Information Technology, and the Global Economy*

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INTRODUCTION

WHEN we are considering which technologies are likely to be the most important for structural change in the industrial economies, there would probably now be fairly widespread agreement that "information technology" is the key. We are using the expression "information technology" (IT) to describe the combination of new technological developments in micro-electronics, computers, opto-electronics and communication systems, which collectively are having such pervasive effects that many people have talked in terms of a "paradigm" change in technology.

Information Technology (IT) is an all pervasive change, which is affecting the design of many existing products and services, as well as the mode of producing and marketing almost all of them. As we will illustrate in the following pages this point emerges every day stronger from sector studies in manufacturing or in services, as well as from general trends in R & D, patenting and innovation. Yet even so, the sharp rise in the share of electronics R & D within total R & D over the past 20 years understates the impact of IT because much technical change associated with computerization in any industry or service takes the form of new software development and applications, which is often not included in present definitions of R & D, and is not patentable.

A new "techno-economic paradigm" began to emerge in the 1960s, and to penetrate most industries and services significantly in the 1970s.** The effects of the new paradigm on product design and innovation can be seen both in assembly industries such as the car industry and in research-intensive industries such as

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** The results of our own research on the UK economy at the Science Policy Research Unit are presented in detail in a set of volumes published by Gower Press (Ed. Clark, Freeman, Guy, Smith, Soete, 1984, 1985 and 1986).

scientific instruments, which have virtually become part of the electronic industry. But it is not only in manufacturing that this change of technological paradigm is apparent. Service industries, such as financial services and distribution, are also being profoundly affected by computerization.

Our analysis in all sectors of the economy points to a change in paradigm from an energy-intensive mass and flow production technology of the 1950s and 1960s to an information-intensive, flexible computerized technology, characteristic of the 1980s. Before going any further it is now essential to define more precisely what we mean by a change of paradigm and to introduce a taxonomy of technical innovations. Our concern especially is with the complementarities and externalities of families of inter-related technical and social innovations. In Schumpeter's analysis, these successive technological revolutions underlie the "Kondratiev" cycles or long waves of economic development, lasting about half a century and characterizing each historical period since the 1780s.

A TAXONOMY OF INNOVATION

An important first step is the identification of the characteristics of those major changes in technology. They have such widespread consequences that they merit some such description as "technological revolution", or "change in techno-economic paradigm", or "change in technological regime". Any such taxonomy or classification system, must of course do some violence to the infinite complexity of the real processes of technical and economic change. Nevertheless we believe that a taxonomy is essential both for analytical purposes and as a tool for empirical research.

We here distinguish between four categories of innovations and their diffusion.

(i) Incremental innovations. These occur more or less continuously, although at differing rates in different industries, but they are concerned only with improvements in the existing array of products and processes of production. They are reflected in the official measures of economic growth by changes in the coefficients in the existing input-output matrix. Although their combined effect is extremely important in the growth of productivity, no single one has dramatic effects. Examples include the steady growth of productivity and energy-efficiency in chemical plants, oil refineries or steel-works.

(ii) Radical innovations. These are discontinuous events and they have been the main concern of most innovation and diffusion studies. New machines, such as NC machine tools, new materials such as nylon, or new consumer products, such as video recorders are examples of such innovations. They could not emerge from the simple incremental improvement of existing products.

(iii) New Technological Systems. Keirstead [1948], in his exposition of a Schumpterian theory of economic development, introduced the concept of "constellations" of innovations which were technically and economically inter-related. Obvious examples are the clusters of synthetic materials innovations and petrochemical innovations introduced in the 1930s, 1940s and 1950s. Another example is the "cluster" of electrically driven household consumer durables innovations. Nelson and Winter's "natural trajectories" help to explain the technical inter-relatedness of these clusters of radical and incremental innovations, but economic interdependencies are also important [Nelson and Winter, 1977; 1982].

(iv) Change in "Techno-Economic Paradigm" (Technological Revolutions). These are the "creative gales of destruction" which are at the heart of Schumpeter's long wave theory. The introduction of electric power or steam power are examples of such deep-going transformations. A change of this kind carries with it many clusters of radical and incremental innovations, and may eventually embody several new technology systems. A vital characteristic of this fourth type of technical change is that it must have pervasive effects throughout the economy, i.e. it must not only lead to the emergency of a new range of products, services, systems and industries in its own right, it must also affect directly or indirectly almost every other branch of the economy. We use the expression "techno-economic" rather than "technological paradigm" because the changes involved go beyond specific product or process technologies and affect the input cost structure and conditions of production and distribution throughout the system. Once established, a techno-economic paradigm is the dominant influence on engineers, designers and managers and becomes a "technological regime" for several decades. Schumpeter's long cycles are a succession of "techno-economic paradigms".

