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The Faster Accelerating Knowledge-based Society

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The Faster Accelerating Knowledge-based Society[1]

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Abstract

Economies in knowledge-based societies grow faster than in previous agricultural and industrial societies. This growth is based on the information and communications technology (ICT) development. The production function of ICT industries shows increasing returns to scale. The network effect of ICT development causes increasingly accelerated production and consumption values as the market gets larger in all supply and demand aspects. Thus, ICT development is the fundamental driving force of the faster economic growth, accelerated by increasing returns to scale and the network effect. Early investment in ICT achieves steep economic growth. The definition and characteristics of a knowledge-based society are given, and the nature, causes, and patterns of the faster acceleration of it are explained.

JEL Classification: L16, O11, O47

Keywords: Knowledge-based society, Information society, Post-industrial society, Economic development, Faster acceleration, Industrial policy, Technical change

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1. Introduction

Radical technological changes have induced major changes in economies with different levels of development and operations. In industrial societies, the population and scale of economy grew much faster than in agricultural societies, and the acceleration is becoming remarkable following the introduction of information and communications technology (ICT). DOS and Windows swooped over the whole operating-system market in a short time and have maintained a dominant market share. Bill Gates, the founder of the company that introduced the operating systems, became the richest person in the world. During this time, the United States enjoyed all the advantages of the high-growth new economy. Moore's law, which states that the number of transistors approximately doubling every two years or less (Brynjolfsson and Hitt, 1998), illustrates the rapid progress of computer technology.

Our study shows that in a knowledge-based society the new economy grows faster than it has in any previously existing society and the development of ICT is the primary cause for this growth. The production function in a knowledge-based society shows increasing returns to scale. That is, output grows exponentially even though the input increases linearly. This is an important characteristic of the knowledge-based society in that it makes economic growth accelerate faster than it had in the industrial society. Based on the economic characteristics of a knowledge-based society, ICT development, and network effects, the value of production and consumption increases in an accelerated manner as the market gets larger in all aspects of supply and demand.

ICT development is one of the fundamental driving forces of increasing returns to scale and the network effect. As a result, industrialized societies that make substantial investment in ICT can achieve even higher economic growth rates. As they take on the characteristic growth of the knowledge-based society, their economic growth largely differs from countries that are still characterized by an industrial society system. This fast economic growth by ICT has been observed in Finland, Ireland, and the United States. Therefore, economic growth that is faster than that in any previous society is possibly due to intensively fostered ICT, which plays a role of driving force in the knowledge-based society. This relationship is investigated in this study.

This study is organized as follows: First, while accounting for different views, we check out the definition of knowledge-based society based on a discussion of preceding research and the characteristics of this new society. In a modern production function, not only are the traditional production factors, such as labor and capital, considered important, but knowledge and information emerge as important production factors. In addition, the tipping effect of network externality,[2] enhanced economies of scale, radical development of ICT, the change of employment structure, social changes, and the characteristics that accompany all of these variables are broadly discussed. In the next section, the background to how the faster accelerating knowledge-based society appeared will be explained.

[2] According to Gladwell (2000), tipping points are the level at which the momentum for change becomes unstoppable. The tipping effect results in ideas, products, messages, and behaviors spreading quickly and unexpectedly.

Increasing returns, path dependence, network externality, enormous research and development (R&D) investment, and the effect of economies of scale due to microscopic marginal production costs are examined theoretically. Moreover, we will explain the nature, causes, and patterns of the faster acceleration of the knowledge-based society. We conclude with cases that show that economic growth in a knowledge-based society is more rapidly increasing than it had been in previous societies.

2. Emergence of the knowledge-based society

In this section, we introduce a definition of and conditions for the emergence of the knowledge-based society before introducing the characteristics of economic growth in such a society. The knowledge-based society, which is also called the knowledge society, information society or post-industrial society, informatizes the whole society so that it can show different social properties from the former industrial society in the view of its qualitative advancement.

2.1. Definition of the knowledge-based society

One of the pioneers to develop the concept of the information society was the economist Machlup (1962) who predicted the emergence of a knowledge-based society. The information society has various names: “new economy”, “knowledge-based society”, and “digital society.” In the information society, the creation, distribution, diffusion, use, and manipulation of information play a significant role in economic growth.

The definition of the knowledge society was further refined by Drucker (1969) and Bell (1973) who put forth the ideas that knowledge is the basis of policy selection and workers who engage in the production and application of knowledge become increasingly important. They stated that theoretical knowledge was necessary to innovate and to operate the technology and policy systems that get more comprehensive and complicated over time. In addition, they stated that the supply of knowledgeable workers increases due to the spread and development of higher education. Therefore, the knowledge industry gets developed and social change follows. These developments are more likely to be seen in industrialized societies.

The theory of a knowledge society extends that of an information society. If the information component is included in an analysis of it, the knowledge society theory includes information society theory. Bell (1973) classified societies into pre-industrial,[3] industrial,[4] and post-industrial and provided information on the characteristics of each. In Bell’s view, the post-industrial society produces knowledge and information and it

[3] A pre-industrial society is based on exploitation of nature. More than 60% of the pre-industrial population is engaged in extraction industries. People in this society depend on nature and do not have much ability to control nature.

[4] An industrial society puts energy into machinery and is therefore called “a game against fabricated nature.” (Bell, 1973)

increases services. Post-industrial services do not include those that involve transportation or public utility; rather, they are professional or human development services. The information society is characterized by the professional services that represent the society that appeared after industrialization.

There is little difference between the information, knowledge, and post-industrial societies. In the absence of defining standards and due to the nature of the new society, each term refers to the same society. However, we should be very careful to define a knowledge-based society academically. Because the knowledge-based society has not attained the required level of maturity, it is quite arguable if the knowledge economy is a change of fundamental mode of production in currently developed societies. Also, no one can be positive that economic and social features of the knowledge-based society are distinguishable from those of the industrial society.

The agricultural society and industrial society can be clearly defined and distinguished because they have each already passed the period of maturity. However, the knowledge-based society is still emerging, and it will take a long time before it matures. Meanwhile unimaginable changes caused by the huge development of knowledge-based science and technology including ICT, biotechnology, and nanotechnology are expected. In addition, we cannot be sure whether the knowledge-based society will become one of the society formed after the industrial society or whether it is the transient phenomenon between the industrial society and another futuristic society.

According to an Organisation for Economic Co-operation and Development (OECD) report published in 2003, the contribution of investment in ICT capital to gross domestic product (GDP) growth was 1% in the United States between 1995 and 2000, and less than 1% in Canada, France, Germany, Japan, and the United Kingdom for the same period. Besides, it is not known if the different economic phenomenon characterizing the faster acceleration of the knowledge-based society should be understood as the advanced development of the industrial structure[5] or should be defined as an independent new society.

To confer a general understanding, the characteristics of the knowledge-based society should be discussed in a broad sense even if we do not have a solid idea of its role in the evolution of industry. Therefore, we discuss the theories regarding the characteristics of this society by expressing the common opinions of many scholars, but we do not offer a full definition of the knowledge-based society.

2.2. Realization of the knowledge-based society

The realization of the knowledge based society is discussed in a number of studies. In this section we introduce Drucker (1969) and Topscott (1996).

In looking at the realization of the knowledge-based economy, Drucker (1969) suggested

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[5] Refer to Kim, T.Y., 2008. Qualitative advancement and acceleration of the industrial society. Unpublished manuscript.

that information or knowledge, as an input in production and management, becomes more significant in economic growth and industrial development than traditional and classical inputs, such as labor and capital. Knowledge includes practical knowledge such as the patent, experience, know-how, and technology that bring economic benefits, such as realized through increased research-dependent productivity, as well as academic knowledge. The output of industrial sectors dealing with information or involved in trading information is increasing rapidly. The service industry (the tertiary industry) is becoming more important. Thus, information becomes a critical complementary input factor to classical input factors such as labor and capital. New services and products have emerged that converge to related industry sectors.

In another study related to the knowledge-based society but with a focus on the realization of the digital economy, Tapscott (1996) suggested that electronic products connected with the worldwide network through the Internet had an effect greater than the simple technology innovations of individual products, such as the computer, mobile phone, and digital TV. The digital economy comes from a remarkable development of the ICT industry, particularly, of the Internet.

Increasing returns at the level of the firm, enhanced by the network effects, and in the presence of the first mover's advantage are among the most important characteristics of the digital economy. Because the R&D cost is huge, the formation of oligopolies and monopolies follow in production. On the other hand, in distribution, productivity improvement based on the information network and increased consumer welfare, as markets near perfect competition due to diffusion of e-commerce in distribution channels, also characterize the digital society.

A schematic picture of the digital economy is shown in Figure 1. It shows the components of the digital economy such as the computer and semiconductor, network, and Internet as well as the development of Internet-related industries. It shows how each component and the digital economy as a whole impact information equipment, information networks, and globalization of networks, as well as changes in social and economic paradigms. It also points to possible new revolutions.

