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Information Technology and Economic Development:

An Introduction to the Research Issues

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M. P.
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ABSTRACT

There is substantial evidence that new information technologies are in many ways transforming the operations of modern economies. More than half of employees use a computer at work in the most advanced industrial countries. About 10 per cent of the value of all private investment in fixed non-residential capital is devoted to computers and peripheral equipment in the United States and some other economies. This share goes up to 25 per cent when investment in information processing equipment is included. Nevertheless, all spending on information technology, including hardware, software and services, does not amount to more than 3-4 per cent of nominal GDP in these countries. The share is, however, increasing rapidly, indicating that a steady state has not yet been reached.

Developing countries spend much less on information technology. The stark contrast in the penetration of information and communication equipment between the industrial and developing world is best summarized by the fact that more than half of humanity has never made a telephone call. The sharp decline in the price of computing and communication—about 20 per cent a year in the case of computers—is, however, bringing this technology within the reach of many, if not yet all, developing countries. The question about the costs and benefits arises naturally.

Even in industrial countries, the impact of information technology has not been as deep or pervasive as the debate about the benefits of the global information society sometimes makes it appear. The literature review on the US experience shows that there is neither a 'productivity paradox' nor a substantial 'information payoff' associated with investment in computers or other forms of IT, but they seem to be 'pulling their weight'. This may, however, be a characteristic feature of the US economy in its present stage of development. Modern business information systems are being developed for the needs of large corporations in industrial countries. More research on other countries, developed and developing, is needed before firm policy conclusions can be drawn for economic development. This research should explore the role of information technology both as an intermediate input in production and as a final good in consumption. This paper prepares ground for such work.

1. INTRODUCTION

The average incomes in the world's richest countries are more than twenty times higher than those in the world's poorest countries. It is evident that such differences in the standard of living lead to large differences in the quality of life and human welfare. About a third of the people of developing countries live in severe poverty as measured by both poverty of incomes and by poverty of basic life choices and opportunities (UNDP 1997a).

It is less apparent what the underlying reasons for such large differences are. What is it that the rich countries have but the poor countries lack? The importance of both physical capital and human capital to economic development is well understood by economists and policy-makers alike, as is the importance of well-functioning institutions such as norms of civic co-operation, property rights and markets. But providing them is easier said than done. Capital has a high opportunity cost in the form of forgone consumption. Institutions take time to develop and mature.

Relative incomes across countries are remarkably stable, proving that no short-cuts to prosperity have so far been found. The rank correlation of gross domestic product per capita for the 28 countries for which data exist is 0.82 over the period from 1870 to 1988 (Easterly, Kremer, Pritchett and Summers 1993). A country that is at the bottom of the relative GDP per capita ranking is likely to remain there. Major changes in the relative rankings require large and persistent differences in growth rates. 'Star performers', like Japan, Hong Kong, Singapore, South Korea and Taiwan, are an exception rather than the rule.

It is, therefore, not surprising that developing countries have shown a great interest in and are placing high hopes on modern information technology (see, e.g., UNDP 1997b; World Bank 1999). Could IT provide them with the short-cut to prosperity by allowing them to bypass some phases of development in the conventional, long-lasting and belt-tightening process of structural change from an agrarian to an industrial and, ultimately, to a knowledge-based services economy? The striving forces behind the so-called information revolution are the sharp decline in the prices of information processing, the convergence in communication and computing technologies and the rapid growth in network computing. Communication networks and interactive multimedia applications are providing the foundation for the transformation of existing social and economic relations into an 'information society'. This is generally viewed as resulting in a paradigm shift in industrial structures and social relations, much like the industrial revolution transformed the then agrarian societies (OECD 1997c).

For example, Negroponte (1998), founder and director of the MIT Media Lab, argues that the Internet will change the fact that none of the theories of leapfrog development has so far survived the test of time. He predicts that the Internet will have one billion users in the year 2 000 and that most of the increase in the number of users will come from the developing world. Fewer than 40 million people were connected to the Internet in 1996, but by the end of 1997 the number had already grown to over 100 million (U.S. Department of Commerce 1998). Negroponte sees the Internet to leverage the developing countries by providing their schools and universities access to the world's libraries. Telecommunications infrastructure—not for telephones but for access to the Internet—will here be the key to education and development.

It is, indeed, widely believed that modern information technology will change the world, but how can such a change be measured and its impacts assessed? What is so special in this technology to make us believe that its impacts are any different from, say, those of the railways or the telephone some one hundred years ago? Like any other technological change, this technology is also expected to increase productivity, to enhance the quality of life and to create new economic activities as well as new employment opportunities. But is it in some sense different from the past technological breakthroughs?

2. DEMATERIALIZATION OF ECONOMIC ACTIVITIES

The truly revolutionary aspect of modern information technology is believed to be the possibility it offers to unbundle information from its physical carrier (see, e.g., Evans and Wurster 1997). This means that the economics of information can be separated from the economics of things. The 'information superhighway' is, as Negroponte (1995) has defined it, 'about the global movement of weightless bits at the speed of light'. Quah (1997a,b) argues that it is this increasing weightlessness or dematerialization of production that is characteristic of modern economies. By this he means that an increasingly greater fraction of gross domestic product comes to reside in economic goods with little or no physical manifestation. Economic value is embedded more and more in intangible goods than in physical objects. This process of dematerialization derives from the increasing output share of all services in general and from the growing importance of information technology in particular.

Romer (1993) summarizes the existing explanations for the persistent poverty of developing nations into the following two extreme views. The first is based on an object gap. A country is poor because it lacks objects, which are valuable in production. These include raw materials, physical capital in the form of engines, factories and roads as well as human capital in the form of educated labour. The second view is based on an ideas gap. A country is poor because it does not have access to the ideas that are used in industrial nations to generate economic value. Ideas are the instructions that are needed to combine physical resources to produce economically valuable commodities. These explanations are not necessarily mutually exclusive because a nation can suffer from both gaps at the same time.