INFORMATION TECHNOLOGY AS A NEW PARADIGM

The new IT paradigm, based on a constellation of industries, which are among the fastest growing in all the leading industrial countries, such as computers, electronic components and telecommunications, has already resulted in a drastic fall in costs and a counter-inflationary trend in prices in these sectors as well as vastly improved technical performance. This combination is relatively rare in the history of technology and it means that this new technological system satisfies all the requirements for a Schumpeterian revolution in the economy.

In considering this technological revolution, we must take into account not only particular products or processes, but the changes in organization and structure of both firms and industries, which accompany the introduction of IT, as discussed by A. Clement in this book. Several commentators, in emphasizing the profound transformation which is involved in the management of large firms have described the changes as a "Cultural Revolution". Information technology

leads to these fundamental changes in the structure of large firms, and in their procedures and attitudes, because of the following features of the technology: the capability which it confers for more rapid changes in product and process design; the much closer integration of design, production and procurement functions within the firm; the reduced significance of economies of scale based on dedicated capital-intensive mass production techniques; the reduction in numbers and weight of mechanical components in many products; the much more integrated networks of component suppliers and assemblers of final products and the related capital-saving potential; the growth of new "producer services" to supply manufacturing firms with the new software, design technical information, and consultancy which they increasingly require; and the extremely rapid growth of many small new innovative enterprises to supply these services and new types of hardware and components.

Changes of techno-economic paradigm are based on combinations of radical product, process and organizational innovations. They occur relatively seldom but when they do occur they necessitate changes in the institutional and social framework, as well as in most enterprises if their potential is to be fully exploited. They give rise to major changes in the organizational structure of firms, the skills mix and the management style of industry.

The overwhelming importance of such technological transformations is that, if the problems of institutional adaptation and structural change can be overcome, they offer tremendous scope for new employment-generating investment as well as labour-saving productivity gains. These opportunities arise both in the provision of new and improved consumer goods and services and in the provision of a new range of capital equipment for all sectors of the economy. Characteristically, they facilitate saving in all factors of production, although initially their effects may be concentrated on one or other factor.

Perez [1983 and 1985] has suggested that big boom periods of expansion occur when there is a "good match" between a new techno-economic "paradigm" or "style" and the socio-institutional climate. Depressions, in her view, represent periods of mis-match between the emerging new paradigms (already quite well advanced during a previous long wave of expansion) and the institutional framework. The widespread generalization of the new paradigms, not only in the "leading" branches of the upswing but also in many other branches of the economy, is possible only after a period of change and adaptation of many social institutions to the requirements of the new technology. Whereas technological change is often very rapid, there is usually a great deal of inertia in social institutions, buttressed by the political power of established interest groups, as well as by slow response times of many individuals and groups. The structural crisis of the 1980s is in this perspective a prolonged period of social adaptation to this new paradigm.

INFORMATION TECHNOLOGY AND COMPUTERS: THE ECONOMICS

Our main argument is that information technology is likely to have a diametrically opposite impact on the service sector of the economy as compared to the manufacturing side. The reason for this has to do with the nature of the new technology and its capacity to store, process and disseminate information at minimal costs. In the case of services, it will be argued, this will lead to the increased "tradeability" of a number of service activities, whereas in the case of manufacturing, the opposite might well be true. We start the analysis with the service sector.

The Impact of IT on Services

Services will be defined here, following Quinn [1986], as those activities (sectors) where output is essentially consumed when produced. This might well be considered as a rather narrow definition and one which would only cover a limited number of sectors presently understood to be service sectors. It is however an analytically useful definition and one which allows for a far more clear-cut interpretation of what the potential impact of IT might be on services. As a parenthesis it is worth noting that it also provides an intellectual argument as to why economists have generally tended to ignore the study and analysis of service activities.

Typically, information technology, practically by definition, will allow for the increased tradeability of service activities, particularly those which have been most constrained by the geographical or time proximity of production and consumption. By bringing in a space or time/storage dimension, information technology will make possible the separation of production from consumption in an increasing number of such activities.

This was certainly the case with regard to the invention of printing in the Middle Ages and the impact this first new information technology had on the limited tradeable "service" activity of monks copying manuscripts by hand. It was the time/storage dimension of the new printing technology which opened up in the most dramatic and pervasive way access to information, and led, to use Marx's words to the "renaissance of science", the growth of universities, education, libraries, the spreading of culture, etc. This opening up, "tradeability" effect would become of far more importance to the future growth and development of Western society than the emergence of a new, in this case purely manufactured-based, printing industry. Similar less pervasive, but nevertheless crucial "trade opening-up" impacts could be ascribed to some of the more modern "copying" inventions, be it of written text, spoken language, music or image (photocopying, recording, taping), allowing, amongst others, for the emergence and growth of "mass" entertainment, as opposed to the space and time constrained individualized entertainment.

