Diffusion of ICT from the view of ICT generation: The experience in the UK during the 1980s *

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Abstract

This paper aims to provide a better understanding about how Information and Communication technology (ICT) has diffused. The investigation is conducted with the consideration of ICT evolution in terms of technological change and usage pattern. The definition used is presented as 'the ICT is a process of convergence of technologies between information-processing and information-transforming technologies, mainly due to the advent of microelectronics'. After examining technological changes of ICT, the diffusion path of ICT is traced through the usage ratio in total input and/or investment based on Input-Output tables (I-O). It shows that the evolution of ICT from the change of usage pattern is an up-and-down usage pattern rather than a uni-modal usage time path. With this recognition, the diffusion index is prepared.

JEL classification : C43, L63, O33.

Key words: ICT, diffusion, generation

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1. Introduction

Since the invention of early computers, there have been many concerns about newly emerging phenomena, for instance the importance of information. Freeman and colleagues (1982, 1988, 1997) focused more on the technological aspects from the perspective of long-term structural change and defined 'information and communication technology' (ICT) as the convergence of computer and telecommunication technology. In line with this definition, Miles and Matthews (1989, 1992)[1] suggested the boundaries of ICT: 'office machinery and computer equipment', 'telecommunications equipment', 'electronic components and subassemblies', 'instrument engineering', 'telecommunication services'. Recently, Hawkins, Mansell and Steinmueller (1997)[2] expanded the boundary to include media, and showed the percolation between older ICT and the media.

The research focuses on the embodied technological aspect of the commodities and services used as inputs in each industry. It follows Freeman's definition and Miles and Matthews' boundaries of ICT, with slight modifications. In this research, ICT is defined such that:

> The ICT is a process of the convergence of technologies between information-processing and information-transmitting technologies, mainly due to the advent of microelectronics.

This research introduces subdivided ICT boundaries such that: the inclusion of semiconductor and telecommunication equipment in ICT is called 'widely bounded ICT' (wICT) and their exclusion 'narrowly bounded ICT' (nICT). When the exclusion of computer-unrelated telecommunication is required, the Computer (COM) is used as an even more narrowly bounded ICT. In the other way, a set of computer equipment, telecommunication equipment and instrumentation including semiconductors is called the hardware part of ICT (hICT) and another set of computer services and telecommunications is called the software part of ICT (sICT).

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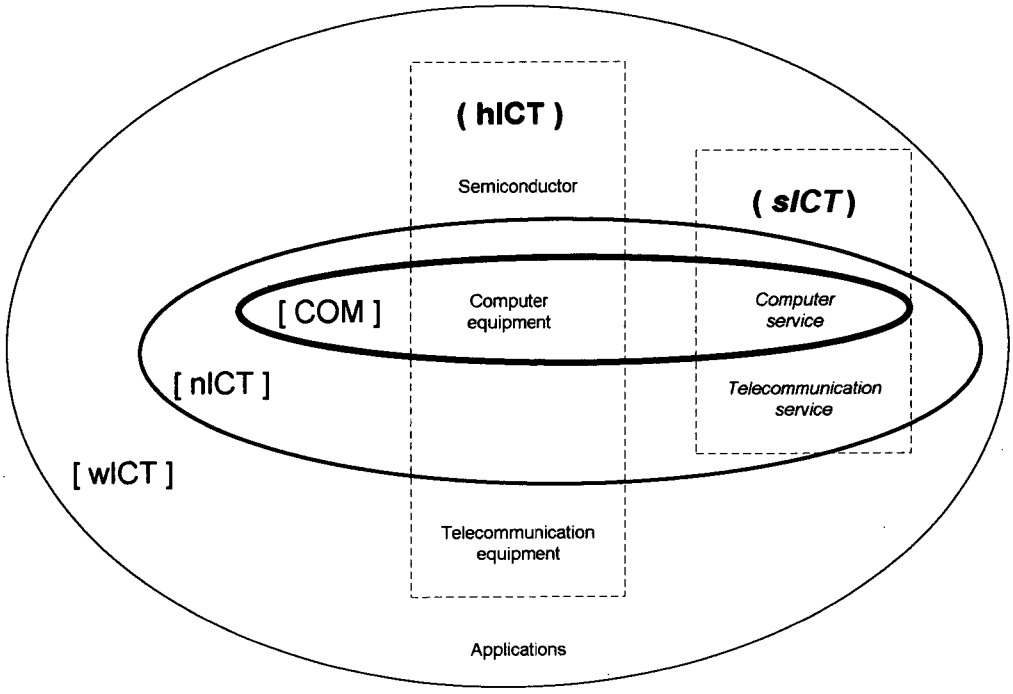
1 They themselves express this as IT (Information Technology).

Figure 1 **Boundary of ICT**



With the above definition and boundary of ICT, the following three propositions are argued. First, the development of ICT is an evolutionary process. ICT is an expanded set and expressed as 'a process' in the definition. When there are newly participating elements, the expansion of ICT can be said to take place. Secondly, the driving force of the evolutionary process seems to be the expansion of computers and technological improvement. The convergence of computing with communication is crucial in the evolution of ICT. Furthermore, with the hardware expansion, another positive force came from the development of software part, whose development reduces the required access-skill for the computer and could accelerate the evolution of ICT. Thirdly, there is a shift in the role of several driving forces over time. In the early period, the role of hardware technology absolutely influenced the maturing of ICT. After a certain stage, this became weaker and the role of non-hardware technology increased. Furthermore, the importance of outer-ICT also increased. It seems that the evolution of ICT became a more co-evolutionary process, interacting with social evolution including changes in

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[2] They used ITEC (Information Technology, Electronics and Communication).

the human factor.[3]

The role of technology is widely believed to be becoming more crucial in economic growth and in many other social changes.[4] It is also broadly accepted that technological change is brought about not only by invention and innovation but also by diffusion. Whereas invention and innovation represent the genesis of technical change, the diffusion is its realisation. Diffusion of technological change can be defined as "the process by which an innovation is communicated through certain channels over time among the members of a social system" (Rogers, 1995: 5). It is generally accepted that diffusion takes time and shows an S-shape from the accumulated degree of diffusion: slow expansion in the early stage, fast during the expansion stage, then a later mature stage with slow expansion, and ultimate decline. Since the early establishment of this pattern, diffusion studies have tried to give better justification of the S-shaped trend, which is briefly reviewed here.[5]

Since the early diffusion of diffusion theory during the 1960s, the typical approach developed consisted of the epidemic model, which came from the application of epidemic phenomena - a gradual adjustment over the course of time. For example, Mansfield (1968) considered information imperfection and uncertainty and suggested the role of learning from experience.[6] It focused on the differences in individual adoption of new technology. The S-shaped pattern is explained by the decreasing individual differences through the expansion of information or messages. The individual-based diffusion model, such as Mansfield's model, usually assumed that the population of potential adopters is homogeneous and constant over time, and that the

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[3] However, this paper focuses on the first and second arguments. For the further discussion and empirical analysis about the third argument, see Hwang (2001).

[4] For a broad survey of technological change, see Freeman (1994); a more in-depth survey and theoretical findings related to economic growth is given in von Tunzelmann (1995); the importance of technology in history and society can be found in Schumpeter (1943[1996]) and Landes (1969).

[5] For fuller literature surveys, see Sahal (1976), Karshenas and Stoneman (1995), and Metcalfe (1995).

[6] The use of new technology is constrained by the number who know of the existence of that technology and are convinced about its profitability. As time proceeds, the existence of users leads to its spread to non-users who in turn become users, leading to a further spread of information.

nature of the technology is unchanging over time.[7]

In observing the diffusion of ICT, which will be shown later, it is believed that there is significant heterogeneity and variety over time in the adopter group, which consists of industries in this research. Even within each industry there is an S-shaped diffusion pattern, moreover each industry can have a different diffusion path, a different starting point for the diffusion, a different diffusion speed, and a different saturation point. In this view, the diffusion seems to be more related to social learning processes or interaction processes. The diffusion process interacts with the sequence of artefacts, developing and improving within a set of closely-related design configurations.

This brings in the concept of co-evolution and the techno-economic paradigm, developed by Freeman and Perez (1988). Since design configurations are typically built in this cumulative fashion through interaction and positive feedback with their environment, past diffusion experience shapes the reaction to current constraints which limit diffusion. Therefore, diffusion could take a path-dependent form. The reason for a different diffusion lag between different adopters as well as the S-shape diffusion pattern can be provided by path-dependent co-evolutionary technological change. Some adopters express a strong motivation towards the new technology with easier adaptability, and tend to be earlier adopters. Others are more weakly motivated towards the new technology with harder adaptability, and tend to be later adopters.

However, this paper is limited in its focus on the diffusion pattern rather than full study covering related issues, i.e. co-ordination between diffusion of ICT and environment, etc.[8] In the following section, a modification of conventional approach to diffusion is discussed. After that, the evolution and the usage of ICT are investigated. Next, industrial comparisons of ICT diffusion is examined. Finally, the index of ICT

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[7] Even though there are many different approaches to diffusion modelling, here the focus will be on some of the work after the basic epidemic model that is relevant to the research.

[8] The set of closely-related design configurations includes organisational and institutional change as well as skill and knowledge-based dimensions. In the early stage, the less well-matched environment prevents fast diffusion, even where diffusion is wanted. The constraints and problems which mark out a diffusion path, together with the market incentives in terms of relative factor costs and user valuations of different performance characteristics, are directly

diffusion by industry is prepared and its possible applications are suggested.

2. Modification of conventional approach to diffusion pattern

Following Sahal (1976), the diffusion of process innovations (quantitative aspects) can be distinguished from the diffusion of product innovations (qualitative aspects). The difference between them lies in their treatment of sequential innovation. In short, the diffusion of process innovations focuses on a single diffusion phase over a relatively short period, while the diffusion of product innovations is more concerned with long-term technological change, allowing sequential multi-diffusion phases. The diffusion of product innovations is considered from an evolutionary viewpoint.

The diffusion paths can be differently expressed as a cumulative diffusion path which is the conventional diffusion path, below called 'cumulated diffusion', or as an individual diffusion path which is the diffusion path explored in this research, below called 'diffusion'. Following standard diffusion theory, the cumulated diffusion curve is expected to follow an 'S-shape', and the diffusion path is expected to be a 'bell-shape' has in Figure 2. In the increasing stage of the diffusion, which is the convex part of the cumulated diffusion curve, the growth rate of diffusion is positive. Conversely, in the decreasing stage of the diffusion, which is the concave part of the cumulative diffusion curve, the growth rate of diffusion is negative.