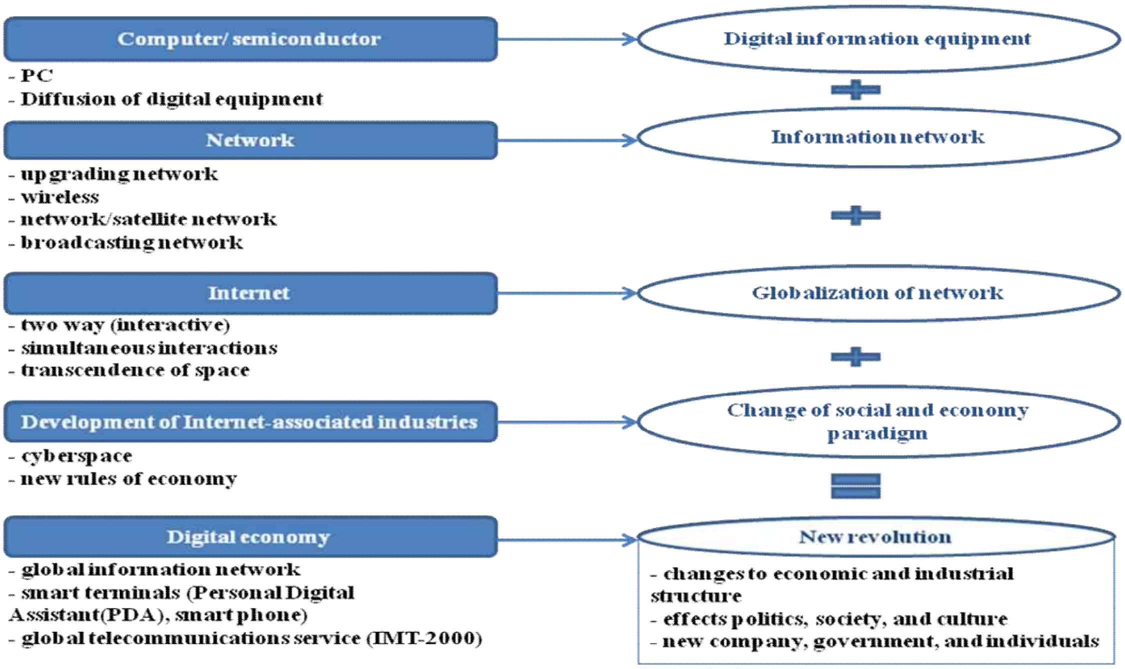


Figure 1. The digital economy

Source: Kim, J.H., 2005. The Economics of Innovation. Sigma Press, Seoul, Figure 3.1, p. 38.

In Table 1, specific characteristics of the Agricultural, Industrial, and Digital Revolutions are presented. The characteristics discussed involve the period, the driving factor, the main input, changes in key industries, and growth rate of each revolution. A detailed description of characteristics of the first two revolutions is beyond the scope of this study, but that of the Digital Revolution is given in the next section.

Table 1. Three revolutions and their specific characteristics

	Agricultural Revolution	Industrial Revolution	Digital Revolution
Initial period	B.C. 5000	Late 18th Century	Late 20th Century
Driving factor	Agricultural technology	Industrial technology	Internet and ICT
Main input	Labor Land	Capital Technology Fossil fuel	Knowledge Information Scientific technology
Changes in key industries	Hunting and gathering → agriculture	Agriculture → manufacturing and commerce	Classic manufacturing → knowledge-based industries
Growth rate	Deceleration and stagnant	Acceleration	Faster acceleration

3. Characteristics of the knowledge-based society

An important characteristic of the knowledge-based society is the faster growth trend due to the application of information systems that leads to accelerating economic development. Unlike an industrial society, increasing returns to scale is observed in the production structure in the knowledge-based society. Thus, the more the input increases, the faster the output increases. Also, production in the long-run accelerates faster because the interaction of increasing returns to scale in production and growing consumption demand leads to high rates of growth.

3.1. Production characteristics in the knowledge-based society

Some evidence supports the contention that the production function of knowledge-based society has increasing returns to scale (Romer, 1986). Compared to an industrial based society, in a knowledge-based society, the increasing output gets faster as the input used in production increases. The short-term production function showing an increasing return relationship between input and output is illustrated in Figure 2.

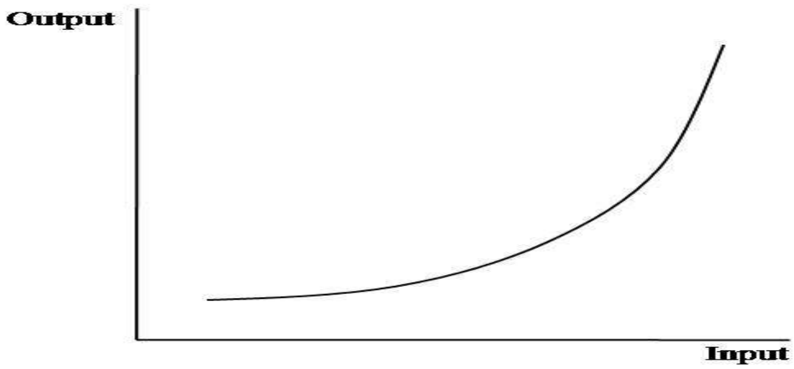


Figure 2. Short-run production function in a knowledge-based society shows increasing returns to scale.

Romer (1986) stated that technology development could make sustainable growth possible. Economists regard the new economy as highly developed because of ICT technologies. Unlike traditional manufacturing, ICT production shows increasing returns to scale. Increasing returns to scale reflects production increases due to the decline in marginal cost of an additional output unit. The computer and software industries are representative examples where increasing returns to scale is found.

3.2. Characteristics of demand and supply in the knowledge-based society

In discussing the demand and supply characteristics of the knowledge-based society we focus on the ease of economic fluctuation as a result of digital economy diffusion, supply and demand during the commencement of the network economy, and enlargement of increasing returns to scale in terms of supply. We also look at the role of information technology (IT) promotion in the information-oriented trend, the increasing importance of the ICT industry, and changes in the employment structure.

Among its positive aspects, the digital economy is diffused such that economic fluctuations are relatively easy to realize. This makes demand forecasting for firms more accurate and it enables them to promptly react to demand fluctuations. Therefore, activities such as stock management become more stable and production becomes more efficient. For example, Dell allowed customers to connect to its website and order PCs as of July 1996. Information about supporting and ordering services is presented through the Dell website. Before Dell, other computer companies manufactured PCs, piled the inventory, and sold the products to wholesale dealers, distributors, and retailers. However, Dell can remove the factors increasing the cost and price of its products and reduce the burden of inventory cost by processing orders through the mail or by phone. As a result, Dell prevailed over competitors with a 10-15% price advantage in December 1997 (U.S. Department of Commerce, 1998).

In addition, the digital economy decreases price fluctuations. In the United States, the prices of ICT products and services contributed to the fall of the inflation rate. For instance, without an ICT industry in 1997, the inflation rate would have been 3.1%. However, total price increases, including those for the ICT industry, were just 2.0% because of significant and continuous price decreases in the ICT sectors (U.S. Department of Commerce, 1998).

The positive cycle structure of industries from the perspective of the macro-economy in the digital economy is shown in Figure 3. The figure shows the link from the development of IT through changes in firm, industry, and macro-economy dimensions as well as its substitution for traditional industry. This cycle leads to sustained high growth and low prices through a feedback effect.

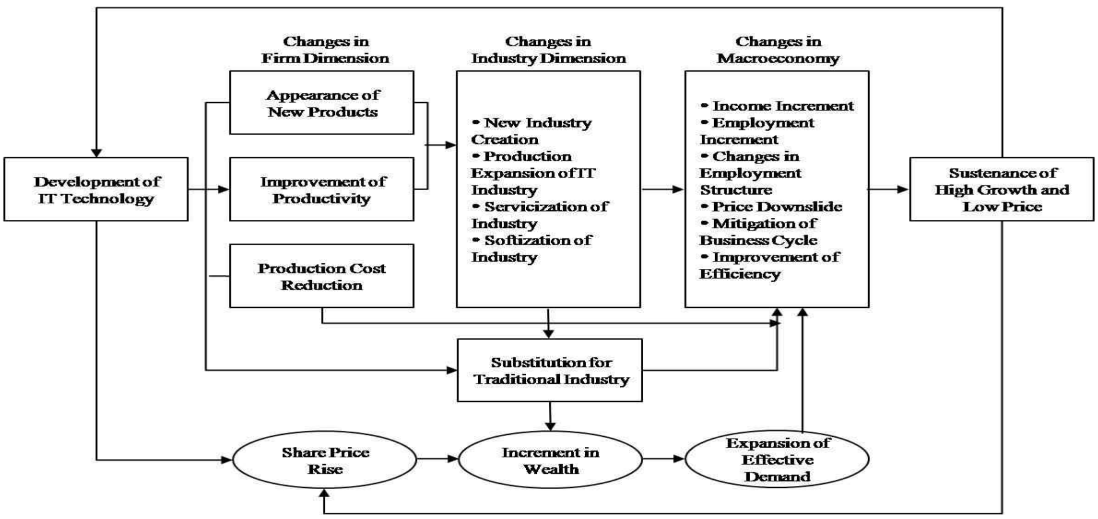


Figure 3. Positive cycle of industry from the perspective of the macro-economy in the digital economy.