Ideas are different from objects in the sense that they have no opportunity costs. Invention, innovation, discovery and technological change are all activities that increase the stock of intangible knowledge or ideas. An idea-like good is something that you can give to someone else and yet still retain it for your own use. The Pythagoras theorem, a computer software code or a blueprint for manufacturing are examples. Once invented, they can be copied and transferred at negligible costs. Idea-like goods or knowledge goods are in fact infinitely expansible in the sense that their use by one person does not prevent others from using them. This property makes them fundamentally different from physical commodities. Information may be appropriable in the sense that others may have high obstacles of obtaining it but it typically entails a non-rival use. Knowledge goods have properties similar to public goods, e.g. they are always underprovided by a free market, but they are themselves commodities created by the purposeful actions of private economic agents.

Ideas are indeed dematerialized and weightless. Economists and policy-makers alike have however, known their importance for economic growth and development for a long time. Ideas are the critical ingredients of research and development, invention and patents. To understand the essential aspects of the information technology, or of information society at large, it is helpful to make a distinction between those ideas which have economic value in their physical manifestation only and those ideas which retain their value independent of the physical medium containing them (Quah 1997a,b). The printing press, the spinning jenny, the steam engine and the railway are examples of the first group of commodities. They all have a very high idea content, and each one of them has certainly made a significant contribution to technological progress and economic development. However, they would have been worthless if the underlying ideas had never taken these specific physical forms.

The second, weightless group of commodities includes, for example, computer software, telecommunications, semiconductors, biological algorithms, financial services, electronic databases and libraries, media entertainment and Internet delivery of goods and services. All these commodities can be expressed in binary bits of logic. Their economic value is independent from their physical carriers. A piece of computer software provides a good example. The thesis of dematerialization is that economic value will increasingly be created by producing and distributing bits of logic rather than atoms of physical material. While computers and information technology form a large part of this activity, the digitalization of production and consumption means that an increasing number of products and services become idea-like goods (Quah 1997a).

The policy implications of the idea gap and object gaps views of economic development are quite different. The object gap view emphasizes the role of saving and investment in both physical capital and education. The ideas gap explanation highlights the need for the transfer of technology from the developed countries to the developing ones. It directs attention to the patterns of interaction and communication between a developing country and the rest of the world.

'Capital fundamentalism', the dominant theory of economic development in the 1950s and 1960s, is a prime example of an object gap explanation. Under this view, differences in national stocks of capital are the main determinants of differences in national product. Correspondingly, capital fundamentalists (e.g. Lewis 1954, and Rostow 1960) viewed rapid capital accumulation as central to increasing the rate of economic growth. Capital fundamentalism provided a coherent foundation for giving advice on development problems: national and international policies designed to increase a nation's physical capital stock were the best way to foster economic development. The modern view of growth and development is more sceptical (see, e.g., King and Levine 1994). There seems to be little support for the view that capital fundamentalism should guide our research agenda and policy advice. International differences in capital per person seem to explain little of the differences in output per person across countries.

The modern version of this doctrine could be called 'human capital fundamentalism'. It emphasizes the importance of human capital in economic development. Indeed, education measured in years of schooling or experience is one of the most important object-like goods an economy or, for that matter, a person can lack. Lucas (1988), Barro (1991) and many others have demonstrated in both theoretical models and empirical analyses the strong effect of human capital on economic growth. But human capital is an object in the same sense as physical capital. There are no easy solutions to object gaps since objects have high opportunity costs in the form of foregone consumption.

The ideas gap explanation for persistent poverty has a more optimistic tone to policy advice than the one summarized above. It emphasizes the fact that people in the industrial nations already possess the knowledge needed for providing a proper standard of living. It directs attention to the pattern of communication between developing countries and the rest of the world. In particular, it emphasizes the role that multinational corporations can play in transferring productive ideas across national borders (Romer 1993).

UNU/WIDER's research project 'Information Technology and Economic Development' is set up to explore quantitatively what the impacts of information technology investments are on economic growth, welfare and development. In doing this, substantial emphasis is deliberately put on the recent contributions of those economists who have studied the impact of information technology on labour productivity and wages. The sociological and psychological aspects related to the changing nature of work receive less attention—not because they are regarded as unimportant but because attention will be focussed on the economic consequences of computerization. The rationale for this narrow approach is based on the fact that information technology equipment, software and services are all inputs in production and, consequently, investments in them can be analysed in much the same way as investments in any other production asset. The aim of the project is to obtain results that could be used in helping developing countries to formulate national information and communications technology strategies, which will maximize the benefits and minimize the risks of these technologies.

Developing countries face the problem that the capital and educational investments required to strengthen national capabilities to produce and use information technology may divert both public and private resources from other activities, which could have greater development impact. Some businessmen in industrial countries already complain that investments in information technology are not earning hefty returns simply because all firms are making the same investments. Various types of market imperfections may in fact allow firms to invest in information technology to redistribute rents from their competitors without improving total welfare (Hitt and Brynjolfsson 1996). If this is indeed the case then developing countries may be in a similar position: they have to invest in information technology just to keep up with industrial countries. Herein lies the risk that they will soon become disillusioned when such investments do not resolve all their development problems.

In any case, the current technological change is a factor contributing to the welfare gap between the rich and the poor countries. Consequently, besides providing developing countries with new opportunities, it also poses the threat on them that, if unable to harness this new source of wealth, they will fall even more behind the developed countries. Information is becoming a factor, like income and wealth, by which people and countries are classified into rich and poor.

3. INFORMATION AND COMMUNICATION TECHNOLOGY MARKET

In 1995, the world information technology market (including computer hardware, data communications equipment, computer software and computer services) was worth an estimated US$ 528 billion as measured by the revenues of primary vendors (OECD 1997b: 13). To put things in perspective, this is about 8 per cent of the US gross domestic product. The market, however, grew at an annual rate of 14 per cent between 1985 and 1995. This was about twice the growth rate of gross domestic product worldwide. The distribution of the IT market by geographic area and by main market segment is shown in Table 1. The market is remarkably concentrated with North America, Western Europe and Asia Pacific accounting for 96 per cent. In 1995 the two dominating countries were the United States with a 41 and Japan with a 17 per cent share of the world market. The growth rate was the highest in Asia Pacific amounting to 19 per cent per year in 1985-95.