Figure 2 **Diffusion over time**

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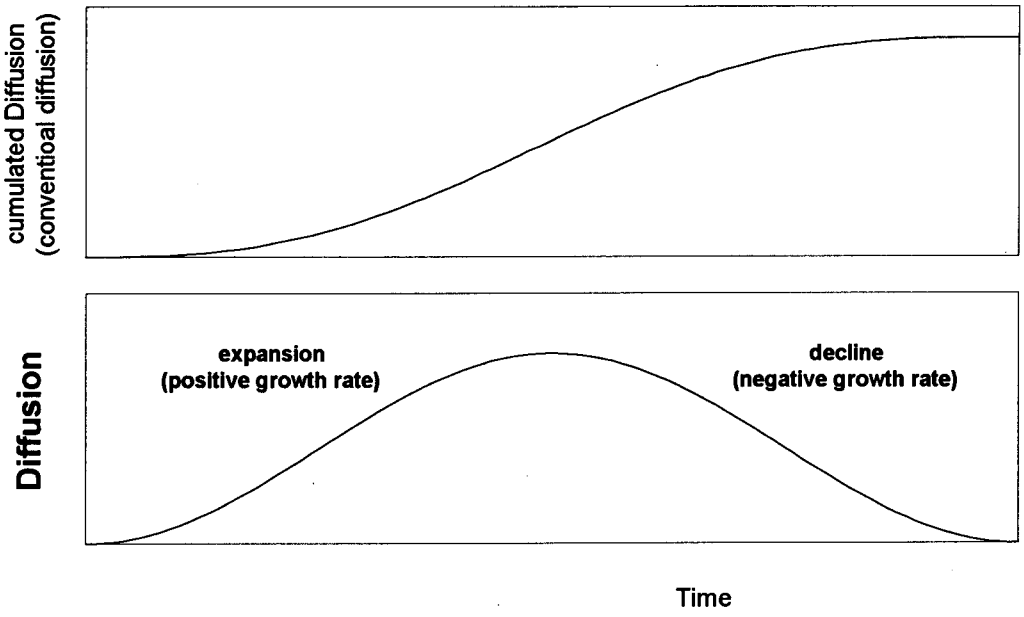
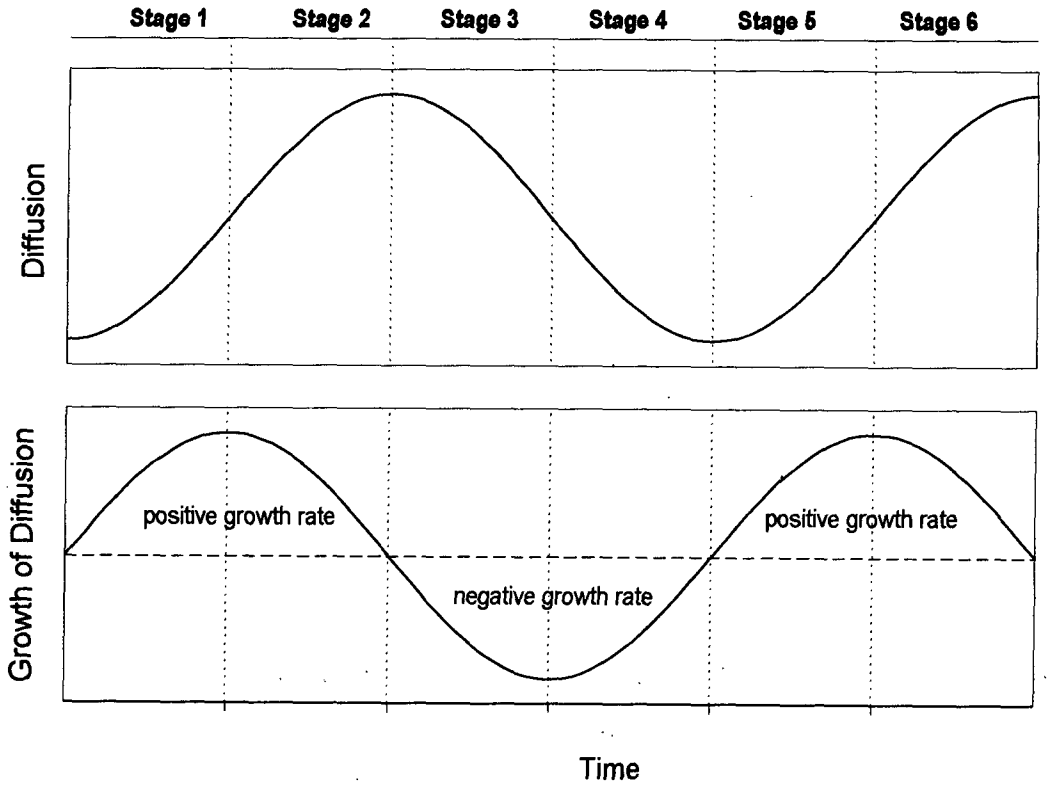
related to the pattern of diffusion. For the discussion and an empirical study about that, see Hwang (2001).



Furthermore, from persistent technical change, typically there might be an up-down-up pattern in the diffusion path: after the maturity of an early generation, it re-expands for a new generation. The interval of re-expansion is not the same in each industry, and some industries accept the new generation before reaching the mature stage of the old generation. When the diffusion pattern appears shaped as an up-down-up pattern (a Sine-shaped curve), the growth rate diffusion, which is the first derivative of the diffusion, also shows an up-down-up pattern. Analytically speaking, the derivative of a Sine function is a Cosine function. The diffusion pattern and its growth pattern can be described as in Figure 3. It is expected that within the Stages 1, 4 and 5 of this Figure, a lower growth rate of ICT will be observed at a relatively early period within each Stage. Conversely, within the Stages 2, 3 and 6, a lower growth rate of ICT is expected in a later period within each Stage.

Figure 3 **Stage of Diffusion**

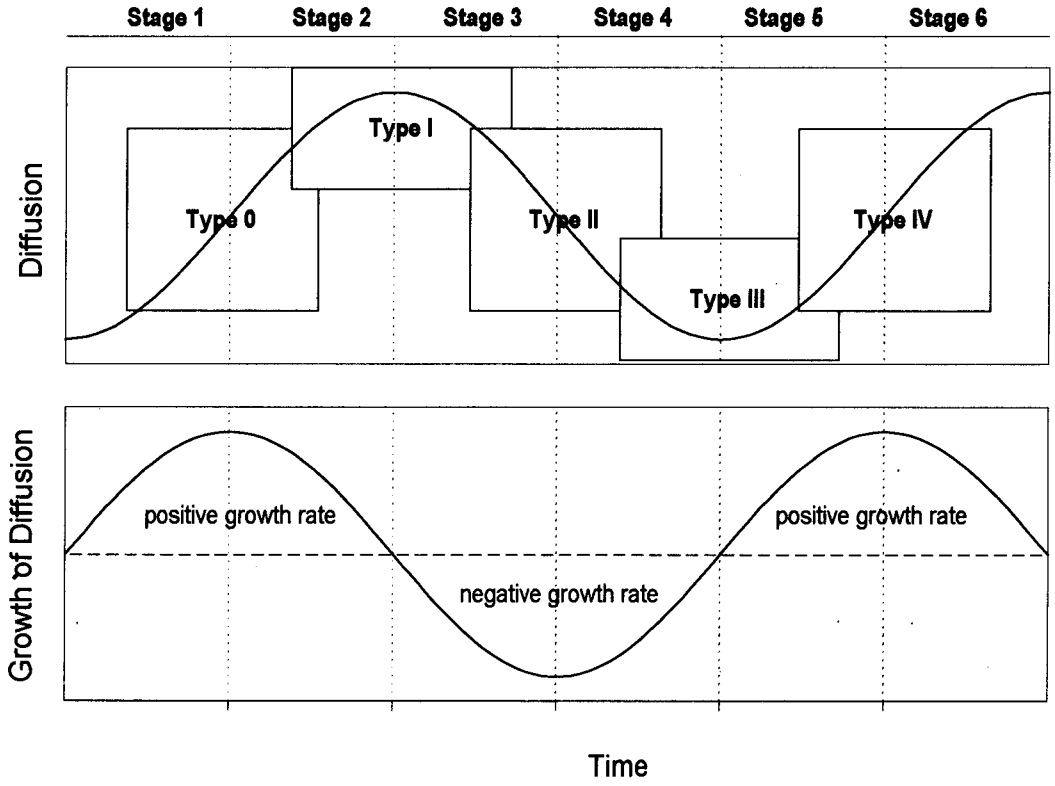


Stage 1 shows an increasing growth rate with positive growth rate. Analytically speaking, the first derivative and second derivative are both positive ($f' > 0$, $f'' > 0$). In other words, the expansion of ICT is shows a fast increase and early expansion. In Stage 2, there is a positive growth rate but the growth rate is decreasing ($f' > 0$, $f'' < 0$). The expansion of ICT is still experienced but the expansion is getting slower, as a later expansion. In Stage 3, the growth rate appears as negative with the growth rate decreasing ($f' < 0$, $f'' < 0$). The investment of ICT decreases with fast decreasing speed, as an early shrinkage. In Stage 4, the growth rate remains negative but the growth rate is increasing ($f' < 0$, $f'' > 0$). The investment of ICT still decreases but the speed of decrease lessens, as a later shrinkage. Stages 5 and 6 are similar to Stages 1 and 2. The difference between them is that Stages 5 and 6 are re-expansion after the decline through Stages 3 and 4.

As later generations appear, the diffusion path is no longer a single 'S'-shape but a mixed path allowing more than one modal value. A typical one is the up-down-up pattern: after or even before the maturity of an early generation, activities re-expand for the new generation. However, the interval of re-expansion is not the same in each industry, and some industries accept the new generation even before reaching the

maturity stage of the old generation. Therefore, the industry diffusion pattern can be distinguished as being of several types.

