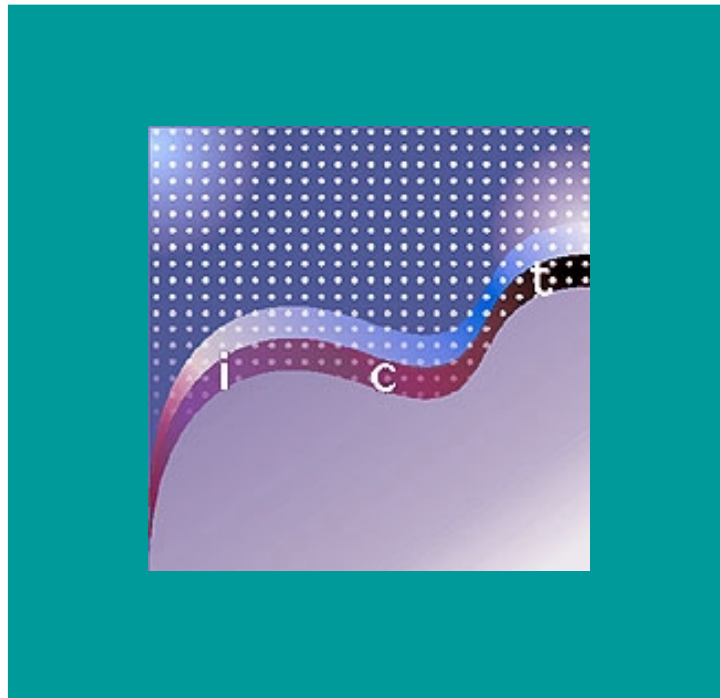


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Chapter 2: ICT, the Internet and economic performance:
Implications for developing countries



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Chapter 2

ICT, THE INTERNET AND ECONOMIC PERFORMANCE: IMPLICATIONS FOR DEVELOPING COUNTRIES

A. The emergence of the information economy

The recent performance of a number of economies, most notably that of the United States, has been fairly strong. In the late 1990s, these economies were able to grow faster than at any time since before the first energy oil crisis in 1973, while keeping inflation at historically low levels. This combination of strong economic growth and low inflation has been linked to the diffusion of new information and communication technologies (ICT), especially the Internet. The productivity gains that ICT have generated in the production and distribution of goods and services, as well as organizational improvements in the corporate and public sectors, have been identified as the mechanisms through which ICT and the Internet have delivered their macroeconomic benefits.

The emergence of ICT and the Internet as drivers of economic activity has increased the demand for knowledge workers, channelled more venture capital for start-up formation into this sector, and accelerated technological innovation. As a consequence, a growing share of enterprises' assets is embodied in various forms of knowledge. This array of macro- and microeconomic changes, by virtue of which information, knowledge and the networks through which they are communicated and exchanged become a major factor of economic performance, has led many observers to coin terms such as "new economy", "information economy," "knowledge economy" and "network economy."

However, the sharp decline in international stock markets that started in March 2000, and the economic slowdown that followed it, prompted questions about the long-term benefits of ICT and the Internet. The fall in stock prices temporarily reduced the level of venture capital and other investment capital available for ICT infrastructure and may have resulted in levels of investment in ICT and the Internet that are lower

than optimal from the point of view of society as a whole.¹

It is also likely that government intervention in the innovation market has made possible the generation of ICT-related externalities that have contributed to the economic performance of the United States and other developed countries. The need for public support for private-sector innovation is related to possible market imperfections that may result in investment levels in innovation that are suboptimal from a social perspective. An example of such a market failure is the extreme difficulty encountered by small high-technology firms when they attempt to raise financial capital to invest in innovation. That is a primary reason why many governments subsidize research and development (R&D) investment by small and medium-sized enterprises (SMEs) (Siegel, Waldman and Link 2003). Policy intervention to address innovation market failures includes support for the venture capital industry and targeted government investment in SMEs. It also includes the adoption of new standards, financial and regulatory support for cooperative or collaborative R&D, subsidies and tax breaks for R&D (Martin and Scott 2000) and public-private technology partnerships. As is noted in Martin and Scott (2000), another instrument for addressing innovation market failures is the public-private technology partnership, which can assume various forms, such as government subsidies for projects funded by private firms, shared use of expertise and laboratory facilities, university technology incubators, science parks, licensing agreements between universities and firms, and university-based start-ups. Some preliminary evidence (Siegel, Waldman and Link 2003) suggests that the adoption of targeted technology programs has led over time to a reduction in the magnitudes of market failures in developed countries.

Although many policy makers, corporate executives, and producers and users of ICT remain optimistic

about the long-term economic impact of ICT and the Internet, a detailed, sober analysis of this question is essential. A comprehensive review of recent research on this topic is of special interest to developing countries for two reasons. First, these countries have not yet fully reaped the benefits of ICT and are still developing policies and strategies to promote its adoption (an issue discussed at greater length in Chapter 3 of this report). Second, they have fewer resources to devote to these activities and therefore cannot afford as large “margins for error” as developed countries. An objective assessment and resolution of the debate on this subject would have important policy implications, since it could allow developing countries to formulate and implement optimal ICT and e-business strategies, which contribute towards the implementation of the United Nations Millennium Development Goals.

This chapter reviews the literature on the relationship between ICT, the Internet and productivity growth at the firm, industry, and national levels. As much evidence as possible is presented concerning the impact on the industries and firms of developing countries, although the availability of this kind of data is limited. The chapter also examines international evidence of the phenomenon of skill-biased technological change (SBTC) and the organizational dynamics of e-business diffusion in traditional sectors of the economy. It concludes with a summary of the key findings of the literature review and offers recommendations to government policy makers seeking to use ICT and e-business as an instrument to support economic growth.

B. The productivity debate

1. The aggregate impact of ICT

The question of whether the Internet will have an overall impact on the economy comparable to that of the great technological changes of the past has attracted considerable attention in recent years. This is understandable given that between 1987 and 2001 the quality-adjusted price of computing declined by more than 95 per cent, encouraging an extremely fast diffusion of these technologies: in the year 2000, 40 per cent of all US business investment was going to ICT. Such intense investment could be expected to have some effect on business performance. Such effects are not, however, always easy to discern, motivating a desire to assess the validity of the “productivity paradox” (Solow 1987).² At the same time a number of studies, such as Liebowitz (2003), have

highlighted the limits of the Internet’s impact on economic performance, especially in the business-to-consumer (B2C) sector.