TABLE 1
WORLD-WIDE INFORMATION TECHNOLOGY MARKET BREAKDOWN, 1995

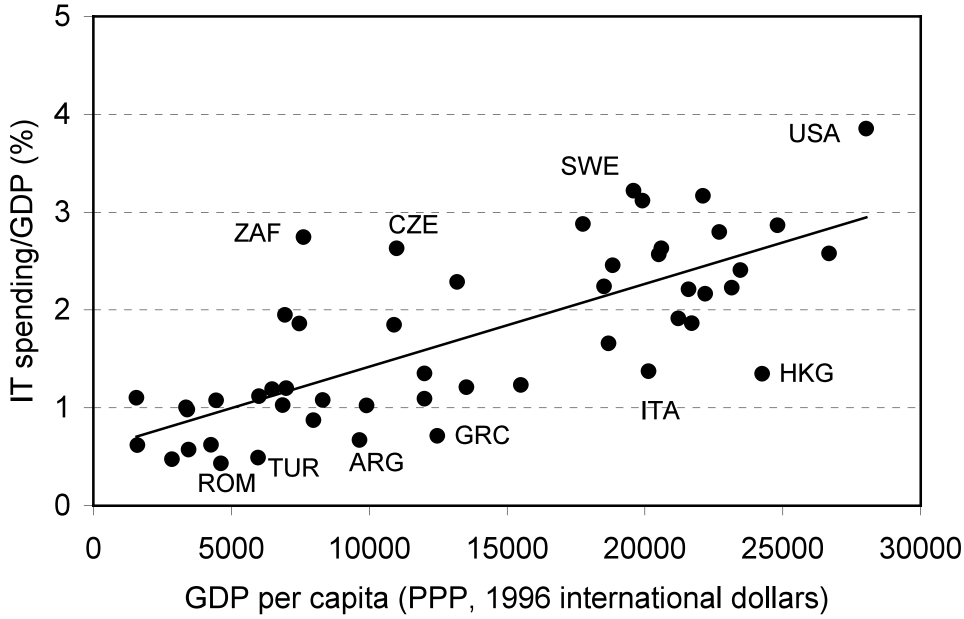
	Market share (%)	Compound annual growth rate 1985-95 (%)
By georaphic area		
North America	43.5	9.4
Latin America	2.0	15.6
Western Europe	28.3	15.6
E.Europe, Middle East, Africa	2.6	10.6
Asia Pacific	23.7	18.9
	100.0	
By main segment		
PCs and workstations	30.5	17.2
Multi-user systems	13.0	4.0
Data communication eq.	4.3	17.0
Packaged software	18.4	16.3
Services	33.7	13.0
	100.0	

Data source: OECD (1997b: Annex Table 1)

In 1995, for the first time, over a half of the world-wide revenues of IT producers came from packaged software and computer services. Most of the shift in the structure of the market is due to the increasing importance of packaged software and the declining significance of multi-user hardware (i.e. mainframes and minicomputers).

Figure 1 reveals how modest the size of the information technology market still is in relation to gross domestic product at market prices in those 50 countries for which International Data Corporation (IDC) has collected data on spending on computer harware and data communications equipment, computer software and services. The average share was 1.7 per cent in 1996. The size of the market seems to correlate positively with the standard of living as measured by GDP per capita in purchasing power parities. The share exceeds 3 per cent in the United Kingdom, Canada, Sweden and the United States, whereas it is only about half a per cent in Romania, Egypt, Turkey, Indonesia and India. Consequently, caution must be exercised when interpreting the direction of causality. It may be more likely that high-income countries tend to purchase more information technology rather than that high spending on information technology makes countries rich.

FIGURE 1
INFORMATION TECHNOLOGY SPENDING AND GDP PER CAPITA
IN 50 COUNTRIES, 1996



Data source: IDC and World Bank (1998)

The worldwide information and communications technology (ICT) market is about twice as large as the information technology (IT) market alone. In 1995 it was estimated at US$ 1,400 billion (EITO 1997: 249). Telecommunications services account for 43 per cent and telecommunications equipment for 8 per cent of the revenues.

The stark differences between the industrial and developing countries in the penetration of communications equipment are shown in Table 2. The ICT diffusion gap is present not only for computers but also for telephones, televisions and radios. Developing countries have about 185 radios per 1000 people, a fifth of the ratio in industrial countries, and 145 televisions per 1000 people, a little more than a fourth of that in industrial countries. The industrial countries' 414 main telephone lines per 1000 people is more than 10 times the ratio in developing countries. The fact is, as Mr. Thabo Mbeki, Vice-President of the Republic of South Africa, is reported to have said, that 'more than half of humanity has never made a telephone call' (UNDP 1997b).

TABLE 2
WORLD COMMUNICATION PROFILE, 1995
(COMMUNICATION EQUIPMENT PER 1000 PEOPLE)

	North America	Nordic countries	European Union	Industrial countries	Developing countries
Radios	1990	928	880	1005	185
Televisions	763	514	522	524	145
Main telephone lines	622	614	486	414	39
Cellular telephone subscribers	124	205	58	61	4
Internet users	38	70	17	18	1
Personal computers	315	222	138	156	7

Data source: UNDP (1998)

It is interesting to see how large differences in the penetration of communication equipment exist even between industrial countries. While North America leads in the number of televisions, radios and main telephone lines per capita, the Nordic countries are on the top of the list when cellular mobile telephone subscribers and Internet users are considered. These countries also fare much better than the European Union in the penetration of personal computers.

Tables 1 and 2 as well as Fig. 1 reveal the enormous gap between developed and developing countries in the accessibility to the global information infrastructure. The scale of the investment required to fill this gap is substantial. It is easy to argue from a normative standpoint that this situation is unjust and that developing countries should give a high priority to information and communication investment in their policy agenda. From a positive viewpoint, however, the question is how productive are such investments and whether they can be substitued for the more traditional means of development.