Figure 4 **Diffusion of ICT**



Further detailed investigation into the diffusion of ICT is conducted in section 4, based on UK I-O. During the mid 1970s to 1990, several kinds of diffusion path can be expected from the viewpoint of successive generations. All of them could be regarded as a part of a typical pattern or a variant. A purely increasing pattern could be an earlier stage of Type I, here called Type 0. Type I may be the early part of a typical mixed diffusion pattern, decreasing after saturation. The later part of this typical mixed diffusion pattern is a declining path followed by an increase (Type III). Between these, there could only be a declining path (Type II), if any at all, as a stage between Type I and Type III. A final type follows an increasing path only (Type IV) as a later stage of Type III. Some industries already highly involved in early generations again accept new generations. On the opposite side, some industries are reluctant to accept ICT, and are just involved during the pervasive expansion era of ICT.

3. Evolution of ICT

The advent of ICT has not come about as an outbreak in any one period but the early part of an evolutionary process. While the explosion of the Internet during the late 1990s clearly shows the advance of ICT, its birth is quite ambiguous. Here, the evolutionary stages are traced in showing how the ICT has grown up into its present form and how the pattern could be characterised.

Since the advent of the computer, the integration between computers and communications can be regarded as the main evolutionary path of ICT. The integration of computing with communications is considered the genuine evolutionary trajectory of ICT. In the comparison of computer and telecommunication, there are no differences in their principles in terms of structural logic and connection. Even though the interface between computers and communications was anticipated and required since this early stage, the lack of 'standards' remained one of the most significant barriers. Consideration was given to the problems of co-ordination, synchronisation, error control, signalling, stream multiplexing and switch control, in addition to minimising the technological interdependence.

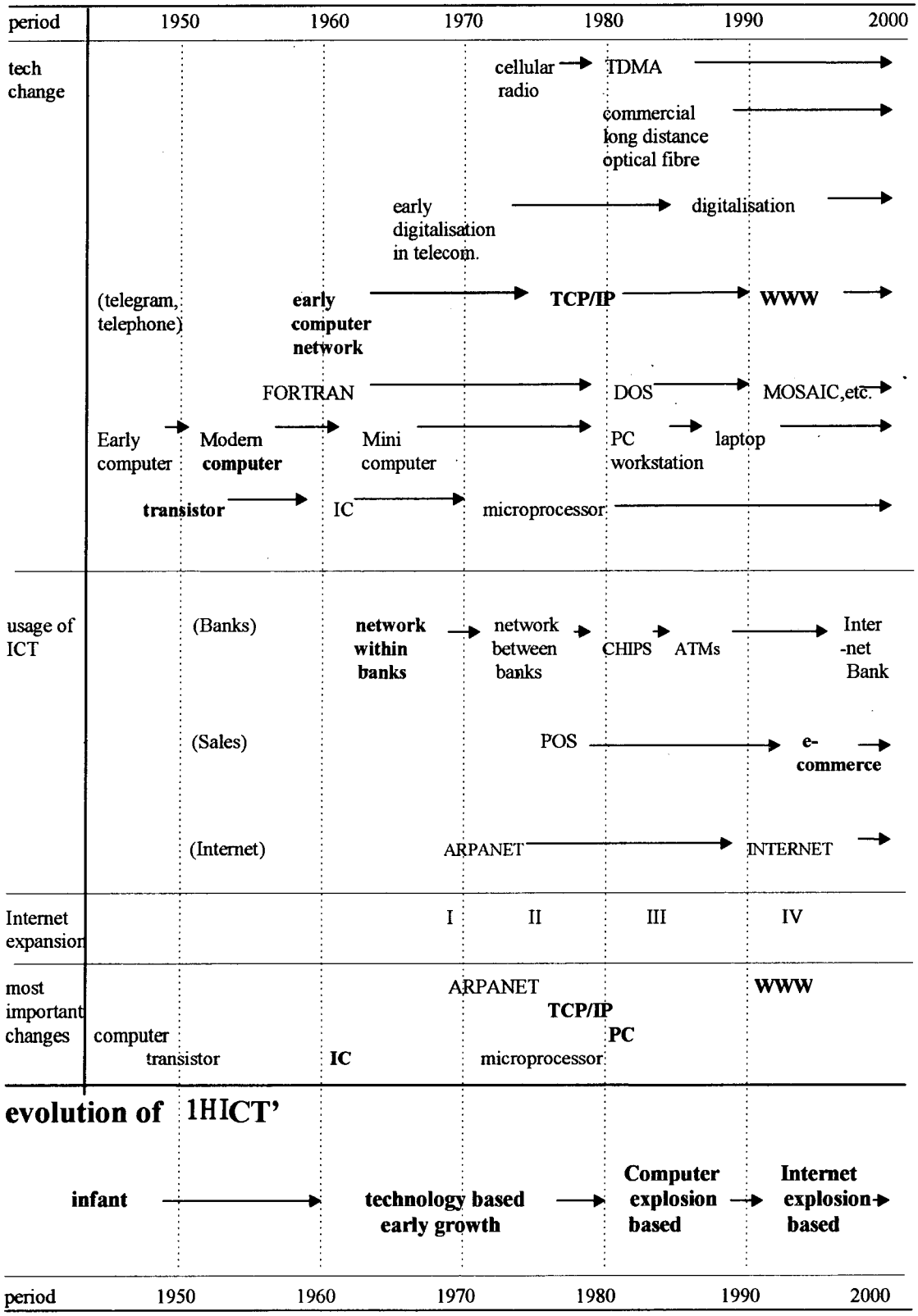
Soon after the early usage of computers, there was a high demand for computer communication, in terms of terminal-computer communication. Moreover, the power of microprocessors rapidly increased and the computer became widely diffused, expanding its applications to every aspect including various business operations. With the expansion of the computer, the need for interconnection between different vendors' systems became quite apparent. This brought a necessity for interconnection.

The development of ICT as defined in this research is intimately connected to the development of the computer and the integration of computers with communications. The advent of the modern computer is evidently the seed or origin for the growth pattern of ICT and is easy to regard as the most important step in the whole evolutionary process. However, it still remained as just a computer rather than a part of modern ICT, which implies the convergence between computing and

communication. The real advent of ICT awaited the development of related technological changes and the expansion of computer applications, associated with the appearance of early computer networking. Since the mid-60s, the shape of ICT has evolved into the modern ICT. Commercial applications in banks and retailing seemed to play a major part in this, as already noted. These converged with less commercial developments linked to the evolution of the Internet, following ARPANET in 1969 and the standard protocols, Ethernet in 1972 and TCP/IP in 1974.

Based on the improvement of microprocessors and other computer-related semiconductor technologies, the PCs and workstations that appeared in the early 1980s allowed the pervasive expansion of computer networking, and the technological improvement of communication also accelerated. With the first public packet data service having appeared in 1974, the first commercial provider of Internet dial-up access was launched in 1990, and the introduction of the WWW in 1991 allowed user-friendly access to the Internet. This caused an explosion of the network through the reduction of the knowledge required, as already implied.

Figure 5 **Evolution of ICT with related changes**



source : Hwang (2001: 160)

- The 'infant' of the advent of modern computer preceding early computer networking. The advent of the modern computer opened a new period of ICT but still too early to show the modern ICT involving the convergence of computing and communication.

- The 'early growth' from the mid-50s to mid-60s. During the early computer expansion, there was a rising need for computer networking, which brought early steps in the convergence of computers and communication as an important step towards the ICT evolution.

- The 'technology-based growth' from the mid-60s to early-80s. During the 60s, banks introduced the computer network for their business, which seems to be the first major commercial usage of ICT. With many important technological improvements during the 70s and early 80s, the points of convergence of computing and communication accelerated.

- The 'computer-explosion-based growth' from the early-80s to early-90s. The explosion of computing with the advent of the PC and workstation in the early 80s allowed ICT to become a crucial part of society in many ways.

- The 'Internet based growth' since the early-90s. Though there was already an expansion of the Internet with the computer explosion during the 80s, the easy accessibility based on the WWW brought the explosion of the Internet during the 90s. This allowed for the public to be more actively involved in ICT.

From the industry pattern of the ICT diffusion path[9] as well as the ICT evolution path, three generations of ICT have been proposed. Since the emergence of the computer to open the era of ICT, the early computer attained only limited objectives in limited sectors. The ICT based on this early computer is regarded above as the 1st generation.

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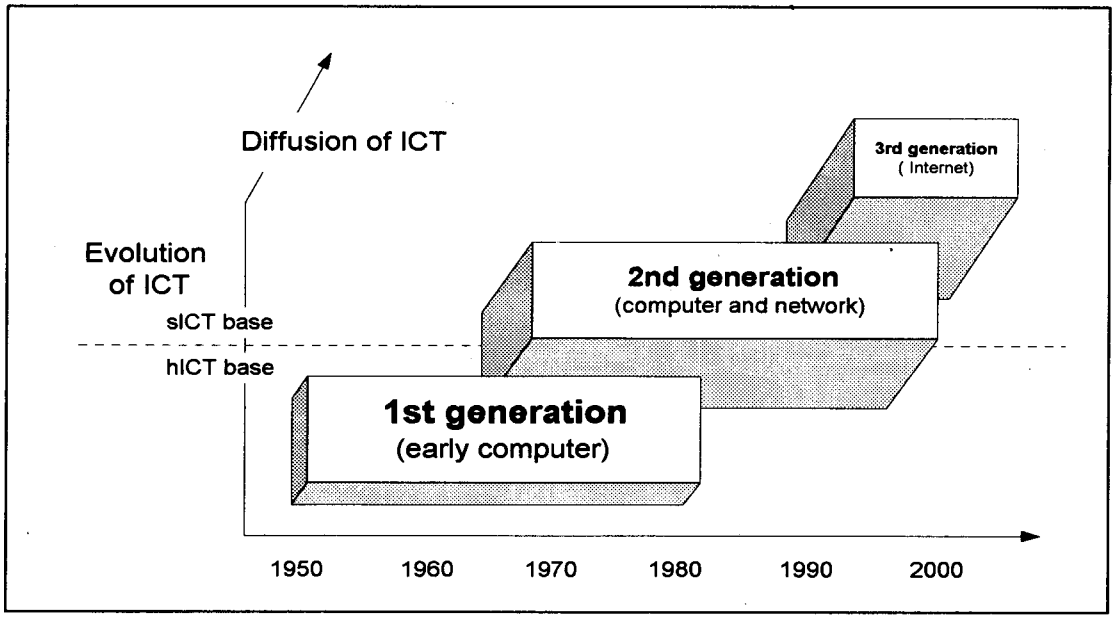
[9] It is re-investigated in terms of industry aspects in the next section.