The literature analysing the relationship between ICT and economic performance has expanded considerably in recent years. Studies have tended to examine the impact of ICT on productivity growth, but some researchers have also looked into issues such as firm profitability and stock prices. Empirical studies have been conducted at all levels of aggregation (i.e. at the establishment, firm, industry and national levels). Many papers present econometric estimates of a simple Cobb-Douglas production function, with an additional input representing investment in ICT capital, as opposed to conventional physical capital (structures and equipment). Other authors (e.g. Lichtenberg 1995 and Brynjolfsson and Hitt 1996) have derived estimates of ICT labour input (typically the number of employees classified as information systems workers).

Many of those research efforts show a positive correlation between Internet and ICT use and productivity growth. Also, much of the recent firm-level evidence suggests that ICT can generate “excess” returns, and there is also some evidence that these private, or firm-level, returns have increased in recent years. This is important because previously there was a lack of consensus regarding empirical results, at least in some of the early studies (Sichel 1997; Berndt, Morrison and Rosenblum 1992; Parsons, Gottlieb and Denny 1993). Using industry-level data, Morrison (1997) also reported that ICT capital had only a very small impact on technical progress.

The tide appears to have changed in the later studies, as most of the recent papers seem to find a strong relationship between ICT and improvements in economic performance. Stiroh (2001) and Jorgenson and Stiroh (2000) report good news regarding the aggregate impact of ICT investment in the United States. In contrast to their research in the early 1990s, Jorgenson, Ho and Stiroh (2002) conclude that the impact of ICT on aggregate economic performance has increased over time, especially in the late 1990s.

The key figures on sources of economic growth in the United States are presented in table 2.1. Based on a comprehensive analysis of ICT capital, the authors report that computer hardware, software and communications equipment accounted for a much larger fraction of economic growth in the last six years than in earlier periods. This may mean that there are substantial adjustment costs in implementing ICT and that policy makers should not expect dramatic

Table 2.1:
Sources of US economic growth, (1959-2001)

	1959-1973	1973-1995	1995-2001
Output growth of which including	4.18	2.78	4.07
Contribution of capital: including	1.77	1.40	2.03
Computers	0.07	0.20	0.49
Software	0.03	0.10	0.27
Communications capital	0.10	0.12	0.17
Other (non-computer) capital	1.57	0.98	1.10
Contribution of labour	1.24	1.12	1.12
Aggregate total factor productivity	1.16	0.26	0.92

Note: All values are average annual percentage growth rates. Input contributions are real growth rates, weighted by average nominal shares (following the convention in this literature).

Source: Jorgenson, Ho and Stiroh (2002).

improvements in productivity growth in the short run.

Dedrick, Gurbaxani and Kraemer (2003) present interesting findings on what they term the “dualistic” nature of ICT capital. The authors note that ICT capital, like other types of physical capital, can be used to generate more efficient production technology that allows organizations to increase labour productivity. This phenomenon is known as “capital deepening” (i.e. increasing capital input per worker). However, the authors note that ICT also plays a second role, which they consider more important – namely, its role in diminishing the cost of coordination of economic activities within and between organizations, and in improving business processes and organization. The authors present evidence suggesting that this coordination effect has a greater impact on productivity than the capital-deepening effect.

In a similar vein, Morrison and Siegel (1997) consider the possibility that conventional empirical studies of the connection between ICT and productivity actually underestimate the returns from ICT, because they fail to take account of externalities that arise from investment in ICT. The authors extend the simple Cobb-Douglas production framework by estimating a dynamic, flexible cost function (i.e. a generalized Leontief functional form) for US manufacturing industries, which takes account of adjustment costs

that might arise from ICT (and other capital) investment. Their paper is a general critique and extension of various new growth studies that use a simple production function approach to assess the impact of what the authors call “external factors” (investment in R&D, computers and human capital) on growth. More importantly, the authors report that increasing investment in ICT (and R&D) in a given industry enhances productivity in other industries (as well as that of their own suppliers and customers). These results fit the notion that ICT and the Internet constitute “general-purpose technologies” (Helpman 1998) that have wide applications and productivity-enhancing effects in numerous downstream sectors.

A recent study by the Organisation for Economic Co-operation and Development (OECD 2003) analysed the contribution of ICT to economic growth, as well as the impact of ICT-using and -producing sectors compared with that of non-ICT sectors on economic growth and labour productivity. The result was fairly conclusive evidence suggesting that investment in ICT made a significant contribution to economic growth in a number of countries (led by the United States, Canada, the Netherlands and Australia) and also had a substantial positive impact on economic performance in other OECD countries. As for productivity, ICT investment has supported labour productivity growth in several countries with strong growth performance (Australia, Canada and the

United States). In some of these countries, sectors in which ICT investment was particularly intense (e.g. distribution and financial services) have experienced faster multi-factor productivity growth. In other countries (Finland, Ireland and Korea), ICT production has made an important contribution to aggregate labour and multi-factor productivity growth. There seems to be evidence that at least part of this productivity improvement is structural, having survived the effects of the latest slowdown, particularly in those countries (e.g. Australia and the United States) where ICT are more widely diffused (OECD 2003).

A critical issue regarding the impact of ICT on the economy concerns whether ICT investments generate “increasing returns” and “network externalities”. Complementary to these notions is the concept of path dependence, according to which increasing returns and network externalities result in winner-take-all situations and monopoly outcomes for firms that capitalize on such first-mover advantages. There

is some controversy in the scholarly literature regarding the importance of path dependency and, more specifically, the question of whether the “best” technology (from a social standpoint) actually ends up being widely adopted. While some observe that allegedly inferior standards and technologies, such as the QWERTY typewriter standard, VHS and certain operating systems, have emerged victorious in the marketplace (David 2000), others dispute these assertions, noting that there is little empirical evidence in support of path dependency (Liebowitz and Margolis 1990; Liebowitz 2003).