4. INFORMATION TECHNOLOGY SPENDING AND ECONOMIC GROWTH

Production of information and communication technology goods and services has contributed quite substantially to economic growth in many developed and newly industrialized countries. The average share of ICT goods in manufacturing value added was 7.2 per cent in the OECD countries in 1993. The shares were highest in Japan and in the Netherlands, 10.5 and 10.6 per cent, respectively (OECD 1997b: 45). Wong (1998) estimates that ICT goods accounted for 44 per cent of the manufacuring value added in Singapore in 1994. This sector has grown spectacularly since the share was only 6 per cent in 1960. Electronics production has certainly played an important role in the development process of all the newly industrialized countries. In 1996, Hong Kong, Singapore, South Korea and Taiwan jointly accounted for 12 per cent and Indonesia, Malaysia and Thailand for 5 per cent of the electronics industry production in the world (Mansell and Wehn 1998: 34-5).

But, as Kraemer and Dedrick (1998) argue, recent research on the use of information technology and related research on computer production suggest that the benefits from IT use are likely to outweigh the benefits from production, which are limited to just one sector of the economy. Moreover, the ongoing globalization of the world economy tends to amplify the importance of IT use, since information and communication systems provide the link to international capital markets and to international technology and production networks. Multinational companies are now in the process of linking their design, procurement, manufacturing, logistics and marketing through Internet-based technologies. Even low-technology industries such as textiles are following suit (see also Lal 1998). The ability to use information technology improves the capabilities of firms in developing countries in facing the competition from multinational corporations or in developing partnerships with them.

Kraemer and Dedrick (1998) also argue that globalization makes it difficult for developing countries to reap the benefits from the production of information technology. While a number of new countries (like Japan, Taiwan, Hong Kong, South Korea, China, India and the Philippines) successfully entered the IT industry during the PC revolution of the 1980s, other countries such as Brazil and Mexico have had little success. Even Japan and South Korea have enjoyed only limited benefits from computer production (as apposed to component production) outside their own markets. The opportunities are even more limited today since some segments of the IT industry (e.g. microprosessors, operating systems, packaged business applications) are virtually closed off because the standards are set by the leading companies in the market (like Intel and Microsoft). Other segments of the industry require large capital investments and specialized skills or have already been preempted by earlier entrants. Attempting to enter such segments through protectionist policies is not likely to succeed, and will impose a high cost to users by raising the prices of IT goods and services.

Table 3 sheds some light on the relative contribution of spending on information technology to the growth of gross domestic product in 32 countries in 1991-96. IT contribution here means spending, not production, and GDP is interpreted as total spending rather than total production. Both IT spending and GDP are measured in nominal US dollars at prevaling exchange rates. To assess the relative contribution of information technology, it might be more informative to consider its real contribution by excluding the effects of different inflation rates between IT and GDP. But such a breakdown is hard to make if prices do not accurately account for changes in quality, as is likely to be the case for information technology.

The average share of IT spending in nominal GDP was 1.4 per cent in these countries in 1991 and 2.0 per cent in 1996. GDP grew at the rate 6.7 per cent on average, whereas IT spending increased at the rate of 15.0 per cent from 1991 to 1996. The relative contribution of IT to GDP growth was less than 2 per cent in Argentina, Brazil, Chile, China, India, Spain, Thailand and Venezuela, but larger than 10 per cent in Canada, Finland, South Africa, Sweden, UK and USA.[1]

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[1] IT contribution is negative for Canada because GDP declined there during the period under consideration. The interpretation still goes through: IT spending prevented GDP from declining at even faster rate.

TABLE 3
NOMINAL GROSS DOMESTIC PRODUCT AND SPENDING
ON INFORMATION TECHNOLOGY, 1991-96

	Share of IT spending in GDP, %		Compound average annual growth rate, %			Relative contribution of IT spending to GDP change, %
	1991	1996	GDP	IT spending	IT share	
Argentina	0.3	0.7	8.8	26.1	17.3	1.4
Australia	1.9	2.6	5.3	12.3	7.0	5.2
Austria	1.4	1.9	6.1	11.9	5.8	3.2
Belgium	1.9	2.2	5.7	8.6	2.9	3.0
Brazil	0.8	1.2	13.2	21.2	8.0	1.6
Canada	1.4	3.2	-0.2	15.7	15.8	-211.2
Chile	0.8	1.1	15.4	21.4	6.0	1.3
China	0.5	1.0	15.4	29.3	13.9	1.4
Denmark	2.3	2.8	5.9	10.2	4.2	4.3
Finland	1.7	2.5	0.4	7.5	7.0	36.7
France	1.8	2.2	5.0	9.1	4.1	3.7
Germany	1.6	1.9	6.3	9.6	3.4	2.7
Hong Kong	0.7	1.3	11.7	24.2	12.4	2.1
Hungary	1.5	1.9	5.9	11.3	5.4	3.3
India	0.3	0.6	6.9	24.3	17.4	1.5
Italy	1.2	1.4	1.0	3.8	2.8	5.0
Japan	1.8	2.2	6.0	9.7	3.7	3.3
Korea, Rep of	0.7	2.3	10.0	33.6	23.6	4.7
Malaysia	0.9	1.8	14.9	29.8	14.8	2.7
Mexico	0.6	0.9	1.3	8.5	7.2	5.0
Netherlands	2.2	2.6	6.0	8.9	2.8	3.5
New Zealand	2.2	2.9	8.9	14.6	5.7	4.1
Norway	1.9	2.4	5.9	10.1	4.3	3.8
Singapore	1.4	2.6	15.4	27.3	11.9	3.6
South Africa	1.8	2.7	2.3	11.1	8.7	10.5
Spain	1.2	1.2	1.9	2.4	0.5	1.5
Sweden	2.2	3.2	0.9	8.2	7.3	24.8
Switzerland	2.4	2.9	4.6	8.2	3.5	4.6
Thailand	0.5	1.0	12.7	26.2	13.5	1.6
UK	1.9	3.1	2.5	12.1	9.6	12.1
USA	2.1	3.9	5.0	17.3	12.3	10.0
Venezuela	1.0	1.1	4.6	5.8	1.2	1.3
average	**1.4**	**2.0**	**6.7**	**15.0**	**8.3**	