In the case of the invention of the telephone it could be said that it was in the first instance the capacity of the new technology to bridge geographical space

which opened up whole new tradeable markets. In this case this led both to the emergence of a new, predominantly service sector, maintaining and servicing an increasingly extensive and international infrastructure network (by 1982 AT & T was about twice the size of the largest US manufacturing company) and a new rapidly growing manufacturing sector. Again though the indirect "tradeability" effects in terms of the use of telecommunications in an increasing number of service activities and the opening up of such activities to private market valuation were significant, including the international trade effects.

As in the case of the telephone it is likely that the "new" emerging IT manufacturing sector (in the first instance the computer manufacturing sector) will remain relatively small compared to the growth and size of the new IT service producing sector. It will be the indirect "trade" effects resulting from the use of IT in many services, and in particular in the IT-using services, which will be most important both in terms of employment and output growth.

The Impact of IT on Manufacturing

With regard to manufacturing, the impact of IT could well be characterized as exactly of the opposite kind. Rather than bringing time/storage or space between production and consumption as in services, IT in its manufacturing user impact will in the first instance aim at reducing the time/storage or space dimension between production and consumption.

Many of the most distinctive characteristics of the "new information technology paradigm" mentioned above are directly networks of component and material suppliers, thus allowing for reductions in storage and production time costs—typified in the so-called Just-in-Time production system [Schonberger, 1982]. At the same time the increased flexibility associated with the new technology allows also for a closer integration of production with demand, reducing the firm's own storage and inventory costs—what could be typified as Just-in-Time selling (see, for exemple, the Italian clothing firm Benetton). Both features clearly work in the opposite direction from what was said above with regard to services, i.e. they aim at reducing the time/storage dimension between production and consumption. However, in doing so they will also reduce the "tradeability" of a number of those intermediary, storage and inventory manufacturing activities.

The increased potential for flexibility and decentralization generally associated with the new information technologies [Perez, 1985 and Clement, in this book] can also be expected to reduce the geographical space dimension between production and consumption in many manufacturing sectors. The relative increase in physical (production or person) as opposed to information transport costs might well lead to closer location of production units to consumer markets. Again and, in this case, more with respect to the international trade implications, it could be said that in contrast to services, IT could well reduce the international tradeability of many manufactured commodities. This is already, but not necessarily for the reasons set out here, the case with regard to the motives underlying much foreign investment in developed countries.

The Impact of IT on International Trade

The long-term implications of these rather different "trade" impacts of IT on services and manufacturing for the future balance of payments constraint of most developed but also some of the newly industrializing countries are far-reaching and have so far received little attention. In many of these countries, it is the "manufacturing" sector balance of payment constraint which has acted as the major bottleneck for sustained recovery or, in the case of the Newly Industrialized Countries (NICs), industrialization growth. Leaving aside transport producer services, where the "trade" impact of IT is likely to resemble more the arguments set out above with regard to manufacturing, i.e. acting more as a substitute for the physical transport of goods or persons, than as a "trade opening-up" complement, the trade in services is likely to increase rapidly as a direct result of the further diffusion and use of IT. Some countries such as the UK, for example, might benefit to a larger extent from this increase in international "tradeability" of services, as a result of both absolute (language and institutional—the City, time zone) and comparative advantage in many such IT-using services. In other words traditional balance of payments growth constraint views might no longer represent a correct picture of many countries' likely future growth prospects. The latter will now also and increasingly depend on the extent and speed of the application of new information and computer technology in both service and manufacturing sectors, as is already evident, for example, in the rapidly increasing Japanese competition in financial services.

The arguments advanced here remain however somewhat speculative. We return to them in our conclusions.

QUANTIFYING THE 'IT SECTOR': AN APPLICATION TO THE UK

In this last section we derive an empirical "guestimate" of what the IT sector should comprise. This empirical question has important policy implications. The question to what extent the IT sector has a sufficiently broad macro-economic impact and as a consequence generates new jobs, rather than displaces more employment, is at the centre of much policy debate.

The implications of the previous analysis for output and employment growth in the various components of the IT-sector are relatively straightforward. Independent of any price or demand-induced compensation effects one would expect a significant different pattern to emerge, particularly with regard to employment growth, as between the manufacturing IT-using sectors and the service IT-using sectors. In the former sector the arguments advanced earlier would suggest that the gains in productivity achieved through the use of IT will have been accompanied by little new "trade", if anything rather the opposite; employment is therefore likely to have fallen. In the IT-using services by contrast, one would expect to witness the biggest output gains in new tradeable areas, in all likelihood accompanied by employment growth. With regard to the IT producing sector, the

distinction between manufacturing and services is clearly of less importance. One would expect rapid output growth in both sectors accompanied with employment gains depending on the underlying rate of productivity growth.