Source: Hong et al. 2000. *The Digital Economy in Korea*. Seoul: SERI Figure 3, p. 18.

In regard to the arrival of the network economy in terms of supply and demand, Shy (2001) suggested that many network industry products are complementary goods, which increase consumption of primary goods (for instance, monitors and computers are often sold together). We also observe consumption externalities; that is, the value of a product depends on how many other consumers use the same product. Therefore, achieving critical mass is important (e.g., fax and e-mail). Switching costs and lock-in effects as well as economies of scale in production with low marginal costs and high fixed costs are among other characteristics of the network economy that affect the service-using rate. If switching costs are high, the lock-in effect becomes strong. A company can secure consumers with strong lock-in effect. Economies of scale in production suggest an economy with a very low marginal cost and a very high fixed cost. A perfectly competitive market is hard to achieve and a dominant firm appears.

In Table 2, a comparison of economies of scale, scope, and network is presented with respect to definitions, keywords, emerging periods, background, and company organization and modifications.

Table 2. Comparison among economies of scale, scope, and network

	Economies of scale	Economies of scope	Economies of network
Definition	A production process in which an increase in the scale of the firm causes a decrease in the long-run average cost of each unit.	Cost reduction of producing broader scope of products is larger than cost reduction for a single product.	The effects of connectivity or organization of both internal and external resources are significant for providing goods or services
Keyword	Cost reduction, indivisibility	Sub-additivity[a]	Networking, information
Period	1960–70	After mid-1970	After late 1980
Background	- Mass production - Mass consumption - High growth	- Mass customization - Differentiation -Divided public, small public[b] - Stable growth	- Multiple variant production - Diversification and satisfying individual taste - Soft, service, information
Company organization and modification	- Hierarchy -Specialization of single or small product	- Horizontal or matrix - Division system - Branch office	- Networked organization -Utilization of both internal and external organization - Increased outsourcing

Source: Lingen, E., 1996. Economics of Networking. NTT Press, Tokyo (in Japanese). Lee, K.D., 2005. The Information Society of Industry and Industrial Development. Chimmundang, Seoul, Table 4.1, p. 170.

Notes:

a. The cost of producing products collectively is lower than that of producing products separately.
b. Consumers are subdivided into each population group based on individuals' characteristics.

The effects of increasing returns to scale in terms of supply are enlarged due to recently increased globalization. The spread of free trade and free movement of capital, labor, and goods, as well as the development of ICT, has enlarged increasing returns to scale in production.

The IT development led to the ICT revolution, which has changed every aspect of the modern economy. Information-related fields have become more important in both input and output. Large firms spin off smaller and separate businesses. Networks are interrelated and outsourcing has spread among companies. The location and hours of jobs have changed (e.g., e-commuting and flexible work schedules), and multi-product and small-sized operations are other outcomes of the process.

According to Moore’s law, which describes trends in the history of computer hardware, the number of transistors that can be inexpensively placed on an integrated circuit has increased exponentially, doubling approximately every two years. The phenomenon is illustrated in Figure 4 for microprocessors and dynamic random access memory (DRAM), which experienced 42% and 52% annual growth rates, respectively, in the period from 1970 to 2005.

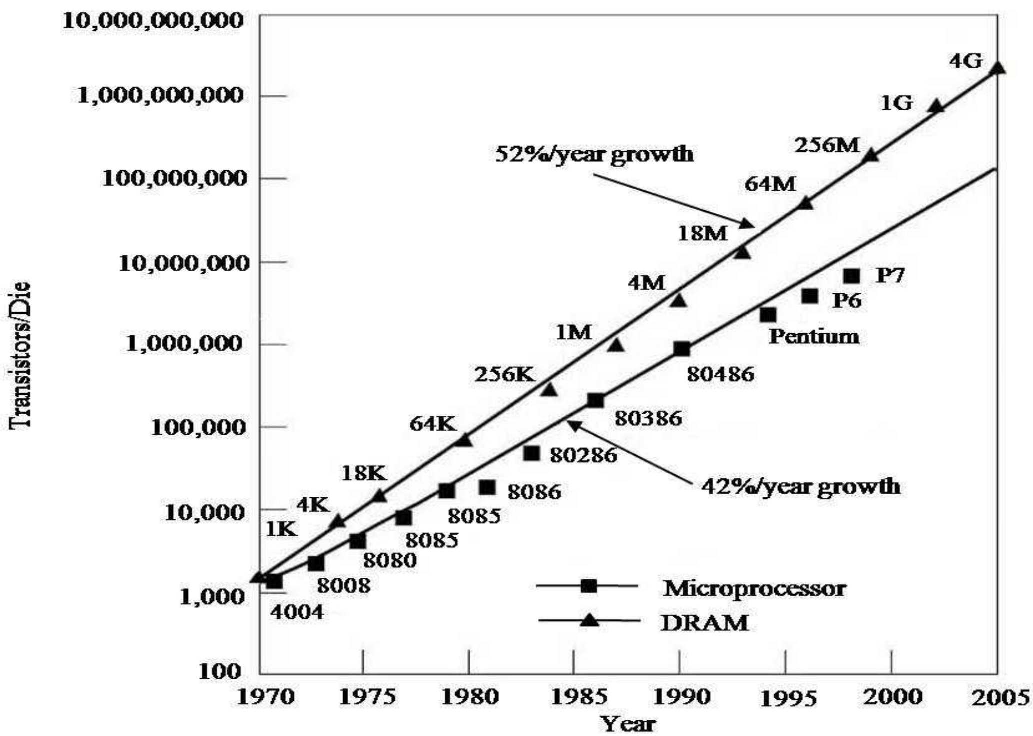


Figure 4. Moore's Law.

Source: Brynjolfsson, E., Hitt, L.M., 1998. Beyond the productivity paradox. Communications of the ACM 41(8), 49–55, Figure 1, p. 50.

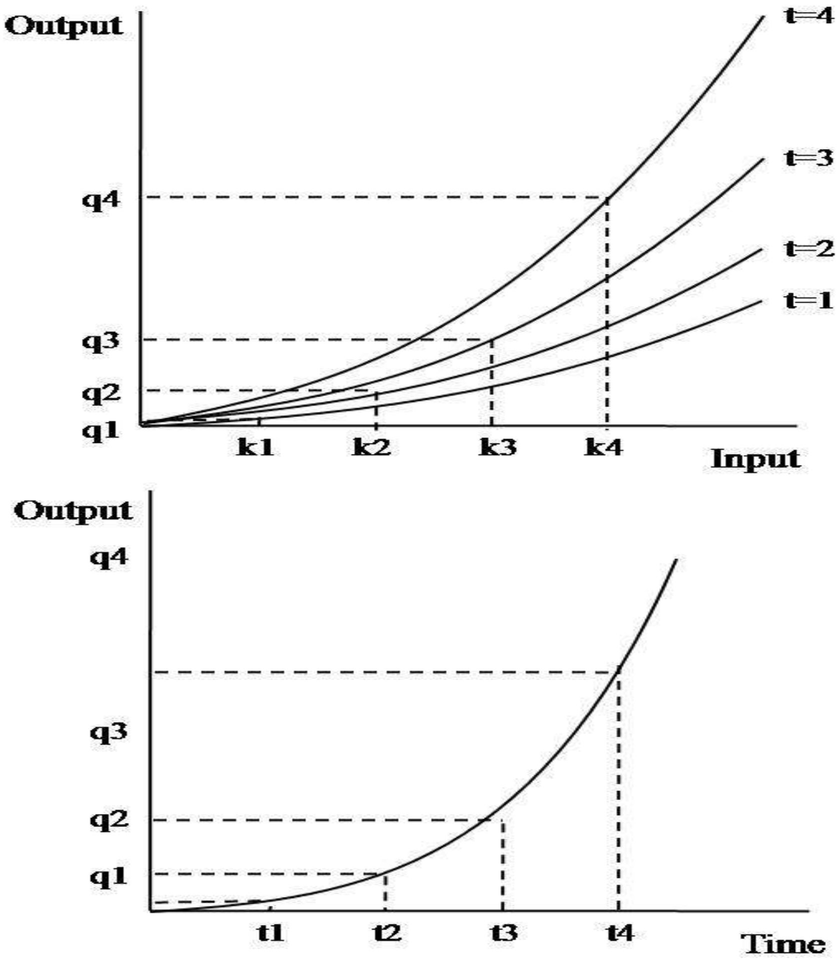
The growing importance of the ICT industry is characteristic of a knowledge-based society. ICT industries contribute to GDP growth and increased investment. In the 1990s, more than one fourth of the yearly, average, real GDP growth rate in the United States was earned through the ICT industry (Gordon, 1999). This ICT success is the result of increased production and investment in the ICT industry as well as exportation of goods and services related to ICT.