Data source: IDC and World Bank (1998)

The conclusion from this analysis is that spending on information technology is increasing in importance. In all the countries considered IT contribution to GDP growth exceeded its relative share in GDP, meaning that the relative share is rising. The average growth rate was 8.3 per cent per year in 1991-96. This growth cannot, of course, go on indefinitely since the share has to lie between 0 and 1. But the development indicates that these countries have not yet reached the steady state in which the relative share of IT is constant over time.

5. THE COMPUTER AS A PRODUCTION FACTOR

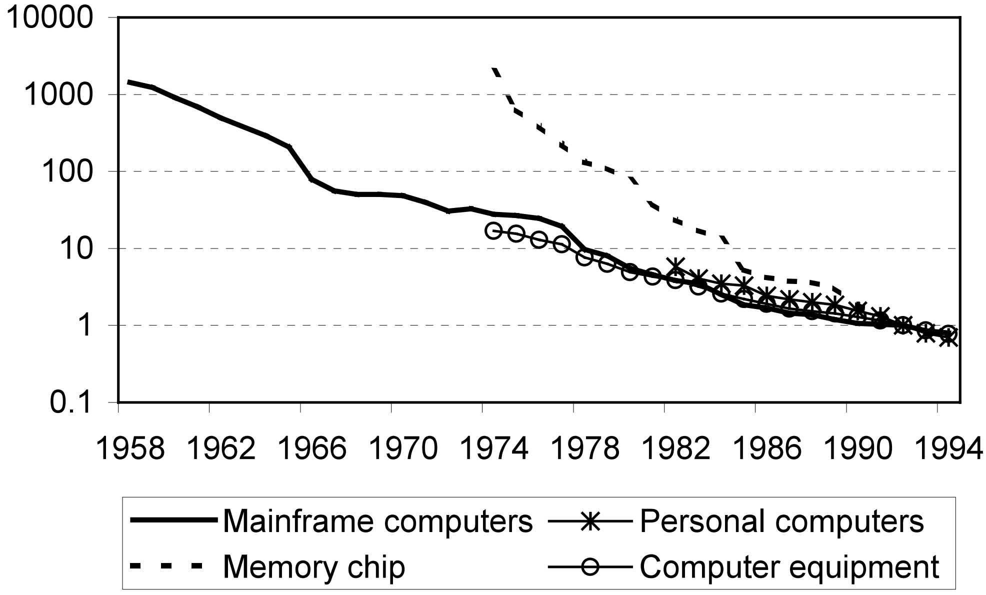
Information technology is nowadays so extensively applied in production that is quite difficult, if not even impossible, to measure its use accurately. However, computers are widely believed to be at the vanguard of the information technology revolution, and information about computer investment exists. Consequently, a good starting point for the analysis of the impacts of IT is obtained by assessing the importance of the computer as a factor of production in the modern economy.

5.1 Computer investment and computer capital stock

The price of computing has plummeted over the post-war period. Figure 2 displays this development with (hedonic) price indices that take account of each year's improvement in the performance of computing equipment. On average, the price of a new mainframe computer as fallen by 21 per cent a year in the United States. Thus, a computer priced at $ 5,000 in 1992 would have cost $ 7 million in the late 1950's. The prices of personal computers and computer equipment have declined almost as rapidly: on average by 18 and 15 per cent a year, respectively. Semiconductor prices have fallen most sharply, about 40 per cent a year since 1974, when measured by the price per kilobyte of memory on the chip. The real price of computers has declined even more dramatically than what these numbers indicate because producer prices in manufacturing and consumer prices have increased at the average annual rates of 4.1 and 4.8 per cent, respectively, in the period between 1960 and 1995 (OECD 1997a).

The rapid technological advance in computer equipment and the resulting decline in its relative price have led to a substantial increase in the nominal share of computer and information processing equipment in fixed investment in the United States. This is shown in Fig. 3. Investment in computers and peripheral equipment accounts for 10 per cent and all information processing equipment investment for 25 per cent of private non-residential fixed investment at current prices. Computer investment share peaked in the 1980's at around 7 per cent and then again in the mid-1990s at 10 per cent. Its recent surge must be associated with joint development of hardware and specific software for use on the Internet.

FIGURE 2
COMPUTER EQUIPMENT PRICE INDICES IN THE UNITED STATES
(1990 = 1, LOGARITHMIC SCALE)