To check for these differential growth trends is no easy undertaking. Output data with regard to the service sector are generally a statistician's invention, based in many cases on employment trends. Employment data on the other hand suffer very often from changes in industrial classification. Finally whereas a definition of the IT-producing sector is always feasible, it is a far more hazardous undertaking to select the "predominantly" IT-using sector. It should also be stressed that to assume such output or employment trends would be purely IT-induced and would be independent of any price-induced output or employment compensation effects is rather heroic.

In the case of the UK, the biggest problem resides in the availability of disaggregated employment data on a common basis only since December 1981. The subsequent analysis will consequently be limited to the last 5 years. One advantage is that over such a relatively short period, the macro-economic price compensation impacts might well be assumed to be relatively limited. In the selection of the predominantly IT-using sector, we have followed the UK IT Advisory Panel's list of information sectors.

Table 1 provides information on the 1985 employment level and trend in employment growth/decline over the last 5 years in the various components of the IT sector, separating out the IT-producing sector from the "predominantly" IT-using sector. The IT-producing sector comprises the manufacturing side the computer, electronics and telecommunications equipment industries and on the service side the telecommunications and computer services sectors. This is a relatively narrow definition of what the IT-producing sector amounts to. It comprises however the "core" IT manufacturing industries, responsible for the emergence of the new information technologies and the "core" IT service sectors essential for the application, maintenance and service of these hardware technologies.

Taken together these IT-producing sectors represented only 3.3% of total employment in the UK. Furthermore, in terms of employment growth, the total increase in employment in the IT-producing sectors over the last five years was a mere 500. Most of this growth occurred in the manufacturing IT-producing sector (+6000) particularly in the non-telecommunications part (+19,600). On the services IT-producing side, the decline in telecommunications clearly outweighted the gains in computer services. The decline in employment in telecommunications, both manufacturing and services, illustrates the predominance of the productivity gains associated with the replacement of electro-mechanical switching equipment by electronic digital equipment over new output outlets. The contrast between the relatively slow growth in output in telecommunications despite virtual total protection from international competition and the significant growth potential resulting from the new technology is, however, striking. There is we would argue little doubt that this failure to develop new services and new "trade" on a large scale was at least partly the result of the "infrastructure monopoly" the telecommunications industry enjoyed for so long, associated with the oligopolistic equipment supply arrangements which prevailed.

Table 1

Employment Levels in the UK Information Technology Industries (Great Britain) (in 1000s)

		1981	1985	Growth
I. IT-Producing Sector				
Manufacturing				
3302	Data Processing Equipment	72.2	75.3	3.1
3441	Telegraph & Telephone Apparatus and Equipment	58.1	44.5	-13.6
3442	Active Components	25.9	26.9	1.0
3443	Radio & Electronic Capital Goods	87.5	94.6	7.1
3444	Components (passive)	29.0	32.9	3.9
345	Other Electronic Equipment	125.3	129.8	4.5
	Total Manufacturing	398.0	404.0	6.0
Services				
7902	Telecommunications	231.7	219.6	-12.1
8394	Computer Services	56.0	62.6	6.6
	Total Services	287.7	282.2	-5.5
	TOTAL IT-Producing	685.7	686.2	+0.5
	% of all employees in employment (Great Britain)	3.2	3.3	
II. Predominantly IT-using Sector				
Manufacturing				
3221	Metal Working Machine Tools	38.8	31.5	-7.3
3289	Precision Engineering	207.4	158.8	-48.6
3710	Measuring, Precision Instruments	58.7	65.0	6.3
475	Printing and Publishing	351.3	348.8	-2.5
4930	Photo Cinematographic Processing	14.2	12.3	-1.9
	Total Manufacturing	670.4	616.4	-54.0
Services				
81	Banking	469.3	525.6	56.3
82	Insurance	225.1	246.7	21.6
83(-8394)	Other Business Services	798.5	918.6	120.1
94	Research and Development	119.8	134.5	14.7
9741	Radio and TV	69.3	72.8	3.5
	Total Services	1682.0	1898.2	+216.2
	Total IT-using	2352.4	2514.6	+162.2
	TOTAL	3038.1	3200.8	+162.7
	% of all employees in employment (Great Britain)	14.4	15.3	