ICT industry development and rapid growth of e-commerce lead to changes in the employment structure as the demand for high quality human resources in the ICT sectors increases. In the United States, employment in the ICT sector was 557,000 in 1985, 1.2 million in 1996, and was expected to reach 2.5 million in 2006 (U.S. Department of Commerce, 1998). More flexible working conditions, such as e-commuting from outside the workplace, contribute to the changing employment structure, and hiring practices will need to be adjusted to the new working environment.

3.3. The relationship between time and production of the knowledge-based society

Due to rapid technological change, the aggregate production function (APF) over time shows patterns similar to those found in Figure 5(a). Each APF reflects the technology level of a certain period. Figure 5(b) is the trace, which connects the production of each period reported in Figure 5(a). When the APF shifts as technology changes, we define production trace of each APF as the APF production expansion path[6]. The APF production expansion path of the lower part of the figure has the shape of a long-run output curve in a knowledge-based society. From Figure 5 we can distinguish a number of specific characteristics of the relationship between time and production. In the knowledge-based society, technology progress is much faster as time passes, production function has increasing returns, and the size and speed of the APF shift are even faster than that of the industrial society. Therefore, we can see that economic growth accelerates faster in the knowledge-based society.

[6] Refer to Kim, T.Y., 2008. Perspectives on the accelerating industrial society. Unpublished manuscript.



(a) (b)

Figure 5. Output relationships of knowledge-based society as shifts in the APF over time.

Increments of the production measured as distances, (q_2-q_1), (q_3-q_2), (q_4-q_3), are getting increasingly bigger as time elapses[7]. The short-run production function of the knowledge-based society leads to these results, and the society itself experiences increasing returns. The range of shift in the short-run production function is also getting larger because the technology progress over time is far faster in a knowledge-based society than it is in an industrial society. That is, the time-output production curve in a knowledge-based society shows acceleration, but the slope is steeper than the curve that represents an industrial society. A comparison of the time-output relationship for industry and knowledge- based societies is illustrated in Figure 6.

[7] See APF production expansion path in Kim, T.Y., 2008. Perspectives on the accelerating industrial society. Unpublished manuscript.

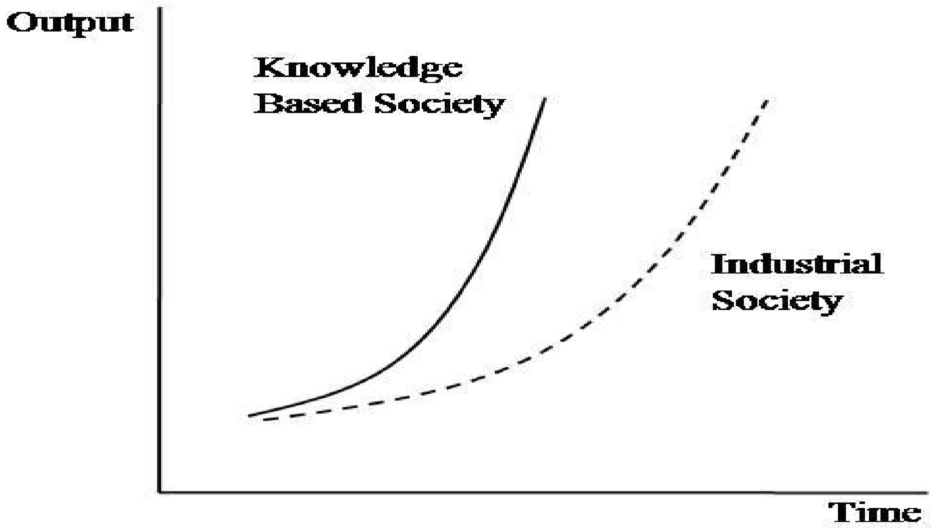


Figure 6. Time-output relationship of the faster accelerating knowledge-based society compared to the industrial society.

4. Theoretical explanations about accelerating economic growth in the knowledge-based society

In this section, we briefly review the opinions of several scholars who attempted to explain the faster accelerating knowledge-based society. Arthur (1994) explained the acceleration effect based on increasing returns and a path dependent economy, and Shy (2001) explained the faster acceleration based on economies of scale in the computer software industry. These two researchers insisted that the production function shows increasing returns for the knowledge-based society. In addition, we introduce the network effect for intercomplementary products and the tipping effect in technology standardization to describe the faster acceleration by network externality.

4.1. Acceleration effect by increasing returns and path dependence

Arthur (1994) proposed that when two competing technologies show increasing returns to scale, we find evidence of path dependence if following agents choose the same technology that the first agent chose. As a result, the market does not reach an equilibrium point, and a “corner solution” appears.

When looking at increasing returns, one cannot easily predict which technology will be adopted in practice. Once a technology is adopted, it is difficult or impossible to switch from the selected technology to alternative technologies. In addition, adoption in the market does not guarantee a path-efficient technology choice.

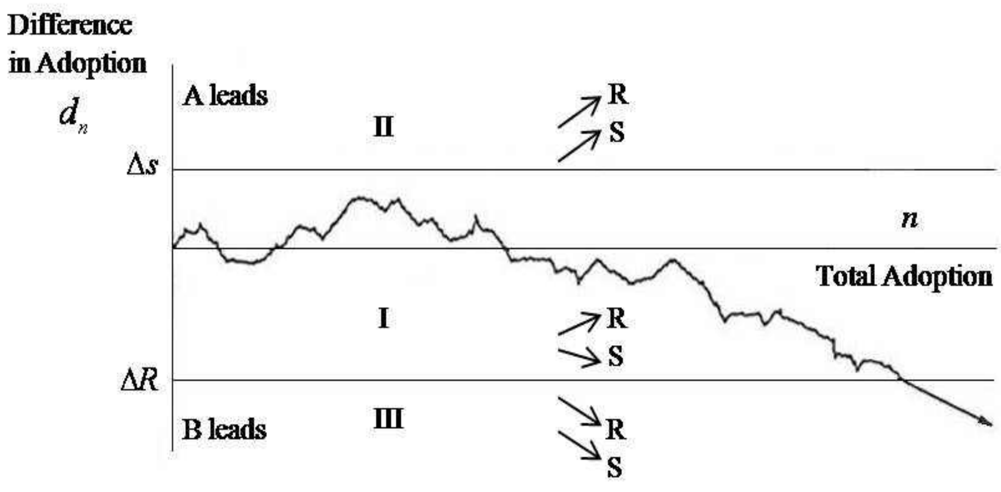
Figure 7 shows the differences in the adoption of technologies A and B by two groups of agents, S and R, under the conditions of increasing returns to scale and path dependence. The range of technology adoption is divided into different distinguishable zones. The leadership in technology adoption by the two agents is evident.

The illustration suggests that when one technology enters the market successfully in an industry with increasing returns to scale, demand is expanded much more than if it enters an industry without increasing returns to scale. In the former case, sustainable market acquisition is possible. If many technologies share the market, the resulting big scale allows for more profit, which benefits the industry and society.

Figure 7 illustrates the change of market share between two products when two competitive technologies (or goods and services) have increasing returns. The X axis denotes the number of consumers or total adoptions of the two technologies, and the Y axis denotes the difference of market share of the adopted technologies A and B.

If the difference of the market share becomes greater than Δs, product A leads the market (area II). On the contrary, if the difference becomes greater than ΔR, product B leads the market (area III). S and R refer to the consumer who prefers product A and B respectively. S buys product A, and R buys product B and when the difference is negligible (area I) neither of the two products dominates the market.

When two products in the market both have increasing returns of scale, if market sales tip in favor of A or B, and if consumers are indifferent and each buys the dominant product in the market, then one technology continuously expands its market (random work with absorbing barriers). This situation is explained in Figure 7.



Source: Arthur, B., 1994. Increasing Returns and Path Dependence in the Economy. University of Michigan Press, Ann Arbor.

Figure 7. Increasing returns: random walk with absorbing barriers.

When both technologies show constant returns to scale, the R agents always choose technology B, while the S agents always choose technology A. Consumer choice is independent of the number of adopters of either technology. Therefore, consumer choices are considered random and hence the two technologies are adopted with the same adoption-selection probability.