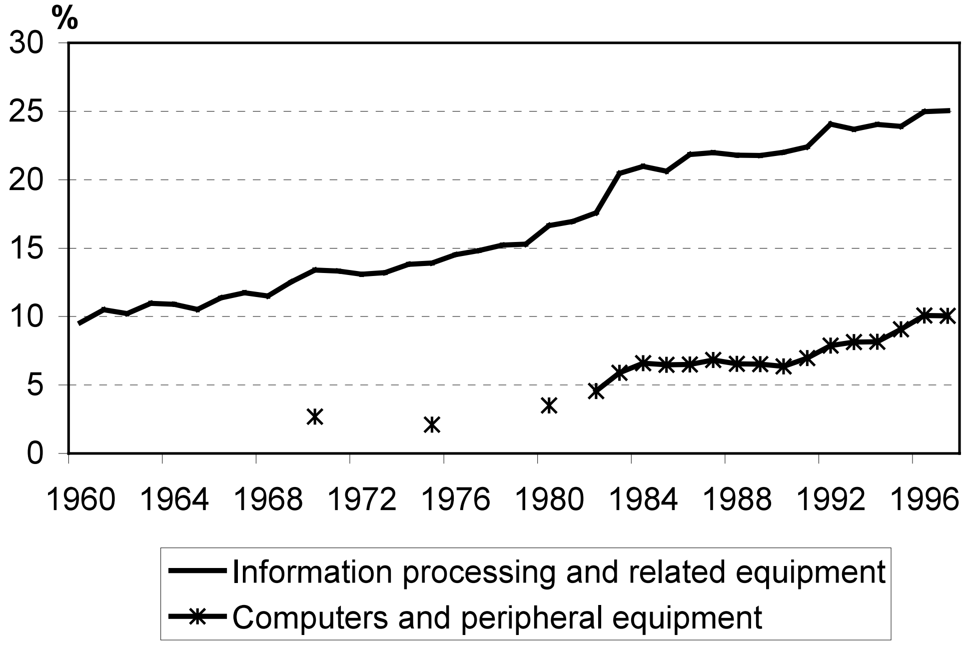


Data source: Triplett (1996)

The computer share in fixed investment is even larger than what is displayed in Fig. 3 if it is calculated in real terms. However, such real shares are not helpful concepts since, given the sharp decline of computer prices, they are very sensitive to choice of the base year for such calculations.

In any case, even if computers and peripheral equipment account for a substantial share of fixed investment in the United States, they are a relatively minor input to production. Oliner and Sichel (1994) have estimated that computer hardware made up only about 2 per cent of the net stock of non-residential equipment and structures in 1993 when measured in nominal terms. Information processing equipment accounted for 12 per cent of this stock in the same year. The difference reflects the large stock of communications equipment, which also has a considerable amount of embedded microelectronics. In 1992 computers accounted for 17 per cent of the nominal net stock of information processing equipment. Communication gear represented 58 per cent, scientific equipment 17 per cent and photocopying and other office equipment the remaining 8 per cent (Oliner and Sichel 1994: 304).

FIGURE 3
NOMINAL SHARES OF INFORMATION PROCESSING AND COMPUTER EQUIPMENT INVESTMENT IN PRIVATE NON-RESIDENTIAL FIXED INVESTMENT IN THE UNITED STATES, 1960-97



Data source: Bureau of Economic Analysis: National Income and Product Accounts, 1959-88 and Survey of Current Business (various issues); Sichel (1997: 3)

Niininen (1998) has produced similar estimates for Finland. He shows that the share of computer hardware investment in private non-residential fixed investment increased from 4 per cent in 1983 to 11 per cent in 1996. The computer capital stock accounted for about 3 per cent of the non-residential stock in the business sector in 1996.

The capital share of computer hardware has remained so small because computers become obsolete very rapidly. Oliner and Sichel (1994) estimated that the depreciation rate for computers averaged 25 per cent a year in the United States from 1970 to 1992. This reflects the capital loss associated with the sharp decline in computer prices (see Fig. 2) rather than the change in their value with the age. In fact, computers seem to be rather durable goods which lose their asset value very rapidly.

The small capital share is one of the possible explanations to the fact that computer hardware's contribution to overall economic growth has turned out to be rather modest in the US economy. This debate on the 'productivity paradox' will be examined in greater detail below.

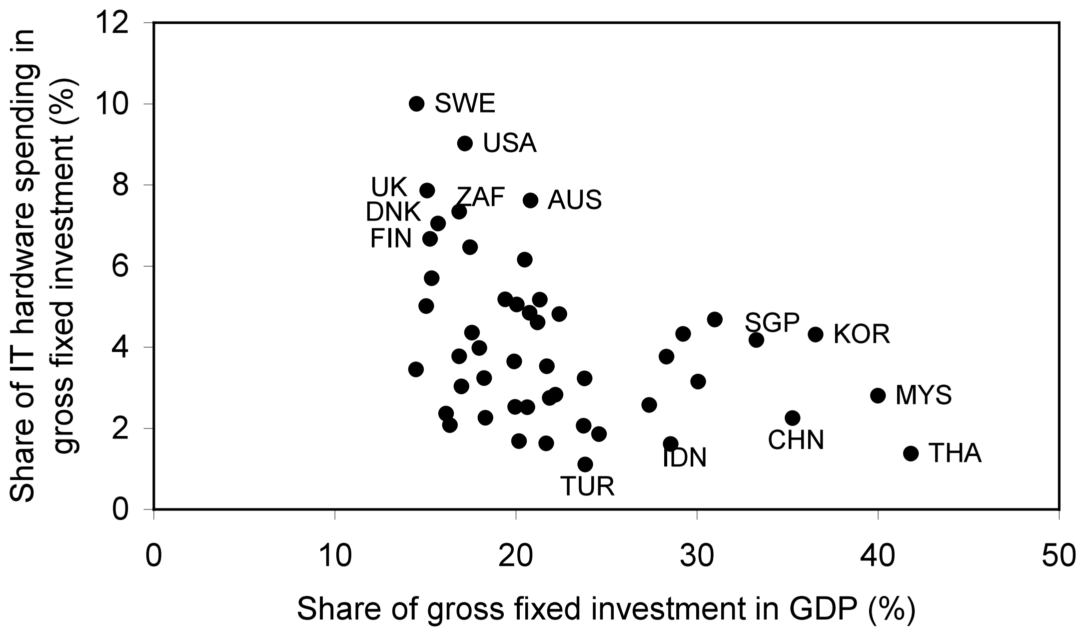
The data presented above are from the US national accounts. They are an outcome of the pathbreaking work began by the Bureau of Economic Analysis in the late 1980s to incorporate computer prices into a national accounting framework (see Triplett 1996). As a result there now exists a view of the role that computers play in the US economy. All the other OECD economies, with the sole exception of Canada, still leave them out of the picture. The lack of data on other countries makes it difficult to study the impact of computers on economic development. It also explains the bias towards the United States which is reflected in many studies in this field.