Due to quality improvement and relative price falls, the computer extended its applicability and pervasively diffused to the whole economy, especially during the 1980s. Computer networks, which can be regarded as the emergence of a second generation, were already launched during the 1960s. The explosion of computers during the 1980s is regarded as the expansion of the 2nd generation of ICT, from the viewpoint of the industry pattern of the ICT diffusion path.

The 3rd generation is regarded above as the real merging of computers with communication, though already communication was merged with computers during the 2nd generation. Compared to the restricted merging in the 2nd generation, the 3rd generation allows any computer to be connectable to any other. Connection through telecommunication became popular and telecommunications became a hub of the new generation of ICT. With the explosion of the Internet during the 1990s, 'ICT' became a common fact of life.

Figure 6 **Diffusion and Evolution of ICT (I)**



4. Usage of ICT

ICT is now highly diffused across the whole of society. In 1990 in the UK, total ICT expenditure except for general consumers was already £45.2 billion and 8.2% of a GDP amounting to £549 billion[10]. Of this total, 57% consisted of the hardware part, which means computer equipment and telecommunication equipment, instrumentation etc., and 43% of the software part, which means computer services and telecommunications.

The expenditure on computer equipment is available from the 1974 I/O. The merged expenditure from input and investment is £657 million in 1974 and had become £9,021 million by 1990. Compared with other hardware parts of ICT, which include electronic components, telecommunication equipment and instrument engineering equipment, the faster expansion of computers is apparent. Computer services are separately treated since the 1990 I/O and show even faster increase than computer equipment,[11] being followed by telecommunication, which appears from the 1984 I/O.

Table 1 **ICT input and investment: 1974~1995** (unit: £ million)

	Input					Investment				
	1974	1979	1984	1990	1995	1974	1979	1984	1990	1995
computer eq.	155	508	1,395	3,641	6,446	502	904	2,499	5,380	8,534
other hICT	1,206	3,392	7,037	10,768	17,441	1,079	1,709	2,984	6,093	6,882
computer serv.	n.a.	n.a.	n.a.	9,465	14,117	n.a.	n.a.	n.a.	604	3,217
telecomm.	n.a.	n.a.	4,493	9,264	14,966	n.a.	n.a.	0	0	137
Int. Input / Int. Investment	90,798	183,577	333,557	505,240	725,527	14,939	35,538	55,388	110,106	116,360
Total Intermediate	105,737	219,115	388,945	615,346	841,887					

Key: 'Total Intermediate' = 'Int. (=Intermediate) Iput' + 'Int. Investment'.
Source : Own elaboration from each I/O and I/O balance.

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[10] The amounts and shares for each industry and service are shown in the industry comparison following section.

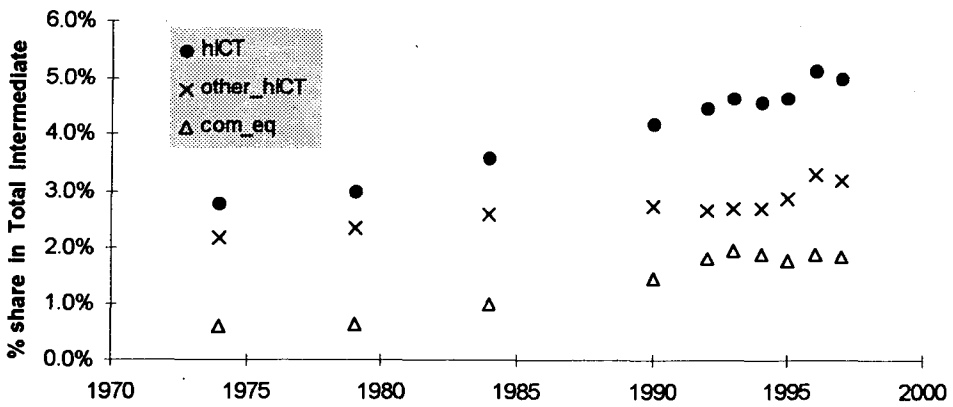
[11] However, it was also influenced by the boundary change of computer services before and after 1990. The maintenance and repair of computers is included in computer equipment in the 1990 I/O but in computer services since the 1992 I/O balance. Therefore the increase of computer service expenditure between 1990 and 1995 should be lower than the difference based on the table, if same boundary were to be kept, conversely the real increase of computer equipment should be higher. However, despite the boundary change, the trend is supported from further comparison of periods.

During the 1980s, the hardware part of ICT (hICT) share shows a generally increasing trend. Decomposing the trend into investment vs. input and into computer equipment vs. other hICT allows more detailed description. Computer equipment investment is believed to be the main driving force of the expansion of hICT, and ICT as a whole, during the 1980s. In 1974, it was less than half of other hICT investment but increased rapidly during the 1980s and overtakes the investment of other hICT in the early 1990s.

The hICT input has different characteristics from hICT investment. Even though hICT input can be treated as a kind of barometer of ICT, it has a different role in the ICT diffusion. Much of it is used by the ICT producing industry, such as in the Electronics industry and Telecommunication Services. In this research, the usage aspects of ICT are the main concern rather than the aspects of production, and the examination of hICT input is conducted in relation to the whole trend of ICT.

During the 1980s, Computer equipment input remained at a relatively low level but the increase of other hICT input was slower than that of computer equipment investment. During the 1990s, the acceleration of hICT investment is slowing down. It seems that the 1980s is an expansion stage of hICT investment mainly due to computer equipment, and that the 1990s is a relatively mature stage of computer equipment investment.

Graph 1 **hICT time pattern: 1974~1997**

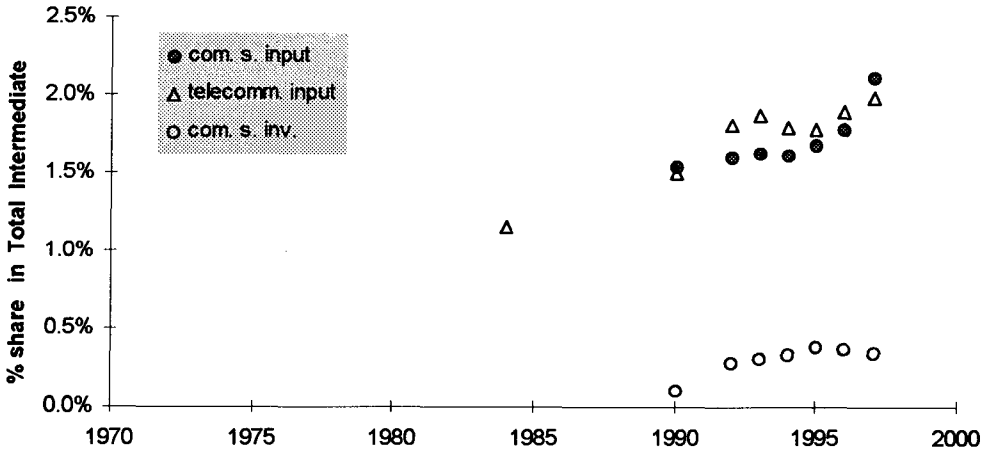


Source : Elaboration based on Table 6-1.

In the case of the software part of ICT (sICT)[12], it is mainly used as input rather than as investment. Telecommunication services seem to have expanded until the early 1990s and re-expanded since the mid-90s. When it started the re-expansion, the telecommunication share shows some similarity to the pattern of computer service input. The computer service input is relatively stable with computer equipment investment during the early 1990s and shows a fast increasing pattern since then. Telecommunication also shows an increasing pattern after the stable pattern in the early 1990s. In the case of computer service investment, it seems to be a steadily increasing pattern in the early 1990s and decline or at least stability after that.

Even though the relatively short period with annual data prevents any strong argument for the time pattern, and especially for any pattern change, the technological development of ICT discussed above supports a pattern change. The increasing importance of sICT input suggests the expansion of the next generation of ICT, which involves the merging of computers and telecommunications. The role of telecommunications and computer services have become crucial in the diffusion of ICT since the mid 90s compared with the earlier period.

Graph 2 **sICT time pattern: 1984~1997**



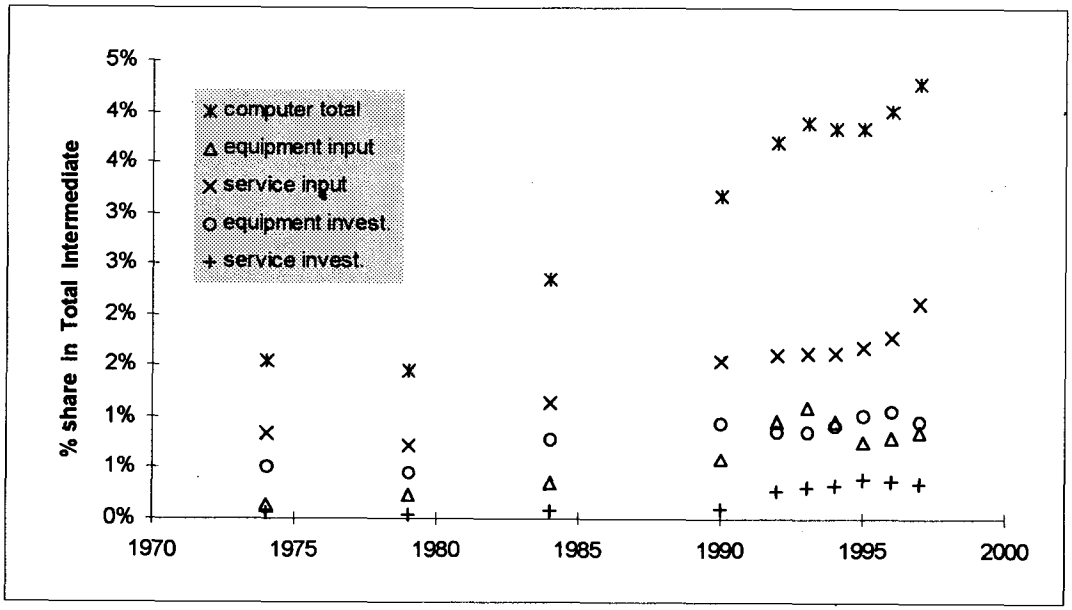
Source : As for Graph 6-2.

