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The Faster-Accelerating Growth of the Knowledge-Based Society

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The Faster-Accelerating Growth of the Knowledge-Based Society

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Abstract: The first contribution of this study is to identify the economic growth patterns of the emerging knowledge-based society of the future, compared to the agricultural society or the industrial society, by analyzing the aspects of future technologies and new humankind and their effects on the value creation structure. The second contribution of this study is to highlight the characteristics of the new humankind in a knowledge-based society. A number of studies related to economic growth from the long and macro perspective have considered only the conventional aspects of individual humans—for example, a rational consumer or a labor supplier—but this study has considered newly emerging groups with different socio-economic characteristics and their effects on the economy and society.

Keywords: Knowledge-based society, future technology, digital native, active senior, economic growth, faster acceleration.

JEL Classification Numbers: L16, O11, O47.

1. Introduction

The pattern of economic growth in a knowledge-based society is expected to be different from that in an industrial society, which depends more on tangible factors of production, such as land, iron, or oil, than on intangible factors [1] [2] [3]. Especially the information technology (IT)-driven economic growth in the era of the 'new economy' at the end of 1990s in the U.S. suggests the possibility of a new society and new pattern of economic growth.

The digital economy, based on IT innovation, has changed society with increasing speed; examples are the shortening of the cell-phone technology cycle or the emergence of rapidly growing companies like Google. Such a rapid change of technological and industrial environment brings not only changes in firm management but also social changes and, in particular, the emergence of a digital generation [4] [5]. The newly emerged generation, as the main actor in consumption and production, drives technological development and industrial growth, and accelerates market expansion [6] [7].

The bioeconomy, driven by economic growth and population aging, will have an impact on the entire economy, including the health, energy, and agriculture sectors [8]. An active senior group, based on economic growth and population aging, is expected to grow rapidly and to have an enormous impact on future consumption patterns [9] [10]. Economic growth and high income will increase health demands. In particular, the growing population of elderly will increase the market demand related to health care and wellness and, therefore, will drive bioeconomic growth (Meara et al., 2004; OECD, 2009a).

The computer, electrical device, and air line industries grew rapidly from the 1970s to the 1990s, reaching a 20–25% share of total production and export in the OECD countries; and more knowledge-intensive industries, such as the education, communication, and information sectors, have been developing more rapidly [3]. The annual average growth rate of the U.S. bio-industry, having a share of more than 70% in the world bio market, remained at 14% for 10 years after 1966 [11][1].

Knowledge-based industrial growth is changing the firms' value-creation mechanism from tangible-factor based to intangible, intellectual-factor based. Investment on intangible assets in the firm has already increased to the level of investment on tangible assets [12]. A U.S. economist, John Kendrick, said that the intangible capital:tangible capital ratio was 30:70 in 1929 in the U.S., but intangible capital overtook the tangible, with a ratio of 63:37 in 1999 [13]. Drucker [2] foretold the birth of the knowledge-based society in which knowledge would substitute for physical capital or labour.

Joseph Schumpeter and neo-Schumpeterians have theorized and empirically proven the relationship between technological change and economic growth. Most research on economic growth focuses on determinants of the economic growth rate across countries [14] [15] [16]. However, not enough studies identify long-term changes in the economic

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[1] Calculation using the data from the annual issues of BT industry report by Ernst & Young

growth pattern from technology, especially as related to the emergence and development of scientific knowledge-based technology and its co-evolution with humankind and society. This study aims to identify the economic system and growth pattern of the future knowledge-based society, and the continuation of hyper-long-term social changes, subsequent to agricultural and industrial societies.

This study presents three phases to analyze the differences between the economic growth patterns of the knowledge-based society and the industrial society (Fig. 1). The first phase identifies aspects of the future knowledge-based society by studying the characteristics of future technologies and their impacts—which are main parts of future global trends—on industry and society (Section 2).

According to the various prospects of future technologies and MIT's annual projections[2], future technologies can be classified into IT, Biotechnology (BT), Nanotechnology (NT), and convergence technologies among these or with traditional industrial technologies. Therefore, this study analyzes IT, BT, NT, and their convergence technologies to identify technological and socio-economic aspects of a future knowledge-based society. In particular, this study examines the socio-economic aspects of the new society to include changes in human behaviour, focusing on Digital Natives and Active Seniors who behave differently from conventional consumers in a traditional industrial society.