The effects of ICT diffusion seem to differ significantly across developed economies. Thus, it appears that the contribution of ICT to productivity and output growth is smaller in many European countries than in the United States.³ This has happened despite a convergence in the rate of investment in ICT between the United States and the European Union (see table 2.2).

Table 2.2
Average Annual Percentage of GDP Devoted to ICT Spending (1993–2001)

Country	%	Country	%	Country	%	Country	
New Zealand	10.3	Colombia	7.0	Chile	5.5	Slovenia	3.7
Sweden	8.8	France	6.9	Slovakia	5.5	México	3.5
Australia	8.7	Czech Republic	6.8	Brazil	5.4	Turkey	3.3
Switzerland	8.4	Israel	6.6	Portugal	5.3	Bulgaria	3.1
Singapore	8.3	Belgium	6.5	Viet Nam	4.7	Philippines	3.1
United Kingdom	8.0	Finland	6.4	Italy	4.6	Thailand	3.1
United States	7.8	Germany	6.2	Taiwan Prov. of China	4.6	Russian Federation	2.9
Canada	7.7	Hungary	6.2	Greece	4.4	India	2.7
Netherlands	7.5	Norway	6.1	Spain	4.2	Egypt	2.2
Denmark	7.3	Ireland	5.8	Venezuela	3.9	Indonesia	2.1
Hong Kong (China)	7.2	Republic of Korea	5.8	Argentina	3.7	Gulf States	1.8
Japan	7.1	Malaysia	5.8	China	3.7	Romania	1.5
South Africa	7.1	Austria	5.6	Poland	3.7		

Source: Pohjola (2003).

Part of the apparent difference in productivity growth rates may result from differences in statistical methodologies.⁴ Another possible reason for the difference in ICT performance between the two regions is the presence of relative rigidities in markets, particularly the labour market, in many of these countries; according to this view, enterprises in the United States can more easily maximize efficiencies generated by ICT by adapting organizational structures and productive processes and re-deploying labour and other resources.

It is difficult to derive systematic evidence of a correlation between ICT use and economic performance in developing nations. However, anecdotal data and case study evidence are available, particularly in these countries' traditional export-oriented sectors. Some of these studies attempt to assess the impact of business-to-business (B2B) markets on export performance and competitiveness. These studies suggest that, while traditional export sectors use some ICT technologies extensively, they are not yet really connected to emerging e-marketplaces. At the same time, however, there is evidence of improved market access and rapidly increased exports by selected developing and transition economies. This is partly the result of business process outsourcing (BPO), including the relocation of back-office operations by transnational corporations (TNCs), a phenomenon discussed in more detail in Chapter 5. The implication is that there may be promising ICT-related niches in global markets for many developing countries possessing skilled labour and sufficient Internet bandwidth access.

2. Industry- and firm-level evidence

It is often more practicable and convincing to focus productivity analysis across several industries, or on particular sectors or firms. Because firms are smaller entities than national economies, the time needed for ICT policy to generate efficiency and productivity gains can be shorter, and it can be more easily measured by examining firms' accounting and financial data.

Carayannis, Alexander and Geraghty (2001) present some interesting examples of how the Internet has been used for B2B e-commerce in two traditional sectors of the economy, the petroleum and chemical industries. They demonstrate how e-commerce Internet technologies can be used as general-purpose technologies, resulting in dramatic improvements in quality and productivity in services. The first case study

describes an integrated system for facilitating B2B procurement transactions, or supplier-oriented e-commerce, used by BOC Gases, a British firm. The company uses e-commerce in warehousing, cargo handling, and distribution to process orders with suppliers and customers. The use of this system has generated substantial inventory-holding cost savings and has resulted in highly efficient processing of orders. BOC also utilized customer-oriented B2B e-commerce for market makers in the chemicals industry. The authors also describe how Boeing uses the Internet and e-commerce to ensure that production lines correlate closely with fluctuations in product demand. Other examples provided in the paper include Wal-Mart's use of electronic data interchange (EDI) with its suppliers and the formation by four chemical firms (Ethyl, Eastman, Chemical and Sunoco) of a "B4B" mechanism for standardized exchange of industry data. The latter is an example of the establishment of technological infrastructure for B2B trading.

Examples of the economic payoff from the Internet abound in a recent Brookings volume edited by Robert Litan and Alice Rivlin (Brookings 2001). The editors commissioned studies of the Internet's impact on productivity growth in eight sectors of the US economy. These industries, which account for more than 70 per cent of gross domestic product (GDP), are manufacturing, automobiles, financial services, trucking, retail services, health care, higher education and the public sector. The productivity improvements come from savings on transactions costs, more efficient management, enhanced efficiency of markets, and other economic benefits, including additional product variety and consumer choice, improvements in health care outcomes, and greater convenience, among others. The general conclusion of this study is that the Internet by itself might add roughly 0.25 to 0.5 per cent a year to US productivity growth during the next five years.

In Brookings (2001), McAfee, looking at the manufacturing sector, presents an interesting case study of Cisco Systems, which is not only the world's leading producer of routers and other Internet networking equipment but a leading user of the Internet in organizing its manufacturing through outsourcing. Cisco estimates that intensive use of the Internet as a management tool over a 4,5-year period enabled it to save \$650 million in 1995–99, which represents 5 per cent of its revenue in 1999. According to McAfee, many manufacturing firms have tried to emulate Cisco's success by forming "virtual supply chains", B2B exchanges that can generate substantial cost savings. This is especially true in manufacturing, where inter-

mediate goods and materials typically constitute more than half of total cost.

According to Fine and Raff (Brookings 2001), the largest Internet-related productivity gains in the automotive sector resulted from significant improvements in supply chain management. They conclude that the clear winner in using ICT and the Internet was Daimler-Benz, which developed an Extended Enterprise approach and even trademarked it. This model constitutes a dramatic change in the way the firm manages its relationships with suppliers. Daimler-Benz committed to long-term relationships with suppliers to develop complete subsystems and to share any ICT-related cost savings with them. Thus, the Internet was facilitating the implementation of a corporate strategy of “quasi-vertical integration”, a tactic commonly used by Japanese firms. The company made heavy use of ICT and the Internet to implement this strategy, which turned out to be highly profitable. The Dell model (where consumers specify the parameters of ordered PCs) would not work with automobiles owing to the higher complexity of automobile production lines and relations with subcontractors.