[12] In tracing sICT, there are serious data limitations for the 1980s. Telecommunication services data are only available from 1984 and the next figure appeared in 1990. Computer services appear from 1990. Alternatively, the unobserved path during 1980s may be traced from the 1990s path with the allowance for technological development.

When the early computer services before 1990 are approximately traced from the investment pattern of computer equipment investment and regarded as an upper bound,[13] the share is approximately 1.5% in 1974, and 2.4% in 1984. In the case of computer service investment, the share is relatively small and the error from approximation seems to be negligible, but the error in the service input does not seem to be negligible. However, its pattern during the 1990s suggests a stable relationship with computer equipment investment until the early 1990s.

The pattern for the computer might be a mix of 'S' shapes: a first 'S' shape until the late 1980s; a second 'S' shape from mid-1980s to mid-1990s; and another one from the mid-1990s. However, here the relatively short period for which we have observations limits further discussion. The suggested generational shifts from Graph 6-4 will be re-investigated through the examination of the industry usage path. With the present focus on the 1980s, more investigation of the first and second S shape is conducted in the industry-based comparison of computer equipment investment.

Graph 3 **Expansion of Computers: 1974~1997**



[13] Pre-1990 computer service investment excluding maintenance is traced from its 1990 ratio to computer equipment investment. With the assumption that there is an increasing trend of computer services in total computer investment, the calculated computer service investment based on the 1990 ratio and computer equipment investment is regarded as an upper bound.

Source : Table 6-2 and I-O.

5. Industry comparisons of ICT diffusion

(1) Non-service sector

The following table, Table 6-4, shows computer equipment in total intermediate investment in the first row in each cell, the share of total computer investment including computer services in the second row and the price-adjusted share in the third row.[14] Similar patterns of the diffusion path during the 1980s are clustered and allocated to the same Type: Type IV, increase through the whole 1980s with a high share in the 1970s; Type III, decrease in the early 1980s and increase in the later 1980s; Type II, decrease through the whole 1980s; Type I, increase in the early 1980s and decrease in the later 1980s; Type 0, increase through the whole 1980s with a low share in 1970; outliers, too small a share to detect a reliable pattern.

With consideration of business cycle effects, if there was no business cycle, the shares in 1979 and 1990 might be higher than observed. The effect does not change Type III but other Types could be changed. When the price-adjusted pattern gives a different Type to the unadjusted pattern, the possible business cycle effect is considered in the classification by Type. However, when the price-adjusted pattern gives the same Type as the unadjusted pattern, the business cycle effect given less consideration.

Type IV : up - up

Machinery : steady increasing path regardless of price adjustment. With an already relatively high share of computer investment in 1974, it is regarded as Type IV.

Printing : Without a possible business cycle effect, the share in 1984 might be lower. With regard to its early involvement in ICT during the 1970s,[15] it is treated as Type IV rather

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[14] The figure for the computer equipment investment share comes from the computer equipment investment relative to Intermediate investment The price adjusted share comes from the consideration of the computer price index 2.383.

[15] In the case of Print and paper industry, even the level is not very high before the 1980s but seems to be already involved in ICT during 1970s. During 1970s-1980s, the Print and paper industry became involved in the technological achievements related to the development of ICT (Guy and Haywood, 1985; Guy, 1985b).

than Type 0.

Type III : down - up

Electronics : steady decreasing pattern (Type II) without the price adjustment, but down-up pattern (Type III) with the price adjustment. Without a possible business cycle effect, the share in 1984 might be lower. With consideration of the business cycle effect, it is regarded as Type III.

Type II : down - down

Chemical : steady decreasing pattern regardless of price adjustment.

Construction : steady decreasing pattern regardless of price adjustment.

Type I : up - down

Vehicle : up-down pattern (Type I) without the price adjustment but steady increasing pattern (Type IV) with a price adjustment. Without a possible business cycle effect, the share in 1984 might be lower but the figure might still be bigger than that in 1979. It is regarded as Type I.

Metal : increasing pattern during the early 1980s and decreasing during the later 1980s regardless of price adjustment.

Clothing : increasing pattern during the early 1980s and decreasing during the later 1980s regardless of price adjustment.

Oil processing : increasing pattern during the early 1980s and decreasing during the later 1980s regardless of price adjustment.

Type 0 : up - up

Food, Cement, Furniture, Energy : steady increasing path regardless of price adjustment. With a relatively low share of computer investment in 1974, these are regarded as Type 0.

Outlier

Oil extraction : it is too strongly influenced by the external conditions, the namely Oil shocks during the 1970s and the development of North Sea Oil, and treated as an outlier as well. The development of North Sea Oil and the Oil shocks during the 70s seems to influence the other energy sector as well. Its path needs caution.[16]

Agriculture, Mining and Water : the investment in computer equipment until 1990 is relatively very small and the path seems to be unreliable during the 1980s, because the

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[16] For the same reason, Chemical and Oil processing seems to be problematic. It will be further examined later.

figures could be strongly influenced by temporary minor investments or rounding errors.

Table 2 Computer share in Intermediate Investment in non-service sector

(base year of price adjustment 1984)

Type	Industry		1974	1979	1984	1990	1992	1995
IV	Machinery	com.eq	3.39	1.76	2.62	2.90	10.47	14.73
		eq & ser				3.30	12.01	18.48
		price adj. com eq	1.23	1.39	2.62	6.65	35.09	
	Print	com.eq	2.17	2.67	3.08	3.07	7.49	12.05
		eq & ser				3.14	8.33	14.75
		price adj. com eq	0.78	2.11	3.08	7.03	27.24	
III	Electronic	com.eq	5.30	9.57	4.12	3.32	5.19	14.75
		eq & ser				5.15	8.76	18.21
		price adj. com eq	1.94	7.69	4.12	7.56	20.20	
II	Chemical	com.eq	1.12	4.75	2.29	0.92	2.44	8.64
		eq & ser				3.37	5.87	11.20
		price adj. com eq	0.40	3.78	2.29	2.16	10.35	
	Construction	com.eq	1.09	1.34	0.46	0.09	0.67	1.34
		eq & ser				0.45	4.79	3.96
		price adj. com eq	0.39	1.06	0.46	0.21	3.03	
I	Vehicle	com.eq	3.54	4.29	6.18	4.82	5.65	5.34
		eq & ser				7.23	10.07	7.39
		price adj. com eq	1.28	3.41	6.18	10.77	21.68	
	Metal	com.eq	1.76	2.07	5.07	1.46	2.35	4.73
		eq & ser				3.55	5.34	7.17
		price adj. com eq	0.63	1.63	5.07	3.40	10.01	
	Clothing	com.eq	2.47	1.26	3.00	0.41	3.24	13.59
		eq & ser				0.61	4.86	17.15
		price adj. com eq	0.88	0.99	3.00	0.97	13.40	
	Oil processing	com.eq	0.00	3.40	10.98	0.94	1.57	0.53
		eq & ser				1.35	3.02	1.74
		price adj. com eq	0.00	2.70	10.98	2.20	6.85	
0	Food	com.eq	0.96	4.28	5.99	8.75	11.41	4.40
		eq & ser				10.90	15.19	6.14
		price adj. com eq	0.34	3.40	5.99	18.60	37.32	
	Cement	com.eq	1.07	1.07	5.37	10.55	9.06	5.81
		eq & ser				15.27	15.50	8.48
		price adj. com eq	0.38	0.84	5.37	21.93	31.54	
	Furniture	com.eq	1.66	2.08	3.14	3.22	4.29	5.65
		eq & ser				3.30	5.26	7.51
		price adj. com eq	0.59	1.65	3.14	7.35	17.16	
	Energy	com.eq	0.08	1.56	1.87	3.21	4.64	6.51
		eq & ser				3.91	5.89	7.92
		price adj. com eq	0.03	1.24	1.87	7.33	18.37	
Outlier	Agriculture	com.eq	0.00	0.00	0.60	0.14	0.32	0.40
		eq & ser				0.91	1.30	1.82
		price adj. com eq	0.00	0.00	0.60	0.33	1.48	
	Mining	com.eq	0.00	1.32	0.29	0.00	0.65	1.06
		eq & ser				2.38	3.59	5.65
		price adj. com eq	0.00	1.05	0.29	0.00	2.95	
	Water	com.eq	0.00	1.91	0.85	1.10	1.95	2.49
		eq & ser				1.18	2.46	3.04
		price adj. com eq	0.00	1.51	0.85	2.57	8.43	
	Oil extraction	com.eq	0.00	0.82	0.20	0.03	0.14	0.02
		eq & ser				0.31	0.39	0.13

price adj. com eq	0.00	0.65	0.20	0.07	0.66

Source : Author's calculation based on. I-O.

(2) Service sector

In analysing the pattern of computer equipment investment and tracing the diffusion path of ICT in the service sector, one of the problems is the lack of classifications within the service sector in the early period. Alternatively, the early unobserved pattern is inferred from the comparison of the aggregated pattern with the dis-aggregated one in later periods. The patterns in the service sector are highly volatile in respect of price adjustments, and the interpretation should be cautious.