The second phase analyzes changes in the value creation system of an industrial society from the economic and social aspects of a knowledge-based society (Section 3.1). The third phase defines the economic growth pattern governed by a transformed value creation system in the knowledge-based society (Section 3.2). This study does not, however, discuss whether or not a knowledge-based society should be defined as fundamentally different from an industrial society.

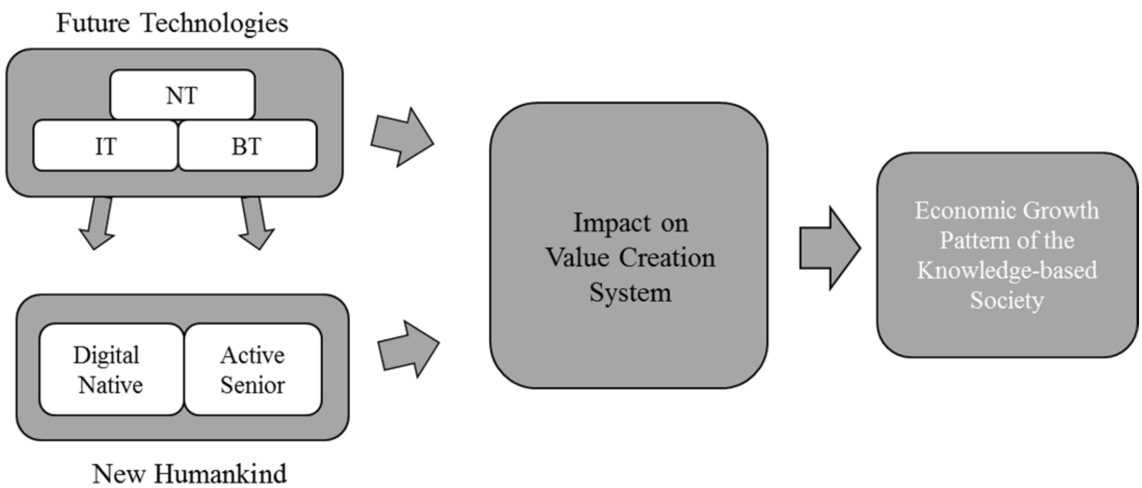


Figure 1. Research framework.

[2] MIT makes a list of top 10 emerging technologies. technologies every year (2001~2009).

2. Characteristics of the Knowledge-based Society

In this chapter, we discuss the technological characteristics, as well as the economic and social influences of IT, BT, and NT, the core technologies of the knowledge-based society, and the convergence technologies that connect legacy industries.

2.1. IT, BT, and NT: Rules of Technological Progress

2.1.1. IT

Information Technology (IT) is technology for handling information, including the acquisition, storage, transmission, process, display, and protection of information [17]. Canton [18] points to the computer, the microchip, and the Internet as the technologies with the greatest influence on jobs, communication, creativity, and entertainment.

The most fundamental convergence technology is IT because it allows information processing to converge with other technologies. The development of semiconductor/computer technology leading IT is represented by Moore's Law [19]. The law states that the power of computing doubles every 18 months while the cost does not; hence, the cost of computing falls over time.

The most important characteristic of IT is that the technology develops information systems to increase the benefit from the enhanced productivity of other industries. An industry's computerization and digitalization make each production process faster and more efficient, thereby improving productivity. In spite of controversy over Solow's productivity paradox in 1987 [20], Brynolfsson and Hitt [21] assert that even though computerization does not automatically deliver a productivity increase, the changes to industrial structures do increase productivity.

The second characteristic of IT technology is its network and tipping effect. Shy [22] theoretically defines the network effect as shown in computer hardware and software industries. His study on the market's characteristic difference arising from the unique characteristics of software products (easy reproduction and network effect) reveals that while the characteristics of competitive markets for traditional products are not shown in the software market, one technology dominates the market in advance. This kind of tipping effect becomes a fundamental of technology-centred growth acceleration in the digital economy. Harrington and Reed [23] also showed a 'virtuous cycle of e-commerce growth'. Based on the circulation structure and having e-commerce itself as a production index in the digital economy, its accelerated revenue increase is well demonstrated.

2.2.2. BT

Bio Technology (BT) is based on the life sciences. The Office of Technology of the U.S. Congress defines BT as the technology for improvement of plants and animals; it also includes technology using living organisms and/or substances to develop microorganisms for special purposes. The European Federation of Biotechnology (EFB) defines BT as the integration of natural sciences of the individual, the cell, a part of the cell, and the molecule for products and services [24].