When both technologies A and B show diminishing returns to scale (see Figure 8), R agents will switch their preference from technology B to A if the number of consumers using the B technology become sufficiently greater than those using the A technology. Similarly the S agents will switch from A to B technology if the number of consumers adopting A technology becomes sufficiently larger than those adopting the B technology (random walk with reflecting barriers).

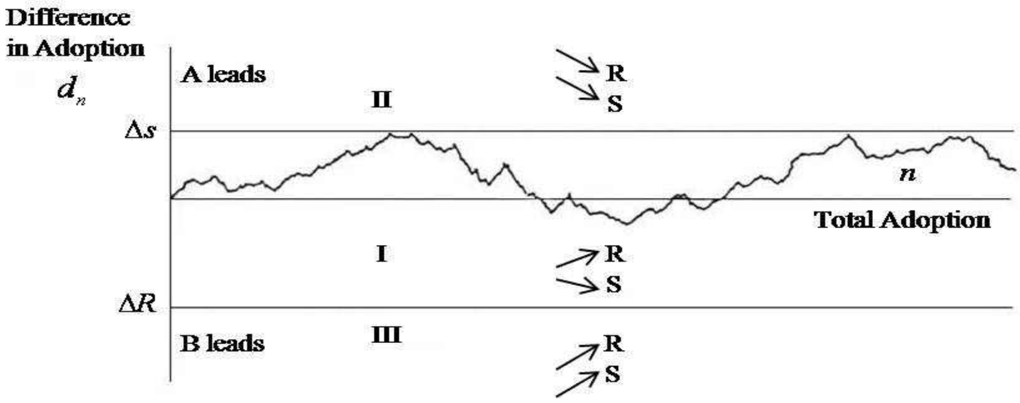


Figure 8. Decreasing returns: random walk with reflecting barriers.

Source: Arthur, B., 1994. Increasing Returns and Path Dependence in the Economy. University of Michigan Press, Ann Arbor.

4.2. Economies of scale in the computer software industry

Because software products are digital, deployment of products and services is the most expensive part of putting forth the output, the marginal cost (MC) for the reproduction of one extra unit is almost negligible. Therefore, software industries require a large amount of development-stage investment and the production of software exhibits sharp economies of scale (Shy, 2001).

The total production cost (TC), average cost (AC), and marginal cost (MC) equations for software industries are written as follow:

$$TC(q) = \phi = \mu q \quad (1)$$

$$AC(q) = \frac{TC(q)}{q} = \frac{\phi}{q} + \mu$$
(2)

$$MC(q) = \frac{\Delta TC(q)}{\Delta q} = \mu$$
(3)

where q is the number of buyers or quantity produced and μ is the MC of producing one extra unit of output.

The AC and TC of software production are shown in Figure 9.

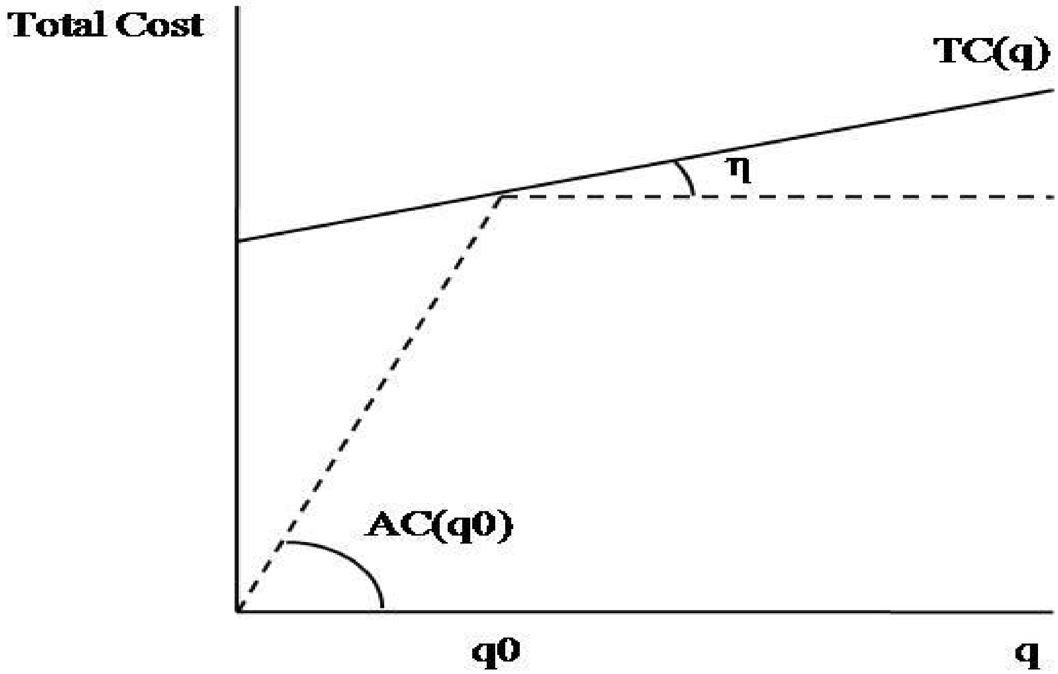


Figure 9. Total software-production cost function.

Figure 9 illustrates that the AC for the production of one unit of output for software development decreases rapidly as software sales increase. The pattern of cost decline is further shown in Figure 10 by the AC and MC functions. Unlike in the case of traditional goods in which the MC is U-shaped, MC in the software industry is horizontal, while the AC continuously declines as the production size increases.

$$AC(q) \longrightarrow \mu = MC(q) \text{ as } q \longrightarrow \infty \quad (4)$$

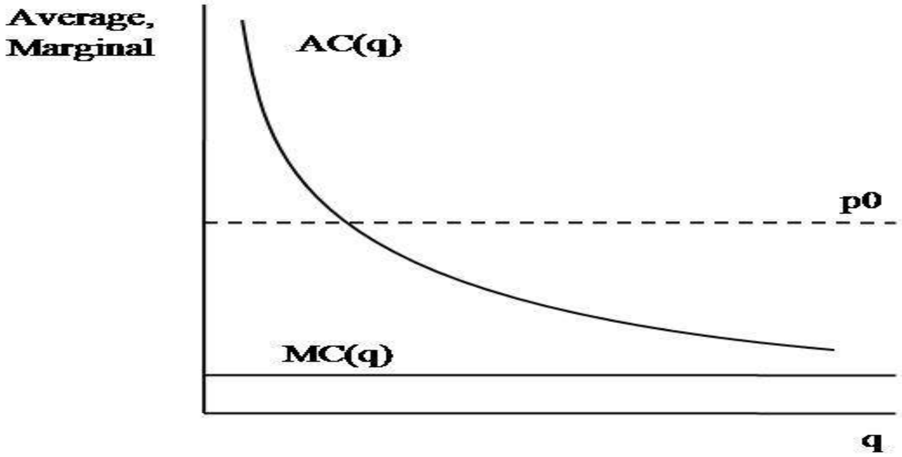


Figure 10. Average and marginal production cost functions for software.

The reproduction of software is not physically limited and the acceleration of marginal production is realized because of the decreasing marginal production cost. Accordingly, the more output produced, the more the net value is increased. Therefore, we can see from this example, that economies of scale in a knowledge-based society are generally larger than those in the industrial society.

4.3. Network effects according to the production of compatible products

In the previous section, we assumed a model that reflects homogenous consumers. Shy (2001) assumed a model with heterogeneous consumers who have different utilities and preferences. Moreover, the preferences of these consumers show the network externality. Under this model, two brands of computer can have the following three compatibility strategies if

- computer brands A and B are differentiated and incompatible,
- computer brands A and B are differentiated and compatible, or
- computer A is made to be compatible with computer B, but B is made incompatible with A.

In each case, a computer that is made to be compatible allows producers to impose higher prices and generate more profit. The third case can be easily illustrated by the relationship between the Hyper Drive of Apple computers and the DOS-formatted 1.44MB diskette in the late 1980s. Users could employ the Apple Hyper Drive in DOS, but the DOS diskette was not compatible with Apple computers. In this case, the producer of the compatible computer (Apple) was able to fix a higher price and generate more profit than producers of the incompatible computer (DOS).

Therefore, the production of complementary goods can multiply the network effect. Complementary products supplied by two producers result in a two-stage game. In stage I, each firm in the market decides whether to make its machine compatible or incompatible with the competing machine. In stage II the firm determines its market price level.

In an alternative scenario a one-stage game is played. If consumer preferences show network externality, a unique Nash equilibrium evolves such that both firms design their products to be compatible with each other. Moreover, this Nash equilibrium is the dominant strategy equilibrium, and it brings about profit maximization. The social welfare function measures the utility consumers get from the scale of network and is maximized when two brands are compatible because network externality is utilized.

The network effect explains the faster acceleration state of the knowledge-based society. More consumers and producers can be connected to each other as a result of product compatibility, and then network effects are further increased and the market expands. Hence, the increased network effect makes a faster acceleration process in the knowledge-based society possible.