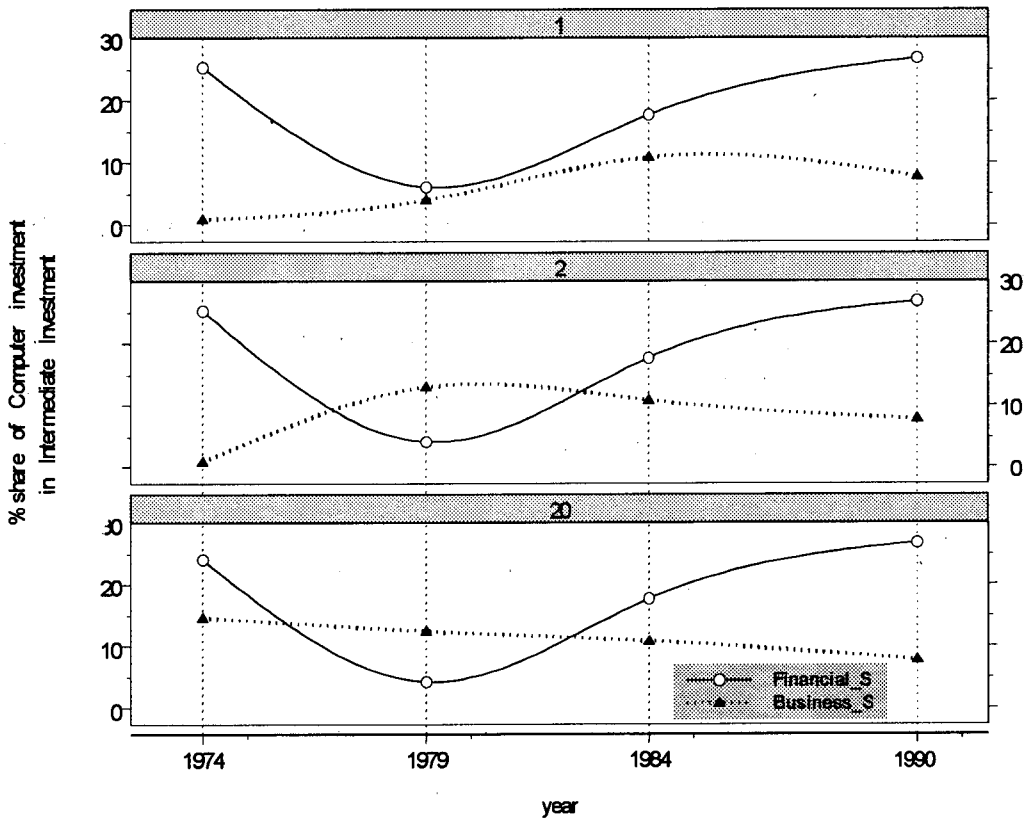
An early high investment in computer equipment is found in the aggregated services (below, FB&PP&Cr) including Financial Services, Business Services, Public Services, Personal Services and Catering Services. Their detailed investment patterns are observable only from 1984. In the 1979 I/O, the aggregated services (FB&PP&Cr) are separable into three divisions: sub-aggregated services including Financial Services and Business Services (below, FB); sub-aggregated services including Public Services and Personal Services (below, PP); and Catering Services. In the 1984 I/O, Financial services, Business Services, Public Services and Personal Services are separately treated from their sub-aggregated services.

In order to trace the unobserved investment patterns, the different investment shares in Financial Services and Business Services in 1974 and 1979 are simulated under the restriction of observed Computer equipment investment in FB. After tracing each of their Total Intermediate Investments from their relative ratio in later periods and merged Total Intermediate Investment in 1974 and 1979, their patterns of Computer investment are simulated through a different division of Computer investment within them. The simulation is obtained from the share of Computer investment for Business Services within fixed Computer investment in FB.

In Graph 6-8, the simulated patterns for Financial Services and Business Services show that Financial Services experienced a declining pattern during the late 1970s and re-expanded pattern during the 1980s, regardless of the pattern of Business Services.

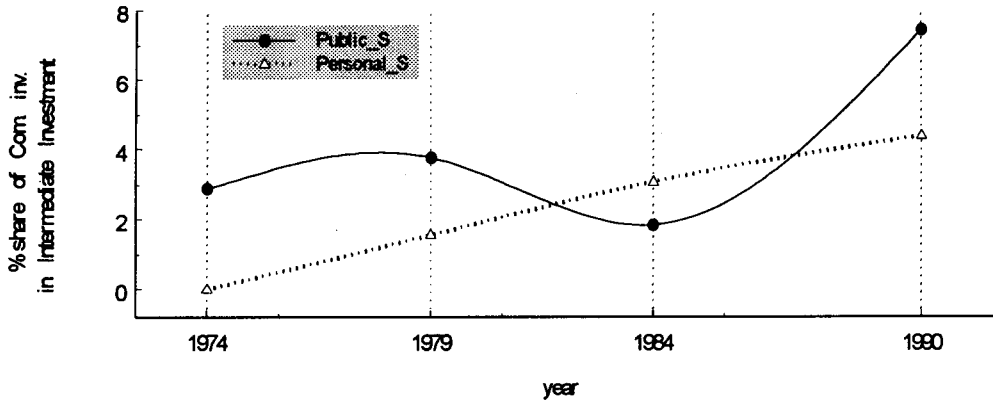
Therefore, Financial Services is regarded as Type IV during the 1980s. In the case of Business Services, it is not clear where it can be included. The only clear piece of evidence is the declining pattern in the late 1980s, so they can be included in Type I or Type II during the 1980s. In the same way the pattern of Public Services is also simulated in Graph 6-9. With the expansion pattern (Type 0) of Personal Services, Type III is suggested for Public Services during the 1980s.

Graph 4 **Investment patterns in Financial Services and Business Services: 1974~1990**



Keys: Case '1' : Business Services is Type I in the 1980s.
Case '2' : Business Services is Type II in the 1980s.
Case '20' : Business Services is Type II since the mid 1970s.

Graph 5 **Investment patterns in Public Services with simulated figures for 1974 and 1979**



Type IV : up - up

FB&PP&Cr : steady increasing pattern regardless of price adjustment.. With an already relatively high share of computer investment in 1974, it is regarded as Type IV.

FB : up-down pattern (Type I) without the price adjustment but steady increasing pattern (Type IV) with the price adjustment. Without a possible business cycle effect, the share in 1984 might be lower. With allowing for the business cycle effect, it is regarded as Type IV.

Financial Services : Based on simulation results, it is regarded as Type IV.

Distribution Services : up-down pattern (Type I) without price adjustment, but steady increasing pattern (Type IV) with price adjustment. With consideration of the business cycle effect, it is regarded as Type IV.

Type III : down - up

PP : down-up pattern regardless of price adjustment.

Public Services : Based on simulation results, it is regarded as Type III.

Catering Services : down-up pattern regardless of price adjustment.

Type I : up - down

Communication Services : up-down pattern (Type I) without price adjustment but steady increasing pattern (Type IV) with price adjustment. After removing a business cycle effect, it might remain in Type I due to the relative high differences of the 1984 share compared to 1979 and 1990.

Type 0 : up - up

Personal Services : steady increasing path during 1980s is expected.

Transportation Services : up-down pattern (Type I) without price adjustment but steady

increasing pattern with price adjustment. With regard to a business cycle effect, it is regarded as a steady increasing pattern. The relatively low figures during the 1970s suggest Type 0 rather than Type IV.

Unclassified

Business Services : From the simulation results, it seems to be Type I or Type II. However, with consideration of a business effect, the classification becomes more complicated. Without further information, a classification is not possible.

Table 3 **Computer share in Intermediate Investment in Service sector**

(base year of price adjustment = 1984)

Type			1974	1979	1984	1990	1992	1995
IV	Distribution	com.eq	4.89	3.32	9.09	7.79	9.31	10.25
		eq & ser				8.29	10.78	14.19
		price adj. com eq	1.78	2.64	9.09	16.75	32.18	
I	Communication	com.eq	0.47	1.23	3.88	1.92	5.02	15.40
		eq & ser				1.92	5.56	17.84
		price adj. com eq	0.17	0.97	3.88	4.45	19.64	
0	Transportation	com.eq	1.66	1.11	2.64	2.06	1.55	6.67
		eq & ser				2.18	3.06	8.41
		price adj. com eq	0.59	0.88	2.64	4.77	6.77	
IV	FB&PP&Cr	com.eq	10.56	4.72	9.26	9.58	11.07	10.68
		eq & ser				9.65	11.28	10.94
		price adj. com eq	4.00	3.76	9.26	20.16	36.53	
III	Catering	com.eq		2.29	1.33	2.28	2.94	0.29
		eq & ser				2.48	3.85	0.96
		price adj. com eq		1.82	1.33	5.27	12.29	
IV	F&B	com.eq	(23.34)	5.76	15.43	12.45	18.85	18.81
		eq & ser				13.05	23.39	26.60
		price adj. com eq		4.60	15.43	25.30	51.78	
IV	Financial	com.eq			17.72	26.83	20.53	18.92
		eq & ser				28.41	31.32	32.76
		price adj. com eq			17.72	46.63	54.42	
unclear	Business	com.eq			10.85	7.80	18.02	18.75
		eq & ser				8.09	19.45	23.39
		price adj. com eq			10.85	16.78	50.40	
III	P&P	com.eq	(2.26)	3.29	2.11	6.68	6.54	6.03
		eq & ser				7.33	9.14	8.93
		price adj. com eq		2.61	2.11	14.58	24.42	
III	Public	com.eq			1.84	7.44	7.72	6.36
		eq & ser				8.09	10.70	9.67
		price adj. com eq			1.84	16.07	27.88	
0	Personal	com.eq			3.07	4.39	2.30	4.98
		eq & ser				5.02	3.54	6.64
		price adj. com eq			3.07	9.87	9.81	

Source : As for Table 2.

During the early 1990s, most of the service sector seems to move gradually to the third

generation of ICT. Computer services show a faster increase than computer equipment except in communication services, which still show a faster increase in computer equipment. Furthermore, Financial Services and Public Services show the declining pattern of the computer equipment share in the unadjusted investment pattern. However, although the rapid expansion of the telecommunication share is expected to be a core element of third generation ICT, the increasing pattern of telecommunication services did not yet arrive until the mid 1990s. The early 1990s seems to be the early expansion stage of third generation ICT in the service sector.

(3) Other elements of ICT

The investment pattern of the other part of ICT hardware followed a similar path as computer investment in the non-service sector until the 1970s but it has separated since then. The relationship showed a 0.91 correlation in 1974 and one of 0.61 in 1979 with statistical significance. It is inferred that the other hICT investment moves far away from the pattern of ICT for computer equipment investment. .