Since the products and services of the BT industry relate to living phenomena, the technology requires complicated processes and source-based technologies [25]. BT is also dependent on basic technologies so that the injected intangible value creates high value-added. Therefore, BT is based on cutting-edge knowledge in need of advanced intellectual talent, while it heavily influences change in the industrial structure not only for manufacturing, but also for IT and NT [26].

BT's production characteristics can be examined through the Carlson Curve [27], which shows the changes in BT's productivity and cost. In 2003, Carlson forecasted that the efficiency of the DNA interpretation machine used in the genome project would double every 18 months and that DNA synthesis would accelerate at a faster rate. He also anticipated that the sharp decrease in the cost of DND synthesis would continue and that the DNA sequence analysis cost would drop to the $2 range from $10–12 in the year 2000.

Figure 2 shows the phenomenon very well: compared with Moore's Law, the representative law in IT, we can see that productivity increases faster. From a cost perspective, the tendency of the analysis construct is found to be decreased (Fig. 3).

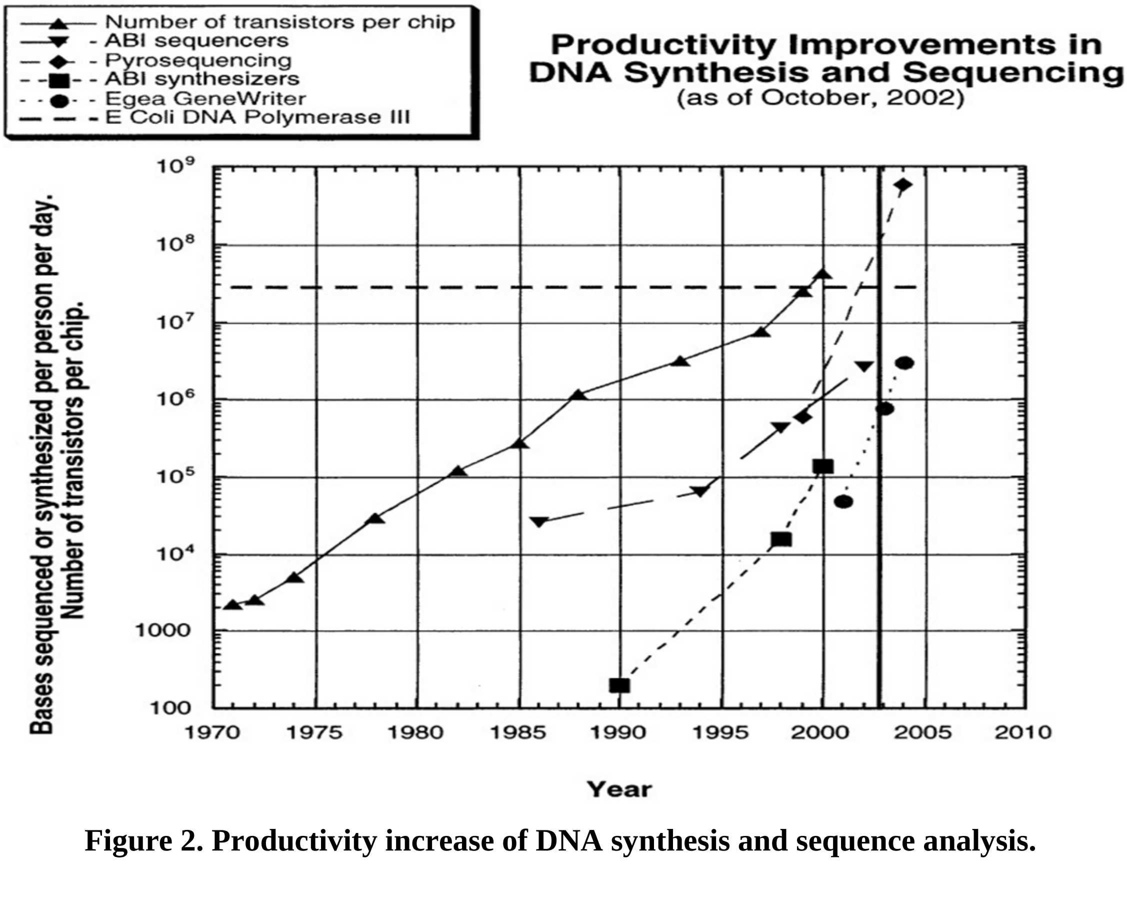


Figure 2. Productivity increase of DNA synthesis and sequence analysis.