4.4. Acceleration by technology standardization

Multiple equilibriums can be seen in a technology-standardization game played under accelerating economic growth conditions. This situation is due to Pareto dominance, and those multiple equilibriums will be tipped to one of the producers.

If users exhibit network externalities for technologies, utility is higher when all users adopt the same technology regardless of its quality. Equilibrium can occur in either technology, but one is selected according to the strategy of the competitor. In utility theory, three possible equilibrium states are possible: two are unique equilibriums according to which one of technologies becomes dominant, and in a third multiple equilibrium networks A and B coexist.

In multiple equilibrium situations, all agents are indifferent to the two networks A and B. When the gap between the services of networks A and B is large, the network effect of B is large enough to offset its comparative inferiority such that subscription to B is indifferent to subscription to A.

Either excess inertia or excess momentum characterizes the movement between networks due to the tipping effect. The tipping effect requires a sustainable market with regard to the adopted technology. Diffusion or adoption of a new technology is determined by the number of network subscribers. If the number of subscribers of a new network exceeds the critical mass, the switching behavior from the old network to the new network is profound. Explosive demand increases bring about supply increases. Accordingly, a larger acceleration can be achieved in a shorter time in a knowledge-based society than in an industrial society.

If adopting the old technology is in Nash equilibrium[8], or if adopting the new technology is based on a Pareto dominant strategy[9], then we call this situation “excess inertia.” Regardless of its status as socially and more technologically efficient, network A will struggle to enter the market where B with lower technology has reached equilibrium.

If adoption of a new technology is characterized by Nash equilibrium, or if adoption of the old technology is based on a Pareto dominant strategy, then we call this situation “excess momentum.” The excess inertia and excess momentum are opposite to each other as they relate to the position of two competing technologies in the game. If the subscription rates of a new network exceed the breakeven point, one can assume that a large number of consumers are switching from the old network to the new one.

4.5. Summary of theories explaining the faster accelerating knowledge-based society

As examined above, scholars of the knowledge-based society do not use the classical economic growth theory of decreasing-returns-to-scale production function, and the traditional relationship between output and input. As Arthur (1994) insisted, the knowledge-based society has the production structure of increasing returns to scale and the path dependency production pattern. Once one technology leads the market, production and demand are concentrated on that technology, hence faster growth appears. This very fast growth could not be experienced in the previous industry society.

Shy (2001) attempted to examine theoretically the faster accelerating society through the network effect, which appeared in the computer hardware and software industries. In a technology standardized field, the phenomenon of development and production of goods leaning or tipping to one increasingly standard technology is also the basis for technology-centered accelerated growth in knowledge-based societies. Accelerated growth is being generated in each industry of the knowledge-based society in this manner. Thus, the whole economy is growing faster in this knowledge-based society than in the previous forms of societies.

5. Cases of faster accelerating knowledge-based society

In this section, we introduce a number of cases that explain the economic growth pattern of a knowledge-based society. A study of the United States, an industrial society leader, shows that a knowledge-based society accelerates faster than an accelerating industrial society. Ireland and Finland, which were developing countries during the industrial-society era of Europe, were early members of the knowledge-based society and so outran the countries that were still characterized by an industrial society.

[8] The situation in which each player regards the strategy of the other and selects the best strategy; Nash equilibrium is the combination of these best strategies. Under the Nash equilibrium, neither party will change their strategy unless the competitor does so first.

[9] One policy is better than all others for a large number of people.

5.1. Productivity effect of information technology capital

To shed light on the effects of IT capital on productivity, Lee (2001) used the amount of ICT investment in a regression analysis in which productivity was expressed as value added per capita for each Korean industry in 1995. The Cobb-Douglas function was used to specify the model. The result shows that labor productivity is improved by an increased proportion of ICT capital investments.

Using the general ICT price index, we obtained the data on the amount of ICT capital investments in whole industries. The result from ordinary least squares (OLS) analysis shows that the coefficient of ICT capital was 0.0895, which is statistically significant at the 5% level. Over time, the productivity of the industries with increasing rates of ICT capital will increase. Nowadays, IT is advancing rapidly and its utilization in production is being improved. As a result, the cost reduction is accelerated and the productivity improvement is significantly large.

We classified manufacturing and service industries by the effect of informatization on productivity. The results suggest that informatization is more effective in service industries. In conducting OLS regression analysis, we found that the coefficient of informatization rate in service industries was 0.3054, which is statistically significant at the 1% level. It showed a significant positive correlation with productivity growth. However, the coefficient is not significant in the case of manufacturing industries. In other words, labor productivity is increased in service industries as the informatization rate increases, but there is no clear and corresponding positive evidence in the case of manufacturing industries.

The result indicates that improvement of labor productivity by ICT investment is more effective and pronounced in service industries. Knowledge is a more important input factor in service industries than it is in manufacturing industries. With regard to IT capital, investors will find that the increase of value added is more significant in service industries. When applied to service industries, IT capital improves the productivity of service industries and explains the faster acceleration of the knowledge-based society.

Lee (2001) demonstrated that the marginal rate of return (ROR) of general capital goods in the whole industry is estimated to be 0.2767, but one ICT capital good is as much as 1.5357 (reflecting 5.55 times the returns from general capital goods). The marginal ROR of ICT capital is 14.0856, which is 88.08 times that of the corresponding marginal ROR for the non-ICT capital in service industries.

5.2. Cases of the knowledge-based society accelerating faster than industrial society

In this section, we focus on the faster accelerating advanced leader, the United States, and the faster accelerating follower-country models. As examples of the latter type of knowledge-based societies we introduce Ireland and Finland.

5.2.1. The faster accelerating advanced-country model

According to the GDP per hours worked in the United States, the increasing rate of labor productivity grew faster after the 1970s than in any period before (Figure 11). This implies that the economic growth speed of the knowledge-based society is faster than that of the industrial society (Gordon, 2000).

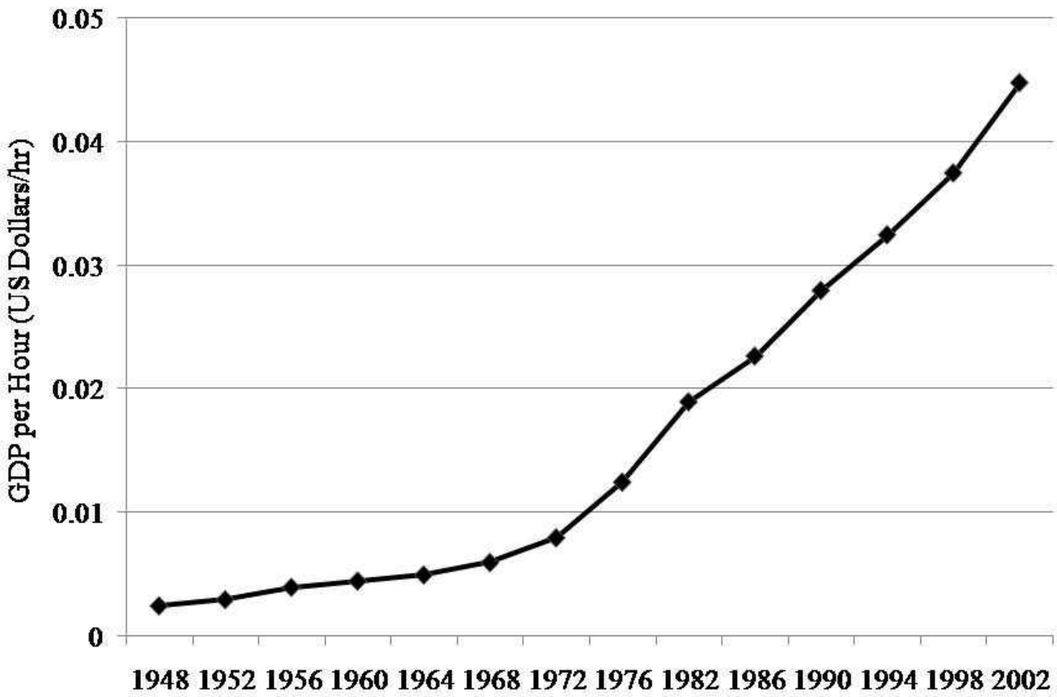


Figure 11. GDP per hours worked in the United States, 1948-2002.

There was a boom in the U.S. economy that is referred to as the “new economy.” It is characterized by the rapid development of the ICT industry during the 1990s. It generated conditions to speed up economic growth faster than it had been in the past, and it could expand the gap between the United States and other advanced countries with a similar growth rate. Figure 12 shows the trend of GDP per capita in the United States, the Organisation for Economic Co-operation and Development (OECD) countries, and Japan from 1990 to 2001 (Seo and Chung, 2002). The gap between the United States and other advanced countries gradually grew wider after the 1990s.