In financial services, Clemons and Hitt (Brookings 2001) assert that productivity gains stem from transparency, pricing and disintermediation. They define transparency as the ability of consumers and corporate customers to assess the full range of prices and qualities of the various financial instruments and services offered. The authors discuss three insurance companies that provide price comparison services: Insuremarket, Quotesmith and eHealthInsurance.com. Differential pricing allows firms to treat customers differently based on the revenue they yield, or (in the case of insurance) on the amount of risk to the firm, while disintermediation refers to the ability to reduce the need for brokers or agents. Similar tactics have been widely adopted in the airline industry (e.g. in “yield management” pricing strategies) and, increasingly, in financial services. The authors estimate the annual cost savings from productivity improvements at approximately \$18 billion in the financial services sector alone.

Nagarajan et al. (Brookings 2001) present some useful case studies from the trucking industry. ABF Freight Systems has set up “transparent direct links,” which allow customers to use data from ABF’s Web site on their own sites. Other Internet-related innovations include programs to streamline efficiency in routing and shipments. These projects have been extremely useful for customers, especially those using just-in-

time (JIT) inventory management systems. In another example, Transplace.com is a start-up formed as an alliance among six of the largest publicly traded firms in the industry. Its corporate strategy is to exploit Web-based opportunities to enhance economic performance, including improvements in the efficiency of logistics and purchasing and load matching, in order to reach optimal levels of capacity utilization.⁵

Fountain and Osorio-Urzuá (Brookings 2001) find substantial cost savings arising from e-government initiatives, which appear to depend strongly on the extent to which Internet use is pervasive in the relevant community. This has important implications for developing countries, where the rate of Internet use among the populace and firms is quite low. Positive productivity effects stem from reductions in paperwork, fewer errors on the part of public employees, the elimination of redundancies (which can be considerable in the public sector) and improved customer service. Goolsbee (Brookings 2001) examines online higher education and other Internet-related initiatives in the educational sector and concludes that there is substantial potential cost savings to be derived from an industry that he characterizes as “massive, regulated, and bureaucratic”.

3. Considerations for developing countries

A number of sector- and firm-level discussions on ICT application in developing countries have appeared in response to the heated debate over whether Internet technologies can help communities, firms or even whole developing countries leapfrog into the digital age. While evidence is scarce, what does exist is somewhat encouraging.

Moodley (2002) conducted an in-depth quantitative and qualitative analysis of the use of B2B e-commerce by manufacturing firms in South Africa. The study is based on 120 firm-level interviews and 31 interviews with industry experts. The evidence indicates that the incidence of use is fairly low. Although 87 per cent of the firms had access to the Internet, only 49 per cent had a corporate site and only 22 per cent were using the Internet for order taking. The author concludes that e-commerce is not yet an important strategic objective for most South African firms. Moodley also hypothesizes that e-commerce is an evolutionary technology, not a revolutionary one, as some of its strongest advocates have asserted. He states that, according to his evidence, B2B e-commerce is in the

early stages of its evolution and is likely to follow path-dependent patterns.

Masten and Kandoole (2000) examine patterns of ICT investment in Malawi. They find that the Government has focused a great deal of attention on helping SMEs use ICT to increase employment and income. This may be because the country does not receive much foreign direct investment (FDI) by large, multinational firms. Malawi is an interesting country to study because the institutions involved in promoting ICT investment among small businesses have received at least some support either from developed countries (e.g. Germany, the United Kingdom and the United States) or from international organizations (e.g. the United Nations and the World Bank) or non-governmental organizations (e.g. World Learning and Women's Village Banking). The authors conclude that there is an extensive support system for companies implementing ICT in this country. Not surprisingly, they find an unusually high level of satisfaction with these services, and they suggest that resources have been used quite effectively. The result appears to be a small-business sector that is growing dynamically, especially given that Malawi is a very poor country, ranked 162 out of 175 nations in terms of economic well-being by the United Nations Development Programme (UNDP (2003).

Humphrey et al. (2003) examined the B2B e-commerce of firms in the horticultural and garment sectors of Bangladesh, Kenya and South Africa. The study was based on field interviews with 74 enterprises. An additional 37 interviews with industry experts, business associations, e-commerce solution providers and government officials were conducted across the three countries. The enterprise interviews were conducted with individuals in senior management positions who were well positioned to provide information on the scale and impact of ICT use to support B2B e-commerce. The authors' findings challenge the view that the mere low cost of information transfer makes B2B e-commerce a particularly advantageous proposition for firms from developing and transitional economies. They attribute this to a lack of awareness regarding the benefits of e-commerce, institutional and regulatory problems, and the current technological divide between the have and have-not nations. On a more positive note, the authors find that in some cases, B2B e-commerce can reduce the costs of making firms known to each other. However, many implementations of Internet applications do not offer packages of services such as payment and settlement mechanisms, insurance, logistic sys-

tems, inspection, certification of quality, and customs clearance. According to the authors, without low-cost access to such services, developing-country firms may find it prohibitively expensive to exploit new external markets.

C. The effects of ICT on wages and work environment

1. The impact of ICT on labour force composition

The ICT revolution has heightened a phenomenon known as "skill-biased technological change" (SBTC), where technological change results in a greater demand for highly skilled, highly educated labour, which leads to an increase in the relative wages of these workers and shifts in the composition of the workforce in favour of such workers.

Studies of SBTC are usually based on estimates of wage equations or cost functions, typically including dummy variables that serve as proxies for technological change. The cost function approach is desirable because it allows one to formally test for whether technical change is non-neutral (i.e. favours one factor of production over another). Under SBTC, the assumption is that technological change favours one class of workers (e.g. highly educated workers) at the expense of another class of workers.

A summary of some recent studies of the impact of ICT on wages and labour composition is presented in Annex II. Despite the fact that researchers have employed alternative methodologies and have analysed data from different countries at different levels of aggregation (individual, plant, firm, and industry levels), each study reports evidence that is consistent with the existence of SBTC. In other words, some proxy for technological change (R&D, computers, adoption of advanced manufacturing technologies) is positively correlated with wages and shifts in labour composition in favour of highly skilled or highly educated workers.