Table 4 **Shares in Intermediate investment: Computer equipment vs. other hICT: 1974~1995**

	1974		1979		1984		1990		1995	
	com_eq	o_hICT	com_eq	o_hICT	com_eq	o_hICT	com_eq	o_hICT	com_eq	o_hICT
Agriculture	0.0	0.0	0.0	0.0	0.6	0.7	0.1	0.3	0.4	0.2
Mining	0.0	1.0	1.3	1.2	0.3	1.2	0.0	8.5	1.1	6.0
Oil extraction	0.0	0.9	0.8	4.8	0.2	2.4	0.0	0.7	0.0	0.3
Oil processing	0.0	1.2	3.4	4.1	11.0	10.3	0.9	0.2	0.5	0.7
Chemical	1.1	3.8	4.8	5.3	2.3	12.6	0.9	12.7	8.6	23.2
Cement	1.1	3.2	1.1	3.2	5.4	1.9	10.5	24.0	5.8	1.1
Metal	1.8	3.7	2.1	6.0	5.1	2.5	1.5	18.5	4.7	11.0
Machinery	3.4	7.8	1.8	10.2	2.6	7.5	2.9	10.7	14.7	1.1
Electronic	5.3	16.5	9.6	16.3	4.1	28.6	3.3	19.3	14.8	21.7
Vehicle	3.5	9.0	4.3	3.9	6.2	4.5	4.8	14.2	5.3	13.3
Food	1.0	1.3	4.3	2.2	6.0	1.6	8.7	1.8	4.4	3.8
Clothing	2.5	3.7	1.3	4.1	3.0	0.2	0.4	4.5	13.6	1.3
Print	2.2	1.3	2.7	6.1	3.1	0.8	3.1	0.1	12.1	1.2
Furniture	1.7	4.2	2.1	4.4	3.1	0.9	3.2	0.2	5.6	4.0
Energy	0.1	2.3	1.6	5.9	1.9	7.7	3.2	13.9	6.5	3.6
Water	0.0	0.0	1.9	0.8	0.8	0.8	1.1	2.6	2.5	2.1
correlation	0.91 (0.0001)		0.61 (0.001)		insignificant		insignificant		0.41 (0.1)	

Notes : 1. Industry output share is used as a weight in correlation.
2. The reject probability of null hypothesis is shown in brackets.
Sources : Author's calculation, based on I-O.

Computer service inputs and telecommunications show opposite patterns during the 1990s. As already reported, because of the lack of proper information, there were no available data for the period-industry comparison of the 1980s, prohibiting any examination for the 1980s. Alternatively, the unobserved trend of the 1980s can be inferred from the experience and trend during the 1990s. However, the relevant aspects of the later period cannot be guaranteed to be extensible to the early period, and the inferred trend for the 1980s needs cautious interpretation.

Table 5 **Growth of computer equipment investment, computer service input and telecommunication in the early 1990s**

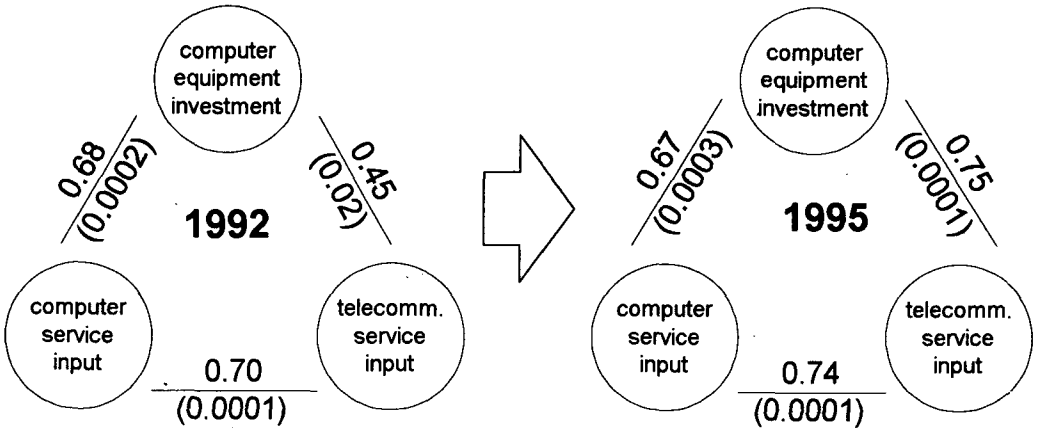
	share in Total Intermediate								annual growth rate during 1992-95		
	com. eq. inv.		com. ser. input		telecommunication						
	1992	1995	1992	1995	1984	1990	1992	1995	com	comsi	tel
Total	0.9	1.0	1.6	1.7	1.2	1.5	1.9	1.8	0.04	0.01	-0.01
non-service total	0.4	0.5	0.4	0.5	0.5	0.5	0.4	0.4	0.12	0.04	-0.02
service total	*1.5*	*1.5*	*3.0*	*2.9*	*2.2*	*3.0*	*3.5*	*3.2*	*0.01*	*-0.01*	*-0.03*
Agriculture	0.1	0.1	0.4	0.3	0.5	0.8	1.0	1.0	0.08	-0.13	0.00
Mining	0.1	0.1	0.5	0.5	0.6	0.5	0.7	1.0	0.15	0.03	0.11
Oil extraction	0.1	0.0	0.2	0.2	0.0	0.0	0.0	0.0	-0.76	-0.04	
Oil processing	0.1	0.0	0.2	0.2	0.0	0.1	0.1	0.1	-0.44	0.14	0.01
Chemical	0.2	0.7	0.4	0.5	0.4	0.5	0.6	0.5	0.37	0.08	-0.06
Cement	0.6	0.6	0.3	0.3	0.5	0.6	0.6	0.5	-0.04	0.02	-0.08
Metal	0.1	0.2	0.3	0.4	0.4	0.4	0.4	0.3	0.29	0.11	-0.09
Machinery	0.7	1.0	0.4	0.5	0.9	0.7	0.6	0.5	0.13	0.10	-0.05
Electronic	0.3	1.2	0.7	0.9	0.7	0.8	0.6	0.6	0.45	0.09	0.01
Vehicle	0.4	0.4	0.9	0.9	0.3	0.3	0.4	0.2	0.00	0.01	-0.14
Food	0.7	0.3	0.1	0.2	0.2	0.3	0.4	0.3	-0.30	0.10	-0.15
Clothing	0.2	0.7	0.2	0.3	0.4	0.5	0.6	0.5	0.49	0.09	-0.08
Print	0.7	1.4	0.3	0.3	1.5	0.8	0.3	0.6	0.22	0.02	0.27
Furniture	0.3	0.4	0.2	0.3	0.8	0.6	0.6	0.5	0.08	0.05	-0.08
Energy	0.9	0.8	0.4	0.6	0.3	0.3	0.2	0.3	-0.03	0.08	0.20
Water	1.2	1.5	0.2	0.2	1.2	0.9	0.4	0.3	0.07	-0.10	-0.11
Construction	0.0	0.0	0.8	0.7	0.4	0.4	0.4	0.3	0.31	-0.02	-0.05
Distribution S.	*1.3*	*1.5*	*2.2*	*2.1*	*3.6*	*1.9*	*2.1*	*1.9*	*0.05*	*-0.01*	*-0.03*
Transportation S.	*0.3*	*1.1*	*3.6*	*3.3*	*0.8*	*1.8*	*1.5*	*1.3*	*0.43*	*-0.03*	*-0.04*
Communication S.	*1.5*	*4.9*	*4.0*	*3.8*	*3.1*	*9.4*	*16.5*	*13.7*	*0.40*	*-0.02*	*-0.06*
Catering S.	*0.5*	*0.1*	*2.5*	*2.5*	*1.0*	*2.8*	*2.5*	*2.4*	*-0.74*	*0.00*	*-0.02*
Financial S.	*1.8*	*1.6*	*4.3*	*4.5*	*5.1*	*6.8*	*7.5*	*7.2*	*-0.02*	*0.01*	*-0.01*
Business S.	*3.0*	*2.5*	*3.3*	*3.4*	*3.1*	*2.4*	*3.2*	*3.1*	*-0.06*	*0.00*	*-0.02*
Public S.	*1.2*	*0.8*	*2.3*	*2.1*	*0.6*	*1.6*	*1.7*	*1.5*	*-0.16*	*-0.03*	*-0.05*
Personal S.	*1.4*	*3.0*	*2.2*	*2.1*	*10.3*	*1.3*	*1.3*	*1.2*	*0.26*	*-0.01*	*-0.02*

Note: The Share came from Total Intermediate, not from Intermediate Investment.
Source : Author's calculation, based on I-O.

During the early 1990s, the computer service input pattern is relatively stable with computer equipment investment. The correlation remained at 0.68 in 1992 and 0.67 in

1995. In the case of telecommunication, the relation with computer equipment increased from 0.45 in 1992 to 0.75 in 1995.[17] If these patterns are extended to the 1980s, it could be suggested that the pattern of computer service is similar to that of computer equipment investment and that the early relationship between telecommunication and computer is weaker than in the mid-1990s.

Figure 7 **Change of correlation among computer equipment investment, computer services and telecommunication equipment during the early 1990s**



Note. weighted correlation. For weight and statistical significance, see Notes to Table 6-8.
Source : Calculation of data from each I-O.

6. Index of industrial ICT diffusion: 1980s in UK

With the technological development in ICT, generational shifts are seen as emerging. The first generation until the 1970s was brought about by the computer and other equipment investment. The second generation was mainly brought about by the expansion of computers. During the second generation of ICT, computer equipment pervasively diffused and the more reluctant industries and services in terms of introducing the first generation of ICT showed faster expansion this time. Computer services were believed to follow a similar pattern to computer equipment investment. Telecommunication seems to be involved in the diffusion of ICT but still remained

[17] The share in the sum of total intermediate input and investment is used with industry output share as a weight. In industry output, joint products are included. The result using normal output share is almost the same.

outside the diffusion pattern of ICT inferred from computers.

The expansion of computer services with the re-investment of computer equipment during the 1990s is regarded as the expansion of the third generation. In many services and the advanced-stage industries in terms of computer equipment investment, there is a tendency to faster expansion of computer services. Also, the relation between computer and telecommunication becomes strengthened and the real merger is growing in this stage.