Source: Employment Gazette, August 1984, April 1986

On the IT-using side, the difference between manufacturing and services is, as expected, far more clearcut. Most of the predominantly IT-using manufacturing sectors, defined here—again in a relatively narrow fashion—as "robotics", instruments (including precision engineering), and printing (including photocopying), witnessed significant employment losses over the last five years; in total some 54,000. By contrast, the predominantly IT-using service sectors, defined here as financial and business services, research and development, and radio and TV, saw their employment growth over this same period increase by some 216,000. The definition of "predominantly IT-using", particularly with regard to services, is of course highly subjective. We have included here most of the sectors suggested by the government's Information Technology Advisory Panel as belonging to the "tradeable" information sector. Some of these service sectors listed in Table 1 include undoubtedly also activities which are not really at the "core" of IT use in services. However, most of the sectors listed have witnessed a significant increase in tradeable activities as a direct result of the use of IT. This is certainly the case in banking where the further use and introduction of IT has allowed the gamma of services (including international service activities) offered by banks to increase significantly. Thus despite significant productivity gains in the handling of money, employment increased over the last five years by some 56, 300. In "other business services" (excluding computer services, which was classified as IT-producing) this is likely to be even more the case, with plenty of opportunities for new demand outlets, often, as in the case of the small instant print and photocopy shops, the direct result of the use of IT.

The total increase in employment in the IT sector over the last five years, taking into account both the producer and user sectors amounted to some 162,700. Primarily because of the inclusion of the predominantly IT-using service sectors, employment in IT represented in 1985 some 15.3% of total UK employment; in 1981 only 14.4%. This has to be set against the 3.3% of the IT-producer sector.

The IT sector discussed in more detail in the next section represents more than 30% of total industrial R & D. In terms of output, Table 2 provides some crude guestimates as to the contribution of the IT sector, and its main components, to GDP over the period 1978–84. That contribution according to our estimate has increased from 17.6% in 1978 to 22.3% in 1984. The IT sector is now more important in terms of its contribution to GDP than the manufacturing sector. Even services (excluding IT-services) have seen their share of GDP decline from 52.6% in 1978 to 50.3% in 1984. As indicated in Table 2 this is primarily the result of the rapid output growth in the IT-producing sectors, and the increase in "tradeable" output in IT-using services.

Table 2

The IT Sectors Share of GDP (in%): 1978-84

	IT-TOTAL	IT-PRODUCING			IT-USING			MANUF [5]	SERV [6]	OTHER [7]
		TOT	*MANUF* [1]	*SERV* [2]	*TOT*	*MANUF* [3]	*SERV* [4]			
1978	17.6	3.3	1.4	1.9	14.3	2.4	11.9	25.4	52.6	4.4
1979	18.2	3.5	1.5	2.0	14.7	2.4	12.3	24.5	51.9	5.4
1980	19.4	3.8	1.6	2.2	15.5	2.3	13.2	22.7	52.4	5.5
1981	20.2	3.9	1.6	2.3	16.3	2.3	14.0	21.6	51.1	7.1
1982	20.8	4.1	1.7	2.4	16.7	2.1	14.6	21.2	51.4	6.6
1983	21.3	4.4	1.9	2.5	16.9	2.0	14.9	21.1	50.9	6.7
1984	22.3	4.8	2.2	2.6	7.5	2.3	15.2	20.9	50.3	6.5
Average Annual Growth Rate 1978-84										
	4.95	7.33	8.68	6.26	4.35	–1.16	5.26	–2.26	0.30	5.82

[1] 1980 GDP weights: AH 330: 0.36; AH 3441: 0.279; AH 3443: 0.484; AH 3444: 0.195; AH 3452: 0.091; AH 3453: 0.202

[2] 1980 GDP weights: AH 7902: 1.832; AH 8394: 0.376

[3] 1980 GDP weights: AH 3221: 0.175; AH 3289: 0.339; AH 3710: 0.179; AH 3733: 0.042; AH 475: 1.605

[4] 1980 GDP weights: 81,82,83 (excl AH 8394): 10.650; AH 940: 2.270; AH 9741: 0.277