Two wage-based studies from the United States and the United Kingdom provide additional support for the existence of SBTC. Bartel and Sicherman (1999) analyse worker-level data from the National Longitudinal Survey matched to industry-level data. They find that there is a positive correlation between wages and proxies for technological change and that this

relationship is stronger for non-production (i.e. services-related and hence more ICT-intensive) workers than for production workers. Finally, their findings imply that the SBTC wage premium can be directly related to enhanced demand for workers with higher levels of education and skill in industries experiencing technological change. Haskel (1999) analyses industry-level data from the United Kingdom and reports a strong positive correlation between relative wages and investment in computers. He estimates that the wage premium for skill grew by 13 per cent in the United Kingdom in the 1980s and that computers account for about half of this increase. Moreover, computerization reduced the demand for manual workers (both skilled and unskilled ones).

An analysis of industry-level data from other countries yields similar patterns. Berman, Bound and Machin (1998) find that shifts in the employment structure in favour of highly educated workers are evident across many developed countries. The authors conclude that these wage and employment shifts can be linked to technological change. Also, the magnitudes of these linkages are quite similar across countries. Additional international evidence is provided by Park (1996), who reports a positive correlation between labour productivity growth and the proportion of multi-skilled workers in Korean manufacturing industries.

Siegel (1999) reports that implementation of a new technology leads to downsizing and a shift in labour force composition and compensation in favour of white-collar workers. More importantly, the empirical findings reveal that there is considerable heterogeneity in downsizing and skill upgrading across different types of technologies. Thus, the magnitude of the skill bias may depend on the type of technology that is implemented.

The existing evidence on SBTC bodes well for developing countries. Berman and Machin (2002) have recently assessed what they refer to as “skill-biased technology transfer” in 37 countries, including several developing nations. Their empirical results suggest that there is no SBTC in low-income countries. More importantly, they find evidence of “transfer” of skill-biased technologies from high-income to middle-income countries and regions, but not from high-income to low-income countries and regions.

The rising demand for skilled, educated labour in developed countries has also led to large wage increases in many high-technology sectors in middle-income countries and lower-income countries with

relatively developed ICT-related clusters or regions. This has resulted in an increase in the propensity of high-tech firms to engage in domestic and global outsourcing. Many major US companies have made significant investments in India in software and R&D to take advantage of considerably lower labour costs for engineers, computer scientists and software developers. Similar firms have also undertaken projects in China.

An interesting study was conducted by Lal (2002), who examined comprehensive data from 51 Indian firms on numerous aspects of performance and other firm characteristics, including data on ICT investment, wages, exports, imports, profits, and the extent to which firms adopt e-business methods. These companies were located in a newly developed industrial town near New Delhi called the New Okhla Industrial Development Area. The firms had access to two private-sector Internet service providers (ISPs) and two public-sector ISPs. The author estimated firm-level Tobin regressions of the determinants of export performance. The regressions included many control variables and a measure of the nature of the firm’s use of e-business methods. The three types of e-business technologies were email, URL, and portal. Lal concluded that firms that adopted more advanced e-business tools generated higher levels of exports. This finding on a key dimension of performance for companies for a cluster in India might be valuable for smaller developing countries, where domestic markets are often quite small. Thus, it appears that the adoption of sophisticated e-business technologies may improve economic performance. Another critical factor is that ICT labour costs are substantially lower in India than in developed countries. For instance, systems analysts were earning an average of \$48,000 a year in the United States and \$34,000 in the United Kingdom in 1995, while their counterparts in India were earning \$14,000.

ICT-induced changes in the labour market have also affected women’s employment, in particular in developing countries (UNCTAD 2002). For example, in services related to information technology (IT), employment for women has grown enormously. Today, women form a significant share of the workforce in the IT-enabled industry in developing countries, notably in Asia, but increasingly also in Africa and Latin America, where IT-related services are being created. Women usually predominate in services requiring rather routine, low-level skills or limited technical training. These include activities such as customer call centres, data entry and processing, transcription services, claims processing and remote sec-

retarial services. It is more difficult for women to move into the higher-skilled, better-paid jobs of the IT-related service sector, such as software development and programming or geographical information systems (GIS) analysis.

2. ICT and changes in work environment

Many economists who have studied SBTC ignore the role of organizational change in the implementation of new technologies. In recent decades, many manufacturing firms have adopted new ICT-based technologies, such as computer-aided design (CAD), computer-aided manufacturing (CAM), computer numerical control (CNC), and just-in-time (JIT) production systems. Implementation of these technologies can dramatically affect the work environment, since they may simultaneously result in downsizing (labour-saving innovations), retraining of the remaining workforce (skill upgrading), and changes in job responsibilities resulting from integration across the functional areas of business (marketing, manufacturing, R&D, accounting/finance, logistics, purchasing and product design).

Some recent studies have examined the relationship between technical and organizational change. They have found that ICT investment is often accompanied by substantial changes in the work environment. For example, Siegel, Waldman and Youngdahl (1997) analysed the effects of the adoption of advanced manufacturing technologies on human resource management practices, including proxies for employee empowerment, such as training, changes in job responsibilities, new career opportunities and enhanced employee control. They report a strong positive correlation between the implementation of certain types of technologies and greater employee empowerment.

In a similar vein, Bresnahan, Brynjolfsson and Hitt (2002) present evidence of the connection among technological change, organizational change and organizational performance. The authors study the effects of declining ICT prices, increased use of ICT and a rise in the relative demand for highly educated workers. They conjecture that, in order to implement new technologies successfully, companies need to decentralize decision making and adopt other "high-performance" workplace practices. Such practices include increased reliance on worker teams and quality circles, where employees can decide on the pace and method of work that will achieve the best results.

To test these theories, the authors estimate three variants of a regression model with ICT demand, human capital investment, and value added as dependent variables. They report that proxies for workplace organization and human capital are strong determinants of the demand for ICT capital, but not other types of capital. This finding is consistent with the argument that there is complementarity among ICT, organizational change and human capital. Similarly, firms with higher levels of investment in human capital, as measured by a greater emphasis on selection, appraisal, and training of employees, tend to have higher levels of ICT investment and more decentralized work organization.