Figure 8 **Diffusion and Evolution of ICT (II)**

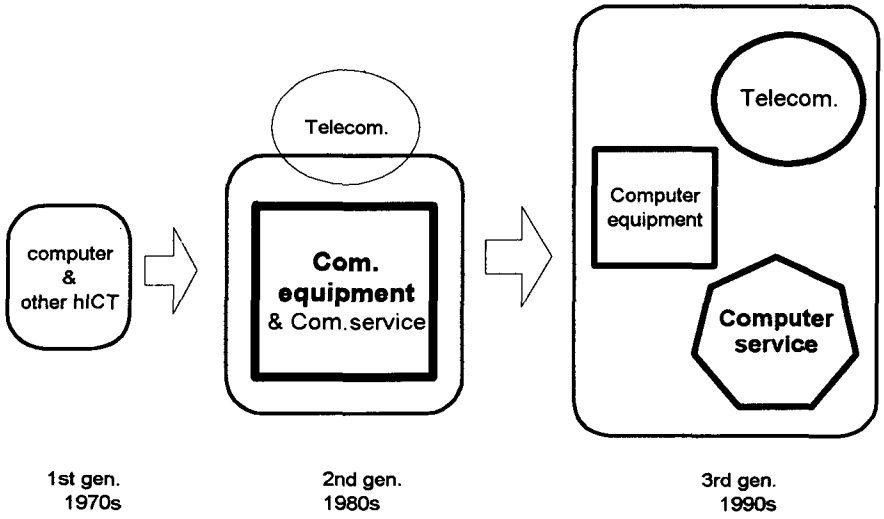


Table 6 **Annual growth rate of computer equipment share without price adjustment**

type		1974-79	1979-84	1979-90	1984-90	1990-92
IV	Machinery	-13.11	7.96	4.54	1.69	64.19
	Print	4.15	2.86	1.27	-0.05	44.59
III	Electronic	11.82	-16.86	-9.62	-3.60	22.34
II	Chemical	28.90	-14.59	-14.92	-15.20	48.77
	Construction	4.13	-21.38	-24.55	-27.19	100.37
I	Vehicle	3.84	7.30	1.06	-4.14	7.94
	Metal	3.24	17.92	-3.17	-20.75	23.80
	Clothing	-13.46	17.35	-10.21	-33.17	103.36
	Oil processing		23.45	-11.69	-40.97	25.65
0	Food	29.90	6.72	6.50	6.32	13.27
	Cement	0.00	32.26	20.80	11.25	-7.61
	Furniture	4.51	8.24	3.97	0.42	14.35
	Energy	59.41	3.63	6.56	9.01	18.42
Outlier	Agriculture				-24.25	41.33
	Mining		-30.31			
	Water		-16.19	-5.02	4.30	28.63
	Oil extraction		-28.22	-30.07	-31.62	77.02

	Non-ser.	12.68	1.23	0.07	-0.90	19.76
IV	*Distribution*	*-7.74*	*20.14*	*7.75*	*-2.57*	*8.91*
	FB&PP&Cr	*-16.11*	*13.48*	*6.44*	*0.57*	*7.23*
	F&B		*19.71*	*7.01*	*-3.58*	*20.74*
	Financial				*6.91*	*-13.38*
III	*Catering*		*-10.87*	*-0.04*	*8.98*	*12.71*
	P&P		*-8.88*	*6.44*	*19.21*	*-1.06*
	Public				*23.29*	*1.85*
I	*Communication*	*19.24*	*22.98*	*4.05*	*-11.73*	*48.06*
0	*Personal*				*5.96*	*-32.32*
	Transportation	*-8.05*	*17.33*	*5.62*	*-4.13*	*-14.22*
unclear	*Business*				*-5.50*	*41.87*
	Service	*-12.20*	*15.76*	*7.08*	*-0.16*	*6.79*
	Total	-5.57	11.46	5.93	1.33	8.84

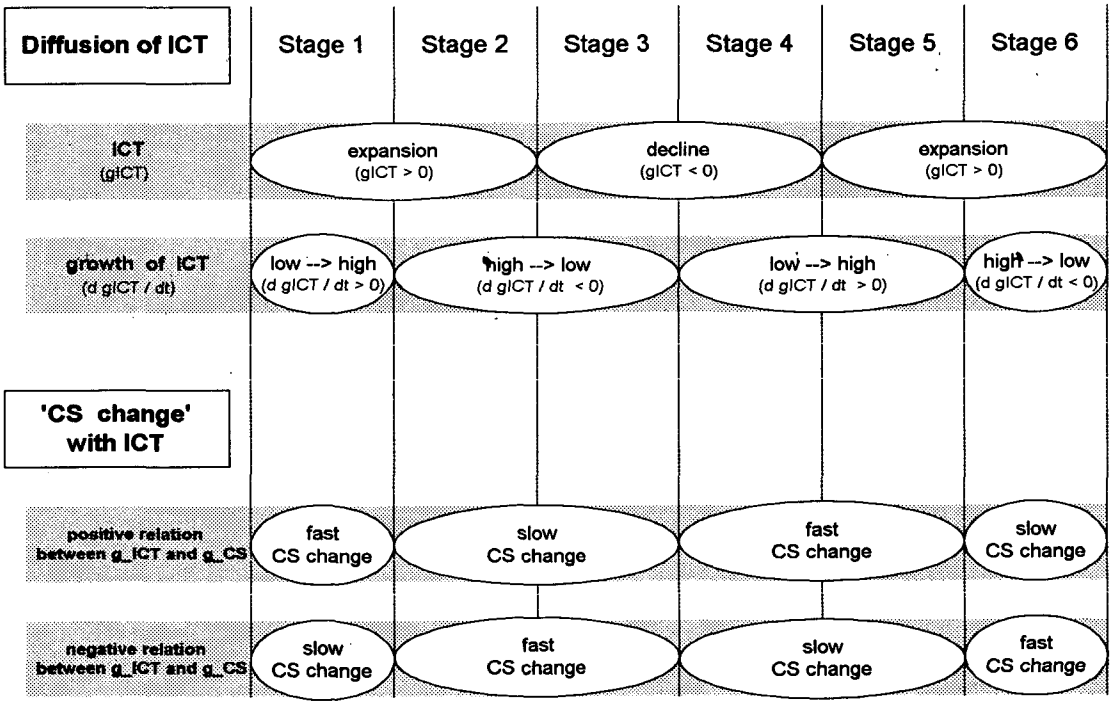
Note : The growth rates are obtained from the exponential growth equation (see Section 4.2 in Chapter 3)
Sources : Elaboration from I-O.

The annual growth rate of computer equipment investment can be regarded as a diffusion index for the second generation ICT during the 1980s. Given the exponential growth equation, $A_t = A_0 \cdot e^{g \cdot t}$, the (instantaneous) rate of growth of, 'g', is defined as: $g \equiv \frac{dA_t / dt}{A_t}$. The exponential growth equation is not always appropriate; however, for practical reasons, the growth rate is calculated from it. This is shown in Table 9. The diffusion paths in this research are different from the conventional diffusion path. The reason for introducing the individual diffusion path, differing from the conventional cumulated diffusion path, is to allow analysis of the growth rate of ICT by industry. The growth rate of ICT, which is easily obtainable, could indicate the relative stage of ICT development and allow further detailed examination.

Through following the diffusion path, differences between early ICT and later ICT appear. This is examined through the comparison of industry paths and the comparison of each element of the ICT. With regard to the diffusion of ICT as a Sine-curve shape, the patterns of ICT growth rate are differently interpreted in each stage (see Figure 3-3). With six diffusion stages, *Stage 1, 4* and *5* are stages of 'increasing ICT growth' ($d\,gICT / dt > 0$) and *Stage 2, 3* and *6* are stages of decreasing ICT growth ($d\,gICT / dt > 0$). Therefore, the higher growth rates in *Stage 1, 4* and *5* involve a relatively later growth '*Period*' within the '*Stage*', but the higher growth rates in *Stage 2, 3* and *6* involve a relatively earlier growth '*Period*' within the '*Stage*'.

The index can be also used for further analysis with others, i.e. skill change[18]. The meaning of the relationship between diffusion of ICT (gICT) and growth of Skill change (gCS) also differs by stage. In the increasing ICT growth ($d\,gICT / dt > 0$) stages, a 'positive relation between gICT and gCS' ($d\,gCS / d\,gICT > 0$) means 'fast skill change' ($d\,gCS / dt > 0$) and a 'negative relation between gICT and gCS' ($d\,gCS / d\,gICT > 0$) means 'slow skill change' ($d\,gCS / dt < 0$). Conversely, in decreasing ICT growth ($d\,gICT / dt < 0$) stages, a 'positive relation between gICT and gCS' ($d\,gCS / d\,gICT > 0$) means 'slow skill change' ($d\,gCS / dt < 0$) and a 'negative relation between gICT and gCS' ($d\,gCS / d\,gICT > 0$) means 'fast skill change' ($d\,gCS / dt > 0$).

Figure 9 **CS change and ICT diffusion**



7. Concluding Remarks

This research shows that the advent of ICT is an evolutionary process. The early

[18] For instances, Hwang (2001) and Hwang and Pastore (2001).

generation of ICT seems to have evolved mainly on the basis of equipment, from the diffusion pattern shown in this chapter as well as the technological development of ICT set out in the last chapter. The early computer is one of the key elements of the ICT. Computers are introduced mainly for office work, and show faster expansion in the service sector, mainly in financial services and the public sector. In such high usage sectors, computers seem to reach the mature stage before the 1980s. During the 1980s, the expansion of computer equipment became the core of ICT and many industries and services came to accept the computer and showed rapid expansion of computer usage. The early adopters also re-expanded their investments in computers. Due to price reductions and the expansion of applicability, the introduction of the computer was accelerated. With the development of computer networks, the merging of computing and communication also came about. The explosion of the computer can be regarded as the second generation of ICT. After the 1980s, the usage of ICT was strengthened. Computer services become more important and show a separate pattern from computer equipment since the mid-1990s. The expansion of telecommunication also accelerates at this time. The explosion of the Internet could be regarded as characterising the expansion of the third generation.

Within each generation, the diffusion can be measured by the growth of the main contributor(s). Faced with these generational shifts, the preparation of a single index does not seem to be very useful because the main driving forces have been changing. However, the investment pattern of computer equipment seems to be an appropriate index for the ICT diffusion during the 1980s. From comparison across industries as well as other elements in ICT, it also appears that there are certain sectoral differences in the diffusion of ICT; generally the service sector and high value-added sectors show an early involvement. On the diffusion path, the time to reach the mature stage differs according to industrial characteristics related to the degree of involvement in ICT. The similarities and differences allow certain patterns to be analysed. In summing-up, the research brings attention to the technological change and sectoral differences in the study of ICT diffusion.

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