[5] excl. IT

[6] incl. construction, excl. IT

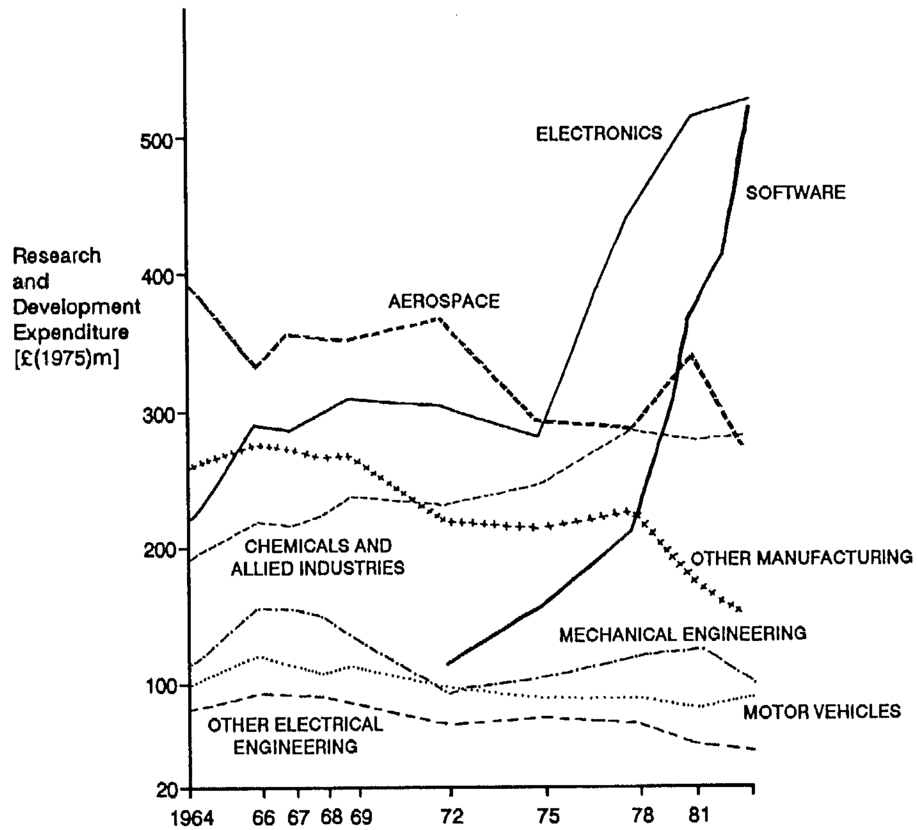
[7] incl. energy

INFORMATION TECHNOLOGY: THE TECHNOLOGICAL EVIDENCE

From a purely technological perspective, the importance of the cluster of information technologies is well recognized today. In terms of R & D expenditure e.g., the manufacturing arm of the sector (electronics, telecommunications, computers) represents now between 25 and 30% of total R & D in most OECD countries. With respect to the UK this percentage is nearer to 30%. However, as illustrated in the case of the UK in Figure 1, the sharp rise in electronics R & D over the last 20 years understates significantly the impact of IT because much of the technical change associated with computerization in industry and services takes the form of new software design and applications, which is not included in present definitions of R & D.

In Figure 1 the trend in software expenditure (in 1975 prices) over the period 1972–83 is given. By 1983, software expenditures were at about the same level of

total electronics R & D expenditures, having grown even faster over the last 5 years. Taken together these sectors, corresponding relatively closely to the concept used earlier of the "IT-producing" sector, amounted by 1983 to just over 50% of what could be baptized as R,D & S: Research, Development and Software. In 1975 this figure was only 28.7%. The information technology R,D & S total has increased over the period 1975–1983 at an average annual growth rate of some 11.25%.



Source: Soete (1987)

Figure 1

Intra-Mural Expenditure on Research and Development at 1975 Prices

The contribution of software expenditure in this IT total is particularly impressive and points at a more general level to the increasing importance of services in bringing about technical change. Richard Barras [1983] has suggested that as some service industries, such as financial services, increase their capability in the design, development and maintenance of new software systems, they will become important sources of new innovative services used elsewhere in the economy i.e. they will tend to become IT-producers as well as users in our terminology.

As we emphasized in the first section, one of the most specific features of IT, which elevates it, in contrast to many other R & D intensive sectors, to the rank of "pervasive" technology is its widespread user impact. We report here briefly on an attempt at measuring the extent of this "pervasive" impact. The analysis relates to innovation data developed in 1981–82 by the British Technology Group in collaboration with the "Financial Times" based on "news" coverage, i.e. a sort of "innovation" bibliometrics. The advantage of this data set is that it not only consists of a rather wide spectrum of reported "innovations" (some 1500 per quarter) classified at a relatively detailed level of disaggregation but also that it provides information as to the origin of the sector of the innovating firm and the sector of potential use.

This allows one to map out in a relatively straightforward way an origin/use "innovation matrix". Such an input/output matrix, covering all countries for the period 1981–82, is represented in Figure 2. The total for the IT-sector, some 611 reported innovations, represents just over a third of the total number. The significant diffusion user potential of the IT-sectors emerges quite strongly from Figure 2. Only with regard to plastics does a more or less similar broad user pattern emerge.

Figure 2 highlights also the importance of the IT control and measuring instrument sectors. These sectors have been, together with the electronics industry itself, among the first to witness their own "electronification" [McLean and Rush, 1978; Freeman, 1982]. These same sectors are now also at the heart of the further diffusion and use of IT-equipment.

CONCLUSIONS

Information Technology is likely to open up many new areas of "trade", particularly in the service sector. Over the last 5 years, employment in the UK in IT, including both an IT-producing and predominantly IT-using sector, increased by some 163,000. On a similar definition basis, it was estimated that IT represented some 22% of total GDP in 1984; a more important contribution to GDP than manufacturing. With regard to what was baptized Research, Development and Software, IT, taking into account software expenditures, represents now more than 50% of total UK R,D & S. Finally with respect to international trade, it was argued that IT will open up an increasing gamma of services to international trade, possibly lifting to some extent the manufacturing balance of payments constraint on recovery growth in the UK.