To examine complementarities in a production or cost function framework, it has been assumed that there are adjustment costs associated with implementing complementary strategies (Caroli and Van Reenen 2002). Adjustment costs are relevant because, while firms may find it easy to acquire and install ICT equipment, they may have great difficulty implementing the required complementary organizational changes to achieve a fit among all their organizational architecture components. Thus, adjustment costs lead to variation across firms in the use of ICT, its organizational complements, and the resulting product mix. Bresnahan, Brynjolfsson and Hitt (2002) provide evidence of the effects of ICT on the work environment, based on a survey of managers. They report that ICT use is positively correlated with enhanced worker autonomy, management's need and ability to monitor workers, and the firm's desire to increase investment in human capital.

Finally, Danzon and Furukawa (Brookings 2001) examine Internet initiatives in health care and pharmaceuticals. They disaggregate these efforts into those relating to connectivity, content, commerce and care. The authors assert that optimal connectivity would enable providers, payers and patients to have seamless access to information, which would greatly reduce the demand for clerical labour, improve customer service and, most importantly, enable physicians to spend additional time with patients. They also focus a great deal of attention on the use of Internet to allow physicians to manage their practices more effectively. With respect to information content, the authors identify physician and consumer information portals. These portals allow doctors to easily follow the latest developments in their fields, and they enable patients to access better information. The authors' discussion of commerce highlights the significant savings that B2B e-commerce can produce in supply chain management.

Several key stylised facts have emerged from the literature on the relationship between technological change and organizational change in developed countries. Brynjolfsson and Hitt (2000) report that ICT use is associated with a cluster of complementary organizational practices. These include a transition from mass production to flexible manufacturing technologies, changing interaction with suppliers and customers (mostly resulting in closer relationships with customers and suppliers), decentralized decision making and other organizational transformations, greater ease of coordination, and enhanced communication. These complementary technological and organizational changes enhance the market value of firms.

Thus, it seems that the way ICT is being used is changing organizational structure, design and control systems. For instance, researchers have reported that back-office jobs are being replaced, while the importance of front-office skills and managerial leadership has increased. Networks of PCs are changing the way people work and the way they are compensated, in the sense that rewards for multi-tasking are increasing and employers seem to prefer employees with broad-based education and conceptual and problem-solving skills, which are valued more and more by companies in developed countries. The OECD (2003) stresses that investment in and use of ICT have a great impact on firms provided that they are accompanied by other changes and investments, including expenditures on employee training and organizational changes. Those complementary investments might considerably increase the positive correlation between ICT and productivity.

One result of this is that more and more people are returning to school, largely owing to technological change and concomitant organizational changes that raise the value of knowledge workers to firms and other organizations. Despite the fairly substantial increase in the number of returning students, the demand for ICT-literate workers continues to outstrip supply, which explains part of the wage premium economists have observed for these workers. This also explains why numerous multinational companies have begun outsourcing jobs requiring high-skilled labour in developing countries, as in the case of software programming in India. Morrison and Siegel (2001) report evidence consistent with this assertion, finding a positive correlation between ICT investment and the propensity of US manufacturing firms to engage in foreign and domestic outsourcing of mostly business services. (For a more detailed discussion of outsourcing, see Chapter 5 of this report.)

D. Conclusion

The findings of the research on ICT and economic performance reviewed in this chapter are remarkably robust in the sense that the majority of researchers have found a positive correlation between some proxy for ICT investment and some proxy for economic performance at each level of aggregation (plant, firm, industry and national economy). Furthermore, there is evidence suggesting that complementary investments in ICT-related labour and organizational factors that provide a supportive work environment for maximizing the returns on ICT investment also contribute to improvements in productivity growth. The evidence seems to indicate fairly clearly that the dissemination of this general-purpose technology will have a sustained, long-lasting impact on productivity and economic growth, provided that policy makers implement policies that facilitate a faster rate of diffusion and better allocation of resources.

Although several sections of this chapter are based on ICT- and Internet-related data and analysis derived from developed economies, the evidence provides important lessons for developing countries. First, developing countries should not lose sight of the big picture regarding the payoff from investment in technology. These nations should focus on implementing technology policies that foster long-term economic growth. Furthermore, policy makers should not misinterpret the recent financial boom and bust in financial markets (which is reversing itself as this chapter is being written) as indicating a decline in the social rate of return on investment in ICT and the Internet. Even in the developed world, where organizations encounter substantially more favourable institutional conditions and better technological and physical infrastructure, it has taken several decades for the benefits associated with ICT investment to result in substantial improvements in economic growth.

The policy areas that e-strategies for development must contemplate in order to generate an environment in which ICT can realize their full potential include problems of awareness, infrastructure and access, regulation, skill building and local content creation, among others. They are the subject of Chapter 3 of this report. However, some elements related to the impact of ICT on productivity can be highlighted here. These refer to key deficiencies that policy makers in developing countries must address in order to stimulate higher social returns on investment in ICT.

The first deficiency concerns a lack of knowledge of best practice in the use of ICT. Thus, governments should foster improved understanding by local firms of the best methods of using ICT in their respective sectors, so that optimal choices can be made regarding the most efficient uses of these technologies. Governments should also support the adoption of best e-commerce and e-business practices by themselves adopting these technologies, particularly in areas such as procurement. In so doing they will not only be generating economy-wide effects on productivity but will also obtain direct benefits in terms of fiscal savings and improved government transparency and accountability.

Another problem governments should address is the danger of under-investment in ICT-related technology. Policies promoting and supporting infrastructure development can help provide greater access to low-cost, high-bandwidth Internet connections. Governments can institute policies supporting the development and use of appropriate software, including open-source software (see Chapter 4). Also needed are policies and legislative action to improve the security of electronic transactions and enhance consumers' confidence in these transactions. Currently, players from many developing countries are sometimes reluctant to share information online, which is a major barrier to the successful adoption of B2B and B2C e-commerce.

The public sector should also play a leading role in addressing another major obstacle: ICT-related skill deficiencies in the workforce. This can be achieved in several ways. One approach is to provide training and skills development, or at least encourage state-run educational institutions to shift their priorities accordingly. Another avenue is to provide firms with incentives (through tax policy or subsidies) to engage in such training themselves.