There are, however, some private providers of information technology data. As already mentioned above, International Data Corporation (IDC) publishes an annual report on the status of the worldwide information technology market in 50 countries. The report contains data, based on the revenues of primary vendors, on spending on computer hardware equipment, data communications equipment, computer software and computer services including both professional and support services.[2] A measure of investment in information technology hardware is obtained by aggregating the first two categories. Figure 4 displays it as a percentage of gross fixed investment and contrasts it with the share of fixed investment in GDP in 49 countries in 1995. The average share of IT hardware spending in fixed investment is 4.1 per cent in this dataset. The highest shares are found in the rich industrial countries: Sweden (10.0 per cent), United States (9.0 per cent), United Kingdom (7.9 per cent), Australia (7.6 per cent), Denmark (7.0 per cent) and Finland (6.7 per cent). South Africa (7.3 per cent) is the exception proving the rule. The shares are the lowest in Turkey (1.1 per cent), Thailand (1.4 per cent) and Indonesia (1.6 per cent).

[2] The IDC data includes spending by households. The household share has, however, been rather modest. For example in Finland, where it is among the highest in the world, it is estimated to account for about 10 per cent of total spending.

It is interesting to observe that the share of IT hardware investment in gross fixed investment is not oustandingly high in those, mostly Asian, countries, where the ratio of fixed investment to gross domestic product is high. In fact, these shares have been at the average or even below the average level in the fast growing economies of Thailand, Malaysia, Korea, China and Singapore. One is tempted to draw from this figure the conclusion that the gross correlation is negative between the IT content of investment and the overall investment ratio. There is consequently an obvious need to control for investment in other types of capital before any assesement can be made about the relationship between information technology and economic growth.

FIGURE 4
INFORMATION TECHNOLOGY HARDWARE SPENDING AND GROSS FIXED INVESTMENT IN 1995



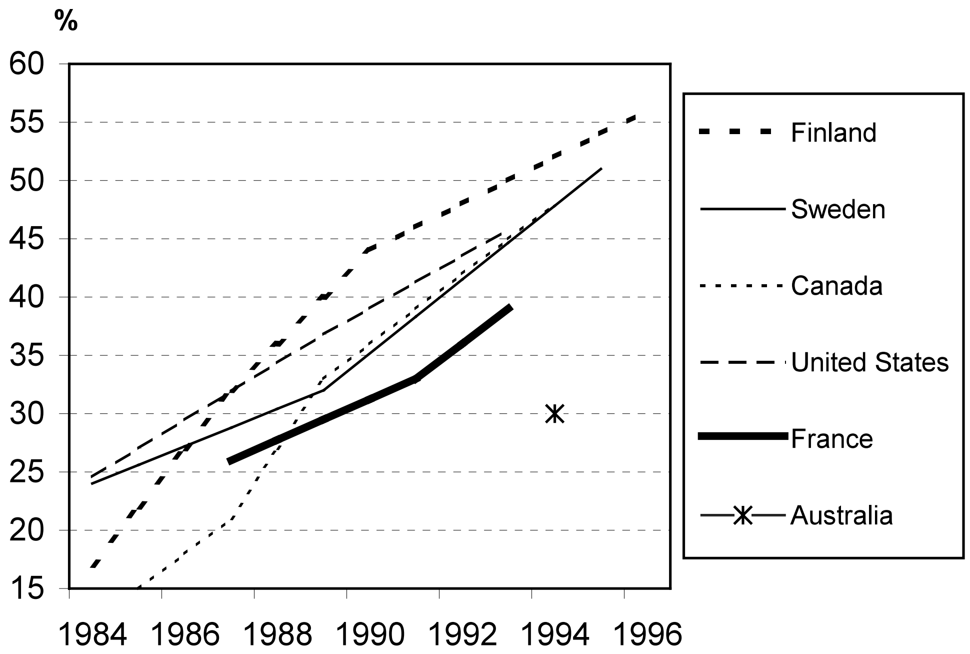
Data sources: International Data Corporation and World Bank (1998)

In any case Fig. 4 indicates that only in Sweden the share of IT hardware investment in total fixed investment was in 1995 higher than in the United States. Consequently, the share of computer capital in the total capital stock is not likely to exceed in these countries the 2-3 per cent share estimated for the United States and for Finland.

5.2 Use of the computer at work

Computers and communication tools have become an integral part of people's working lives in industrial countries. Fig. 5 displays information about computer use in the workplace in five OECD countries. The share of employees using a computer increased from less than a quarter of workers in the mid-1980s to between 40 to 56 per cent by the mid-1990s. Finland seems to have the highest computer penetration, whereas the fastest growth over the period occured in Canada.

FIGURE 5
PERCENTAGE OF PERSONS USING A COMPUTER AT WORK



Source: OECD (1998)

It is interesting to observe how similar the patterns of computer penetration are in the countries displayed in Fig. 5. Computer equipment and software also tend to be quite similar in these countries for two reasons. First, their production is concentrated in the hands of only a few multinational companies (OECD 1997b). Second, fast technological progress makes their service lives rather short, meaning that the latest innovations are adopted almost simultaneously in all these countries. Consequently, the labour market outcomes of computer use should also be quite similar if information technology has universal impacts. This is one of the hypotheses which needs to be tested in empirical work.

While information technologies are being used in both manufacturing and service industries, the OECD (1998) report indicates that penetration remains low in agriculture and construction. Persons employed by the finance and insurance services make greatest use of the computer generally followed by those in public administrations. Workers in real estates and business activities, utilities and mining also tend to use information technologies more than the average.

Computers in the workplace are used for a wide variety of purposes with word-processing often taking the lead (OECD 1998). Data on networked users in Sweden show that about 60 per cent of employees use the computer to share various type of information within the firm, 30 per cent use it for electronic mail and 20 per cent to access external databases, including the Internet.

6. INFORMATION TECHNOLOGY, PRODUCTIVITY AND ECONOMIC GROWTH

The often-advocated view that information technology will change the world must stem from a basic premise: namely, that computing equipment and information processing equipment have a visible impact on productivity, income and/or welfare. But if this is the case, then how can we measure it and how large is it? It is undeniable from the survey presented above that IT plays an enormous role in the operation of most modern economies. However, the assessment of the benefits and the factors that influence them has been rather difficult.