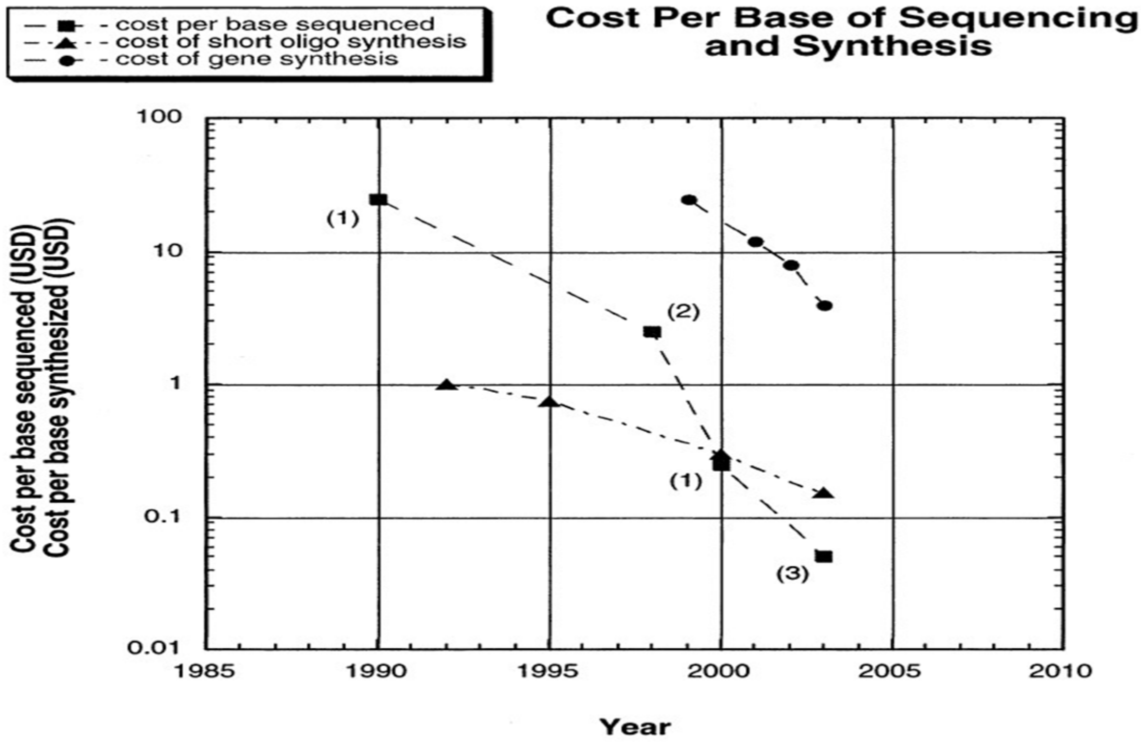


Figure 3. Base sugar synthesis and sequence analysis cost.

The transistor density applied to Moore's Law is heavily influenced by large-scale investments. However, the cost of biology is relatively lower, so the effect of the investment scale is lower while the change is faster. Over time, it is also expected that the error of productivity will be lowered. Thus, it can be forecasted that BT's production function will show a larger acceleration than IT's production function. The data also shows that by 2009, productivity had increased and cost had decreased continuously [28].

2.1.3. NT

Nanotechnology (NT) is technological manipulation of matter on an extremely small scale known as the nanoscale. Though a standard global definition of NT does not exist, in general, it includes the following three elements [29]: first, 1-100 nm is the standard scale; second, nanotechnology deals with the characteristics and structures of material; third, it deals with the measuring and restructuring of the structures [30].

NT has three main advantages. First, since it is based on multidisciplinary characteristics, it promotes convergent development for IT and BT and provides immense possibilities in such divergent fields as agriculture and medicine [31] [32]. Second, NT is particularly suited to efficiency and miniaturization; for example, electronic components can be manufactured to consume less power, and lightweight, strong materials have been developed for more efficient use of energy and space [33]. Finally, NT is forecasted to be an extremely influential technology that will provide breakthroughs in engineering and technology via research on the atomic and molecular levels into the basic structure of materials. It is also expected to contribute to human welfare improvement in convergence with bioengineering and information technology [34].