Overall thus, as the UK case study illustrates, the emergence of IT over the last decade as a new pole of economic growth is clear cut and by any standard impressive. However, the potential impact of IT on the growth and "efficiency" of the rest of the economy will, we would argue, be even more important and

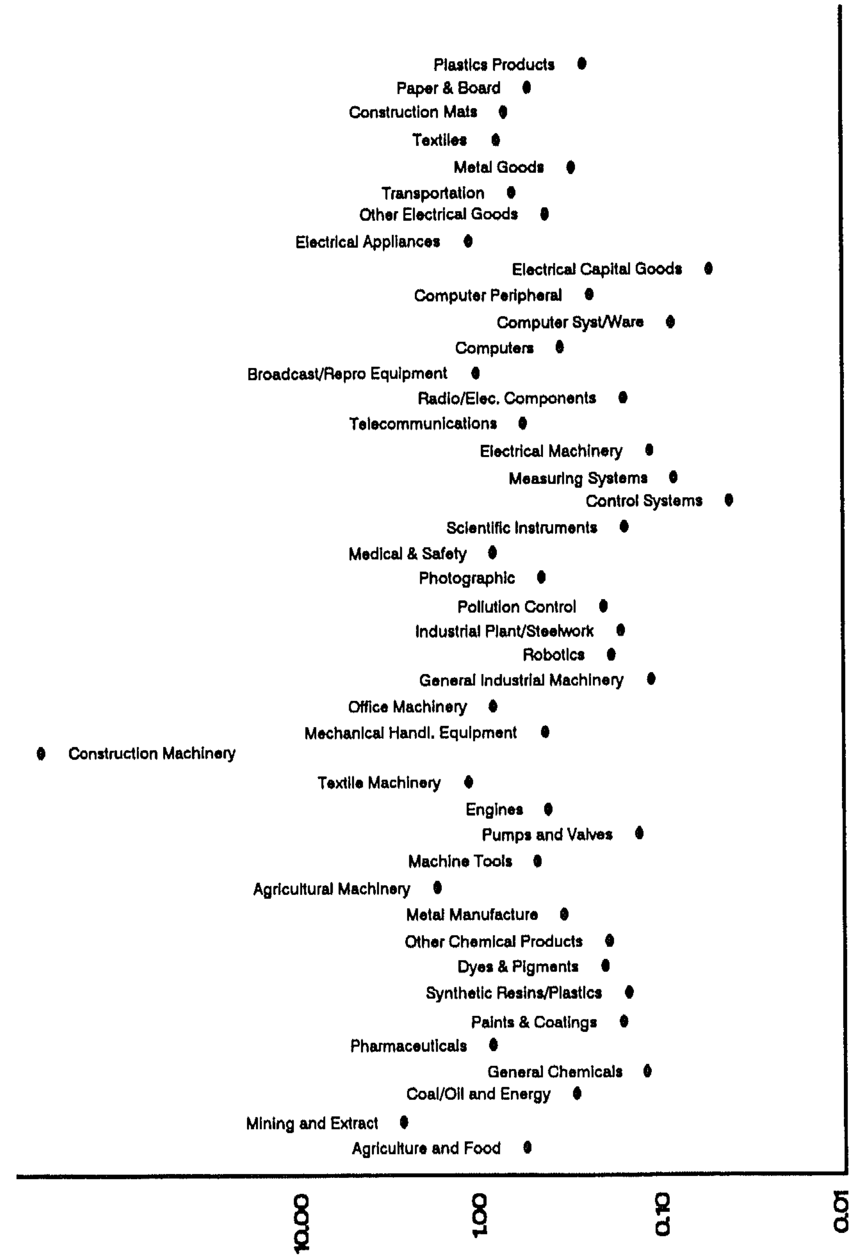


Figure 2

emerge as an even more striking feature of the pervasive impact of the new technology.

The possibility to collect, generate, analyze and diffuse enormous quantities of information at minimal cost affects the productivity of all factor inputs. It is this feature which distinguishes information technology in its economic impact so clearly from automation. Some of the most significant productivity gains linked to the introduction of IT relate to more efficient inventory control, as well as significant energy, materials and capital savings. The potential future growth and efficiency impact of information technology is from this perspective by any standard enormous; it amounts as we have argued here to a technological transformation, a new techno-economic paradigm.

IT represents indeed a formidable challenge in terms of the required need for radical institutional change. Most of our present institutions were created under and are still geared towards the older technological paradigm. These institutions, with their self-perpetuating interest groups represent the most formidable barriers to the rapid diffusion of IT and the realization of its potential growth and productivity gains.