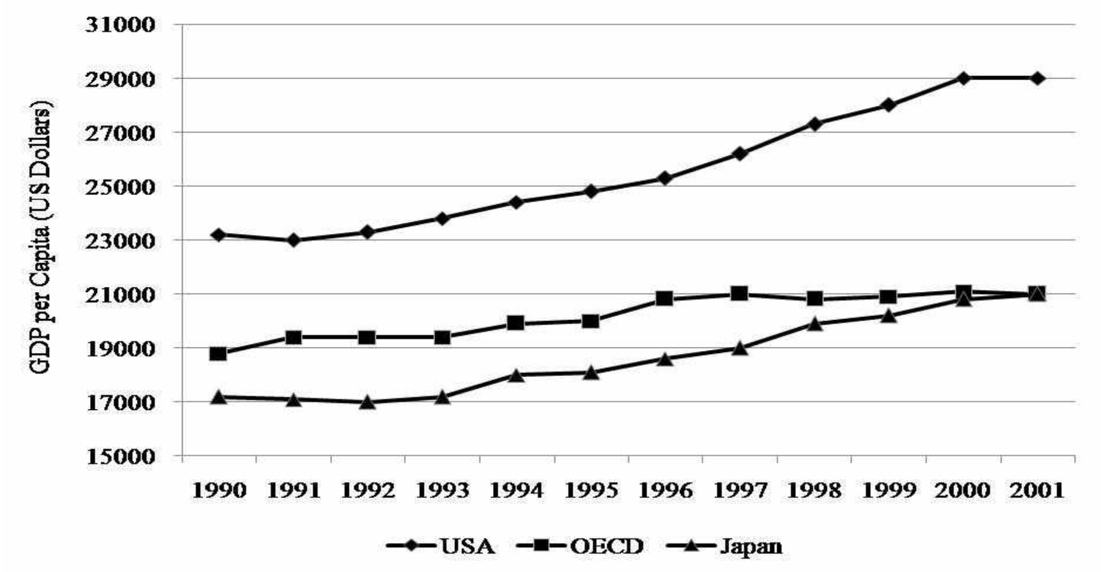


Figure 12. Development of GDP per capita in the United States, OECD countries, and Japan, 1990-2001.
Source: GGDC, Total economy database. (http://www.ggdc.net/dseries/growth-accounting.shtml)
Notes:
1. OECD countries include Australia, Austria, Belgium, Canada, Denmark, Finland, France, Ireland, Italy, the Netherlands, New Zealand, Norway, Sweden, Switzerland, and the United Kingdom.
2. The unit is U.S. dollars, and the numerical value is the constant market price in 1996.

According to Gordon (1999), U.S. aggregate productivity from 1995 to 1999 increased by 2.15% yearly (Table 3). The computer industry led the growth of productivity, and the total productivity increased in spite of the poor performance of other non-computer industries because the productivity increase in the computer industry was estimated too high (Gordon, 1999).

Table 3. The growth rate of sector productivity in the United States

Sector	Growth rate (%)		
	1952-1972	1972-1995	1995-1999
Non-agricultural private business	2.63	1.13	2.15
Manufacturing	2.56	2.58	4.58
Durable goods	2.32	3.05	6.78
Computer	-	17.83	41.70
Non-computer	2.23	1.88	1.82
Non-durable goods	2.96	2.03	2.05

Source: Gordon, 1999. Has the "new economy" rendered the productivity slowdown obsolete? Northwestern University Working Paper, Table 1, p. 29.

Atkinson and McKay (2007) insisted that IT contributed the most to the recent improvement in U.S. productivity. The difference in total factor productivity growth in IT and non-IT industries is illustrated in Figure 13. Two patterns are revealed. First, there is an increasing trend in total factor productivity growth in the IT industries for different time periods between 1948 and 2002. Second, there is negative or reverse relationship between productivity growth in the IT and non-IT sectors.

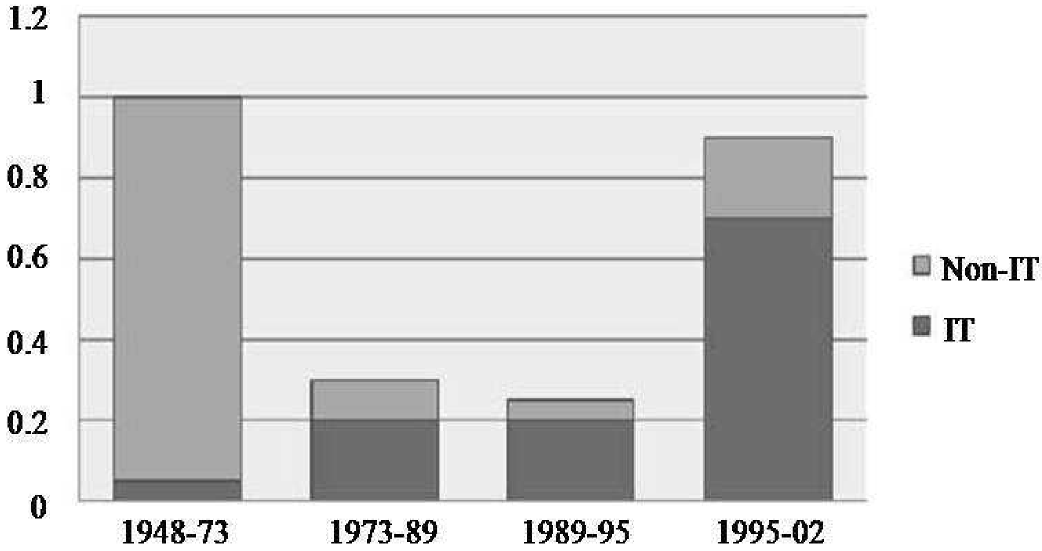


Figure 13. Sources of total factor productivity growth, 1948-2002.

Source: Atkinson, R.D., McKay, A.S., 2007. Digital prosperity: Understanding the economic benefits of the information technology revolution. Social Science Research Network Working Paper Series, ITIF. Figure 6, p. 17.

5.2.2. The faster accelerating follower countries

The technology-based follower countries can establish a knowledge-based society before others, and then they overcome the leading countries that are characterized as industrial societies. Figure 14 illustrates such a process.

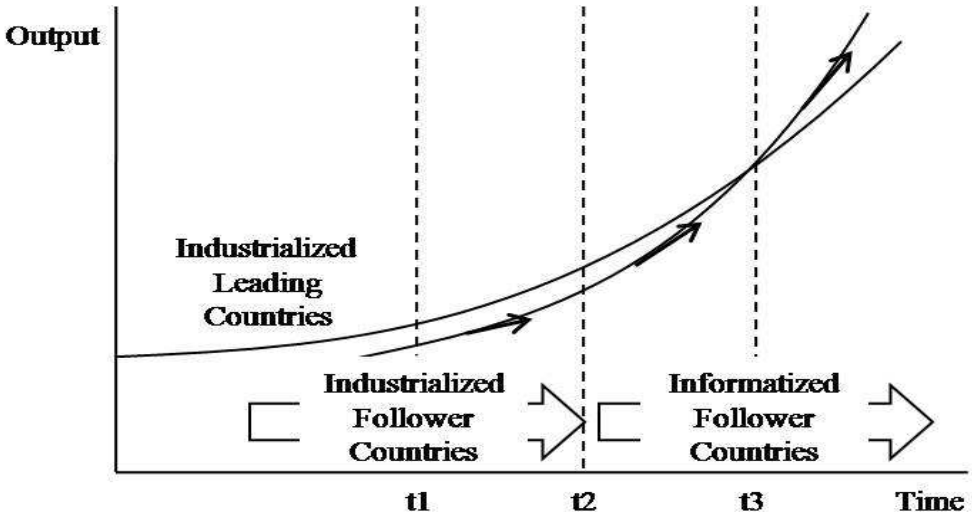


Figure 14. The overcome model in a knowledge-based society.

Source: Kim, T.Y., 2008. Perspectives on the more accelerating knowledge-based society. Unpublished manuscript, p. 43.

In a knowledge-based society, service industry development as a result of ICT results in accelerating economy growth, which is faster than the expanded reproduction of manufacturing that characterizes an industrial society. This phenomenon is shown by the slope of the time-output curve, which accelerates faster for the knowledge-based society than for the industrial society. If the economy of the leading country is informatized first, the productivity gap with the following country will get broader. However, if the follower county invests in ICT intensively and becomes the faster accelerating knowledge-based society, it can overcome the gap in economic growth. In Figure 14, the growth gap is getting wider because of this type of industrialization process from t_1 to t_2. After the follower country enters the knowledge-based economy, the growth speed of the slope starts to get faster from t_2, it catches up with the leading country at t_3 and overcomes it from this point in time. In our study, evidence of such a pattern is found in the cases of Ireland and Finland.