This assessment has been approached at the level of the economy, the industry and the firm. In their survey of the field, Brynjolfsson and Yang (1996) considered over 150 articles. Their conclusion is that in the 1980s and early 1990s disappointment in information technology was chronicled in a number of studies disclosing broad negative correlation between IT investment and economy-wide productivity in the United States. This 'productivity paradox' is often summarized by referring to Robert M. Solow's (1987) much-quoted sentence 'you can see computer age everywhere but in the productivity statistics'.

More recent research has, however, found increasing evidence that there exist positive relationships between information technology investments and various measures of economic performance across firms in industrial countries (see, e.g., Brynjolfsson and Hitt 1996 and Lichtenberg 1998 for evidence on the US and Greenan, Mairesse and Topiol-Bensaïd 1998 for France). Interestingly, however, this correlation tends to vanish when estimated in the longitudinal dimension, implying that caution must be exercised when making conclusions about causality. Moreover, Lal's (1998) study on Indian garments industry indicates that the returns to computer investment are still quite limited in developing countries.

Analyses of the labour market impacts of information technology also reveal an interesting thing. As Fig. 5 shows, computer use and diffusion rates are roughly similar in Western industrial countries. The labour market outcomes are, however, quite different: both wage and employment effects of computer use vary from country to country (Kramarz 1998). This observation casts doubt on the existence of a universal force (like skill-biased technological change caused by IT) shaping the world. Instead, it drives the attention to the operation of labour market institutions.

Economy-wide and industry level findings on IT impacts are more mixed than firm level findings. Many US studies (e.g. Oliner and Sichel 1994; Jorgenson and Stiroh 1995; Sichel 1997) show that productivity gains have not substantially accelerated despite rapidly increasing investments in computers and other types of IT. Five prominent hypotheses have been proposed to explain this 'productivity paradox': no paradox, mismeasurement, mismanagement, diffusion delay and small capital share.

Jorgenson and Stiroh (1995) argue that declining computer prices have generated sizable pecuniary externalities through the substitution of computer services for other inputs in production. But there is no evidence that productivity growth would result from spillovers of benefits of computers to people who are not involved in investing in them, that is, there seems to be no evidence for non-pecuniary externalities generating productivity growth. Consequently, there is, after all, no paradox.

The mismeasurement hypothesis suggests that a large proportion of the benefits of IT will not appear in productivity statistics because they take the form of improved product quality, variety, timeliness and customization, which are not well-measured in productivity statistics. Improving living standards result in an increasing demand for services in industrial countries and, consequently, induce companies to invest in computers even if they do not add to productivity measured in the conventional way. The weakness of this explanation is, as Schreyer (1998) among others has pointed out, that it requires mismeasurement to increase over time. Technological progress has resulted in new products and improved quality for already many decades, even centuries. There is no indication that information technology has made the measurement problem any worse than it was before.

Mismanagement may lead to wasteful or unproductive IT investments. For example, Brynjolfsson and Hitt (1997) found in their survey of large US firms that IT is broadly associated with a work system that includes decentralized authority and supporting practices such as teamwork, subjective incentives and increased importance of knowledge work. To reap the benefits of IT investments, firms have to match their organizational architecture to the use of information technology. IT is complementary to changes in other aspects of the organization. This may explain why not all firms succeed in such investments but those that do succeed are highly rewarded by the stock market: there seems to exist a positive correlation between IT capital and the value of the firm (Brynjolfsson and Yang 1997).

The diffusion hypothesis suggests than it may take a long time before the productivity benefits of IT investment are fully realized. Greenwood (1997) and Greenwood and Yorukoglu (1997) show how a major technological revolution, such as the microprocessor and the computer, can initially lead to a prolonged decline in productivity because it takes time to learn to operate a new technology. This learning period is also characterized by increasing wage inequality since skilled labour has an advantage at learning and since the advance in technology is associated with an increase in the demand for skills needed to implement it.

The last explanation to the 'productivity paradox' is that, as shown above, computers are still only a small fraction (3-4 per cent) of the existing net capital stock. Consequently, even if they earn hefty returns, the share of nominal gross income accruing to computers is rather small. Sichel (1997) calculated that it was on average about 1 per cent in the United States in 1987-93, and Niininen (1998) estimated it to have been close to 2 per cent in Finland in 1983-96. Therefore, standard growth accounting methods give the conclusion that, in spite of the large investment in computers and other forms of IT, they have added only about 0.1-0.5 percentage points of growth to the overall economy in both the US and Finland. Although substantial, this contribution is not overwhelming.

7. CONCLUSIONS FOR RESEARCH

In its report (UNCSTD 1997) on the implications of information and communication technologies for economic development, the Working Group of the United Nations Commission on Science and Technology for Development Group was unable to reach firm conclusions about many aspects of the debate. There is substantial evidence that the new technologies are transforming some sectors of some societies. The impact is not, however, as deep or pervasive as the debate about the benefits of the global information society sometimes makes it appear. As yet, the evidence that ICTs will transform the world and bring benefits to all its citizens is inconclusive. The Working Group argues, however, that there is sufficient evidence of their potential to indicate that it would be wise for all governments and other stakeholders to take steps needed to access and use these technologies. For this reason, it recommends that each country establish a national ICT strategy aiming at maximizing the benefits of ICTs and minimizing their risks.

The survey presented above confirms these conclusions on the impacts of information technology. The literature review on the 'productivity paradox' shows that there is neither a paradox nor a substantial 'information payoff' associated with investment in computers or other forms of IT in the United States. Computers seem to be 'pulling their weight'. This may, however, be a characteristic feature of the US economy in its present stage of development. Modern business information systems are being developed for the needs of large corporations in industrial countries. More research on other countries, developed and developing, is needed before firm policy conclusions can be drawn for economic development. This research should explore the role of information technology both as an intermediate input in production and as a final good in consumption.

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