If, as seems possible, the magnitude of the market failures leading to sub-optimal levels of investment in ICT is sufficiently large, then the public sector in an individual country may be unable to effectively overcome them. This is especially true for the smaller developing nations. A wide range of collaborative arrangements can be used to address these market failures, including public-private partnerships, alliances and consortia. These partnerships would be useful for:

- providing better access to financial capital to stimulate investment in ICT;
- enhancing the development of human capital to facilitate implementation of the new technologies;

- stimulating the development and extension of networks that increase the private (firm-level) and social returns on ICT and e-business; and
- allaying concerns regarding sharing proprietary information.

National governments, the private sector, society at large, and especially the R&D community in developing countries must realize that ICT cannot be treated as a homogenous phenomenon. There is considerable heterogeneity in the challenges and policy issues associated with each type of ICT investment. Still, the empirical evidence suggests that the potential for investment in ICT to generate substantial productivity gains may actually be greater for firms in developing countries than those in developed ones. Still, the vast potential of ICT cannot be exploited without considerable attention being devoted to understanding sector-specific characteristics relating to market structure (e.g. the extent of consolidation in the industry), the state of the supply chain, and resources available to firms to support their businesses. UNCTAD's E-Commerce and Development Report has on several occasions addressed sector and industry specificities and possible ICT policies and strategies (2001, 2002).⁶

In developing countries, these characteristics are likely to be different than in developed countries, even within the same industry. Developing countries, having relatively weak risk management systems in place and fewer resources to invest, cannot afford to waste their limited technical, financial and human resources on yet more dot-com hype. They must make prudent decisions regarding ICT-related investment while targeting their niches in the information economy.

In the long run, ICT and the Internet will generate high social returns to countries that invest in these technologies and use them wisely. The pace of technological progress in ICT goods and services shows no signs of slowing. As a result, these products are becoming more affordable to businesses and households in countries with lower per-capita income. Hence, existing cost barriers to acquisition of the new technology in these nations are diminishing. The bottom line is that there exists a critical opportunity for developing countries striving to improve their global competitiveness and enhance economic growth through ICT-related investment. Thus, it is incumbent on policy makers in these countries to ensure that domestic firms encounter a conducive environment and sufficient incentives to join the information economy at all levels, and hence improve their export competitiveness.

Given the strong connection between technological investment and economic growth, it is conceivable that developing countries could achieve higher growth rates through optimal investment in ICT and Internet-related technologies. In this regard, the evidence from the surveyed research, the majority of which was conducted in a developed-country context, could also be used by policy makers in developing nations as they implement more active ICT and e-business-related strategies. Policy makers should, however, keep in mind that the experience of developed countries in North America, Europe and Asia, as well as of some leading adopters among developing countries, illustrates the trade-offs that governments

face in the area of ICT, as a consequence of differences in the environment (physical, political and legal), the sources of comparative advantage of their respective economies and the predominant conceptions about the role of the state in the economy and in society as a whole. In other words, they should be aware that there is no model path that all countries should follow in their progress towards an information society. As they mainstream ICT into their national development strategies, developing countries should endeavour to reflect their society's own economic, social, cultural and political preferences and priorities.

Notes

1. At the height of the dot-com revolution, the perceived optimal level of investment in R&D was considered by some researchers to be at least four times larger than the actual R&D investment. See Jones and Williams (1998).
2. The controversy surrounding the role of ICT in productivity enhancement stems largely from Nobel Prize winner Robert Solow's famous quip in 1987 that one "can see the computer everywhere except in the productivity statistics" (Solow 1987).
3. See, for example, Daveri (2002).
4. See Lequiller (2001).
5. Load matching refers to a firm's ability to match shipments with trucks having excess capacity, a major problem in this highly fragmented industry.
6. UNCTAD has analysed the development of e-commerce in the tourism, logistics, banking, insurance and publishing industries, as well as agriculture and e-government.

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Annex I

Recent Empirical Studies of the Impact of ICT on Economic Performance

Author(s)	Methodology	Country/Sector	Level of aggregation	Results
Dunne, Foster, Haltiwanger and Troske (2000)	Regressions of labour productivity on computers	United States/ Manufacturing	Plant level	Positive association btw. computers and labour productivity, which appears to be growing over time
McGuckin and Stiroh (1999)	Cobb-Douglas production function with computer capital	United States/ Manufacturing and service	Aggregate, major sector and 2-digit SICa industry levels	Evidence of excess returns on computer capital at each level of aggregation
Lehr and Lichtenberg (1999)	Cobb-Douglas production function with computer capital and labour	United States/ Manufacturing and service	Firm level	Excess returns on computer capital, especially PCs; returns on computers appear to have peaked in 1986 or 1987
Wolff (1999)	Regressions of non-parametric measures of total factor productivity growth	United States/ Manufacturing and service	Industry level (85 sectors)	No evidence of positive relationship btw. computers and productivity growth; weak evidence of positive association in goods industries during 1977–87
Licht and Moch (1999)	Cobb-Douglas production function including 3 types of computers (terminals, UNIX workstations and PCs)	Germany/ Manufacturing and service	Firm level	Strong positive relationship btw. PCs and productivity in manufacturing and services
Gera, Wu and Lee (1999)	Cobb-Douglas production function with computer capital	United States and Canada/ Manufacturing	Industry level	Positive correlation btw. investment in computers and labour productivity growth
Bharadwaj, Bharadwaj and Kronsynski (1999)	Regressions of Tobin's q on measures of investment in IT	United States/ Manufacturing and service	Firm level	Positive association btw. investments in IT and Tobin's q
McGuckin, Streitwieser and Doms (1998)	Regressions of labour productivity on dummies denoting whether plant uses computer-based manufacturing technology	United States/ Manufacturing and service	Plant level	Plants using advanced computer-based technologies have higher productivity levels; weaker evidence on relationship btw. technology use and productivity growth
Lehr and Lichtenberg (1998)	Cobb-Douglas production function with computer capital and labour	United States/ Public sector	Organizational level (government agencies)	Excess returns on computer capital
Stiroh (1998)	Sectoral growth accounting methods and regression analysis based on Cobb-Douglas production function	United States/ Manufacturing and service	2-digit SIC industry level	Computer-producing sector (SIC 35) has made a strong contribution to economic growth; computer-using sectors have not made a similar contribution. No evidence of positive relationship btw. computers and total factor productivity growth at the sectoral level.
Siegel (1997)	Latent variables model: regressions of parametric and non-parametric measures of total factor productivity growth on rate of investment in computers	United States/ Manufacturing 4-digit SIC	Industry level	When controls are included in the model for measurement errors, computers have statistically significant positive impact on productivity
Morrison and Siegel (1997)	Dynamic cost function estimation with high-tech capital	United States/ Manufacturing	4-digit SIC industry level	"External" investments in computers by related industries (4-digit industries within a 2-digit sector) enhance productivity