5.2.3. Ireland outruns the United Kingdom

The GDP per capita of Ireland in the 1980s was 69% of the European average, but it increased to 136%, which means it became one of the richest countries in the Europe. Besides, GDP per capita in 2005 was €28,000 and it had already surpassed the United Kingdom in 2001 (see Figure 15). These data show that a country with only 3.5 million people has a GDP per capita that is ranked sixth in the world. Ireland accomplished this turnaround through a government policy that encouraged software companies and concentrated on the high value-added ICT industry.

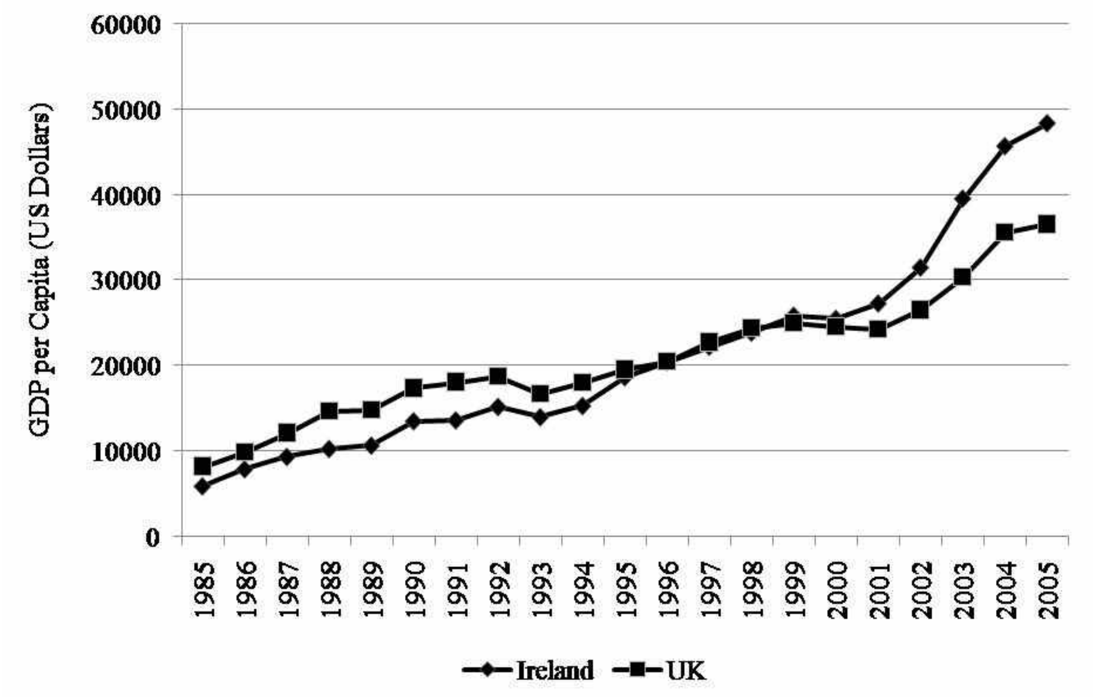


Figure 15. Development of GDP per capita of the United Kingdom and Ireland.

Source: International Monetary Fund, 2001. Data and statistics. (http://www.imf.org/external/datamapper/index.php)

5.2.4. Finland Outruns EU 15

Finland faced a financial crisis in the early 1990s in the aftermath of the Soviet collapse. The Finnish economy was highly dependent on exports to the Soviet market. Lack of foreign exchange and discontinuity in the trade relation with the Russian Federation led Finland to change its industrial structure. The electronic device industry, which produced mobile phones and other technical devices, become the main industry. The GDP growth rate was estimated at an average 5% from 1995 to 2000 (see Figure 16) (OECD Stat, 2002). In the rating of global competitiveness, Finland became recognized as the representative of the small countries in Europe. That is because the government decisively raised the ICT industry, developed technology, and invested in human capital (International Monetary Fund, 2001). The three main ways that Finland accomplished high-level global competitiveness are through the institutional frame of public innovation, policies of science and technology, and policies related to the R&D budget in science and technology.

In Figure 16, the development of GDP per capita of Finland is compared with that of average EU15 during 1992-2002. In 1997/1998 Finland caught up to the level of the EU15 and exceeded it. The gap since 1998 has been increasing.

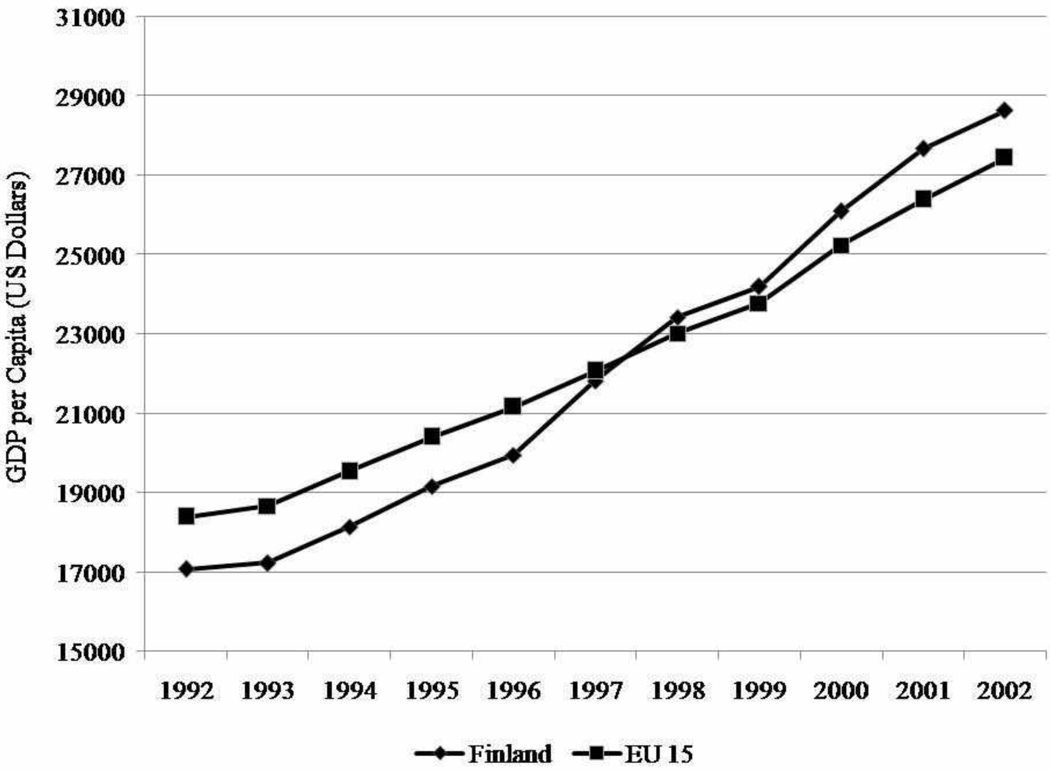


Figure 16. Development of average GDPs per capita of EU15 and Finland.

Source: OECD Stat, 2002, Country statistical profile.
(http://stats.oecd.org/wbos/Default.aspx?usercontext=sourceoecd)

6. Summary and conclusions

The commencement of the knowledge-based society allowed for a single and major change: Knowledge and information as production factors were added to traditional ones such as labor capital, material, and energy. These new production factors are increasingly contributing to the economic growth and industrial development of nations. In the industrial society, the economic growth is found to be much faster than that in an agricultural society. After the ICT revolution, this acceleration was even more intensified and was particularly apparent in the knowledge-based society.

Unlike in the agricultural and industrial societies, the faster economic growth of a knowledge-based society shows higher increasing returns in the short-run production function. This fast growth results from the faster demand expansion and technology progress in a knowledge-based society. This is maximized by characteristics of supply and demand. First, the expansion of globalization makes the effect of economies of scale larger. Moreover, the importance related to the information industry was greatly increased in terms of input and output production quantities due to the development of ICT in the Information Revolution. Industries with network externality became increasingly prominent, and the importance of the ICT industry in investment, GDP, and employment became higher. In the United States, more than one fourth of the real GDP growth rate was contributed by the ICT industry in the 1990s.

The faster accelerating knowledge-based society can be explained by several theories including those explaining increasing returns, path dependence, network externality, economies of scale in the software industry, and the tipping effect of technology standardization. All these theories explain how the knowledge-based society can be accelerated on a larger scale than the industrial society.

The United States, Ireland, and Finland are typical examples of the faster accelerating knowledge-based societies. These three countries entered the knowledge-based society earlier, and the speed of their economic growth is getting faster than before. The ICT industry not only brings GDP and higher increments of productivity, but it also multiplies the economic growth of countries by multiplier effects that promote the growth of other traditional industries.

In this paper, we discussed the definition, characteristics, and mechanism of the faster accelerating knowledge-based society. The innovative development of ICT was the driving force that can make the faster acceleration possible.

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