The scope of the institutional change needed is still under-estimated. It will involve changes in the educational and training systems; in management and labour attitudes; the pattern of industrial relations and worker participation; in working arrangements; in the pattern of consumer demand; in the conceptual framework of economists, accountants and governments, and in social, political and legislative priorities.

Perhaps the most important point is that "intangible" capital investment must now be recognized, in its own right as more important than the transitory physical capital investment, which is today still the main focus of attention for most managements, accountants and economists. For a long time already firms in the computer industry (and other R & D intensive industries) have devoted greater resources to R & D, Education and Training Information Services, Design and Software Development, than to physical capital investment. This balance will now be tilted even more towards intangible investment as the information system available to firms, government departments and other institutions is becoming its most critical resource. There is of course a very close link between the "intangible" software, and the "tangible" hardware in an information system, but it is increasingly necessary for the "intangible" resources to be recognized fully as the main focus for strategic long-term development. This means that they must be considered as a form of investment and not as consumption or current expenditure.

This applies both to formal information systems and data banks and to the costs of developing, educating and training the people involved. Particularly the scale of the change in skills and in occupations is still under-estimated. Even in a period of high unemployment there are persistent skill shortages for certain types of labour, particularly in relation to electronic engineering, software designs, and systems analysis. In addition, there are many types of skilled people whose level of training and qualification is inadequate for the new types of work which they are being called upon to perform, or ought to be able to perform.

This applies perhaps most of all to management at all levels, but it also applies to many types of craftsmen, who frequently lack the requisite combination of electro-mechanical with electronic skills.

The information "revolution" also affects the whole climate and conduct of industrial relations. In principle it would be possible to introduce computerization in the style of "1984". It does make possible the most sophisticated centralized type of "Big Brother" time and motion study, whether of sales workers in a supermarket, or of miners operating an underground shearer-loader, but it also makes possible a very high degree of decentralization, local responsibility and initiative if the computerization and information systems are designed in that way, and if industrial relations are properly conducted.

Computerization could also facilitate the introduction of much greater flexibility in working hours. In many occupations, flexi-time has already been introduced, and the scope of this will be increased. Part-time work and work-sharing are likely to become more widespread. But here again this social change can take a variety of different forms. It could be introduced as a means of depressing wage levels and of reducing social insurance benefit, if part-time workers, are treated as a lower grade type of labour. Or it could be introduced mainly as a response to the desire of many workers, male as well as female, at various stages of their working lives to work part-time, so that they can spend more time with young children, or pursuing education and training, or other activities. It ought to be possible to humanize working arrangements in this way, but it will not be easy in view of the enormous strength of the old management and union attitudes. The involvement of the social services and humanities in developing social policies is just as critical as the technology itself.

The institutional framework for future economic recovery is only now being shaped. Most of our institutions and ideologies are still geared to the old post-war technological paradigm. Only through social and political debate and conflict shall we determine how we re-shape our institutions and our way of life to match the potential of the new technology and to humanize its innumerable potential applications. The new patterns of employment which will emerge should be of a kind which encourage great variety in hours of work and in continuing education and training, but which ensure to everyone, who is seeking paid employment, the opportunities to work in socially useful activity. This should mean a renewed commitment by society to the goal of "Full Employment", but in a new social context which takes account both of changes in technology and of changes in society.

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Growth, Productivity and Innovation
Theories and Facts

Riccardo Petrella

Summary: *The first section describes two major concepts concerning the role of technical change, and in particular of Information and Communication Technology (ICT), in productivity gains and growth. Present trends in real life, however, do not correspond to the theories. The second section, therefore, deals with the "gap" between theory and reality.*

THE WEALTH OF THEORIES

A (still) Linear Concept, and Related Policy

Though economists differ in the way they assess the role of technical change in the economic growth (depending on whether they belong to the classical economists, the neo-classicals, the Keynesians, or the structuralists),[1] they share a basic view: technical change increases productivity and this will be reflected in an increase in real aggregate income; thus, technical change is a determinant factor in generating growth.

Applied to the specific family of technologies that is represented by Information and (Tele) Communication Technology (ICT), such a view is even more strongly shared, due to the fact that almost everybody (including economists) agrees with popular view that ICT are the main source of the so-called "third industrial revolution".

What is important to note here is still that of a linear concept of growth: from knowledge to technology, to "industrial" productivity, to growth (see Figure 1).

In accordance with this concept, most public (national) technological development and innovation policies tend to follow a linear process. They give, first, top priority to measures that are destined to support R&D activities in order to enhance the capability of the system to supply new knowledge and new key technologies in areas such as semiconductors, microprocessors, new materials.