Annex I (continued)

Author(s)	Methodology	Country/Sector	Level of aggregation	Results
Greenan and Mairesse (1996)	Cobb-Douglas production function with computer capital	France/ Manufacturing and service	Firm level	Impact of computers is positive and at least as large as for other types of capital. Returns appear to be higher in services than in manufacturing
Brynjolfsson and Hitt (1996)	Cobb-Douglas production function with computer capital and labour	United States/ Manufacturing and service	Firm level	Excess returns on computer capital and labour
Lichtenberg (1995)	Cobb-Douglas production function with computer capital and labour	United States/ Manufacturing and service	Firm level	Excess returns on computer capital and labour
Oliner and Sichel (1994)	Growth accounting methods to estimate the contribution of computers to economic growth	United States	Aggregate level	Under standard neoclassical assumptions, computers account for only a small percentage (0.15%) of average annual economic growth
Jorgenson and Stiroh (2000)	Sectoral growth accounting methods	United States	Aggregate level	Growth contribution of computers increased substantially in mid- to late 1990s
Parsons, Gottlieb and Denny (1993)	Estimation of a translog cost function with computer capital	Canada/ Service	Industry level	Very low returns on investments in computers for banks
Loveman (1994)	Estimation of a Cobb-Douglas production function	United States/ Manufacturing and service	Business unit level	Output elasticity estimates for computers insignificantly different from zero (imarginal product of computers is 0)
Siegel and Griliches (1992)	Correlation btw. non-parametric measures of total factor productivity and rate of investment in computers	United States/ Manufacturing	4-digit SIC industry level	Positive correlation btw. rate of investment in computers and total factor productivity growth

Positive correlation btw. rate of investment in computers and total factor productivity growth

^a Standard international classification.

Source: Link and Siegel (2003), pp. 93–95.

Annex II

Recent Empirical Studies of the Impact of ICT on Wages and Labour Composition

Author(s)	Methodology	Country	Level of aggregation	Indicators of technical change	Measures of labour input	Results
Bartel and Sicherman (1999)	Estimation of wage equations	United States	Worker data (NLSY) b matched to industry-level data	Expenditures on computers, R&D	Non-production and production workers	Positive correlation btw. wages and proxies for technical change, which is stronger for non-production workers than for production workers; wage premium attributed to greater demand for ability in industries experiencing technological change
Haskel (1999)	Regressions of changes in relative wages of workers on computers	United Kingdom	3-digit SICa industry level	Dummy variable denoting whether a plant introduced new equipment using microchip technology	Skilled and unskilled workers	Positive correlation between relative wages and computers; wage premium for skill rose 13% in 1980s in UK; computers account for about half of this increase
Morrison and Siegel (2001)	Dynamic cost function estimation with high-tech capital	United States	4-digit SIC industry level	Computer capital and R&D	Four types of workers, classified by level of education	Computers and R&D reduce demand for workers without college degree and increase demand for workers with at least some college. Trade has a strong indirect impact on demand for less educated workers, because it stimulates additional investment in computers
Berman, Bound and Machin (1998)	Cross-country correlations of within-industry changes in proportion of non-production workers	9 OECD countries	2 and 3-digit SIC industries	Expenditures on computers, R&D	Employment and wage shares for production and non-production workers	Positive correlation across 9 OECD countries in within-industry changes in shares of non-production workers
DiNardo and Pischke (1997)	Estimation of wage equations	Germany	Worker data (NLSY) b matched to industry-level data	Dummies for whether a worker sits down, uses a telephone, calculator, pen and pencil	Detailed data on workers: age, sex, race, union status, region	Workers who use a computer earn a wage premium, but so do those who sit down while they work or use a calculator, telephone, pen and pencil
Park (1996)	Regressions of changes in relative wages of skilled and unskilled workers on computers	Korea	2-digit SIC industry level	Growth in labour productivity	All workers, excluding unskilled	Positive correlation btw. labour productivity growth and proportion of multiskilled workers in Korean manufacturing
Entorf and Kramarz (1998)	Estimation of wage equations	France	Data on workers and firms that employ them	Firm-level data on use of 3 computer-based technologies	Occupational mix: unskilled and skilled blue-collar, clerks, managers, engineers, professionals	Positive correlation btw. technology use and wages; highest wage premiums earned by those with lowest skill level

Annex II (continued)

Author(s)	Methodology	Country	Level of aggregation	Indicators of technical change	Measures of labour input	Results
Regev (1998)	Estimation of production function	Israel	Firm level	Technology Index based on quality of labour and capital and R&D investment	No decomposition of labour	Technology intensive firms pay higher average wages, generated new jobs during a period of downsizing

^a Standard international classification.

^b National Longitudinal Survey of Youth
Source: Link and Siegel (2003), pp. 82–87.

Annex III

Examples of Innovative ICT Initiatives in Developing Countries

Country	Description of initiative
Chile	Developed a successful software industry through a public-private partnership involving firms, universities and government
Egypt	Initiated several useful IT applications in employment and e-government and established a regional information technology development centre
Gambia	Developed an effective telecommunications infrastructure with several applications
India	Developed its own satellites to establish information and communication systems that reach rural areas
Singapore	Use of EDI at harbour, which is now ranked among world's best in IT use
Tunisia	Established a regional information technology development centre

Source: Udo and Edoho (2000).