Nanotechnology is expected to overcome the approaching limits of IT and BT development, hence continuing the accelerated development of technology [35]. First, NT is thought to have the greatest potential to break through the limit encountered by Moore's Law, the representative law of IT industry growth, which according to an announcement from Intel in 2003, is forecasted to reach its end in 2013 with no possibility of continuation after 2025 (Fig. 4). NT also plays a role in fostering the continuous development of IT [36].

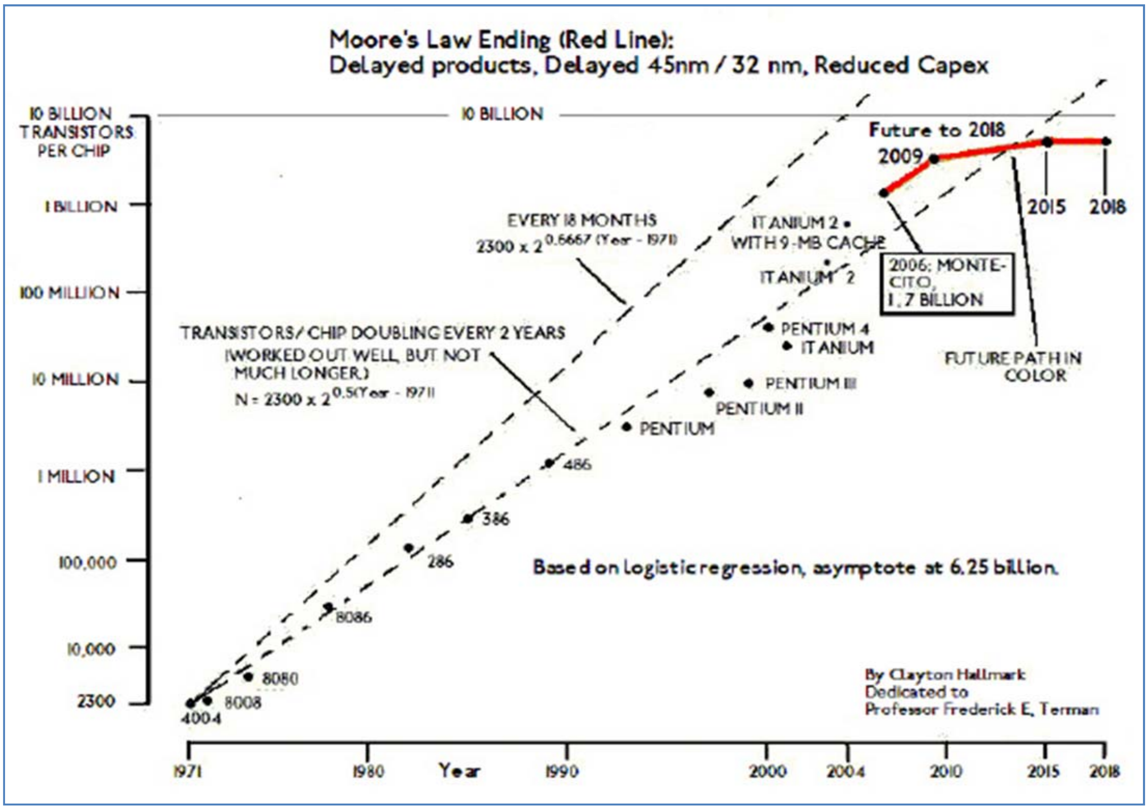


Figure 4. Moore's law ending [37].

The demise of Moore's Law is due to physical and cost limits. Because of the tunnelling effect, controlling electrons becomes physically impossible, precise signal delivery cannot occur, and heat is produced in chips. In theory, it is possible to reduce the size of the gate to four nanometres. However, in this case, the amount of energy required to reduce the tunnelling effect generates more heat so that the chip is melted. Therefore, it is expected to be unusable [38] [37].

In terms of cost, the cost of building a semiconductor factory doubles every three years. Currently, the cost per fabrication facility (Fab) is 3 billion won [39], which means that the increasing cost of chip manufacturing devices has become an issue. Len Jelinek, an analyst at iSuppli, a market research firm, forecasts that Moore's Law, which has been applied to the semiconductor industry, can be sustainable only if it is converged with NT after 2014 because the high price increase of chip manufacturing devices will make the business unprofitable, as shown in Figures 5 and 6.

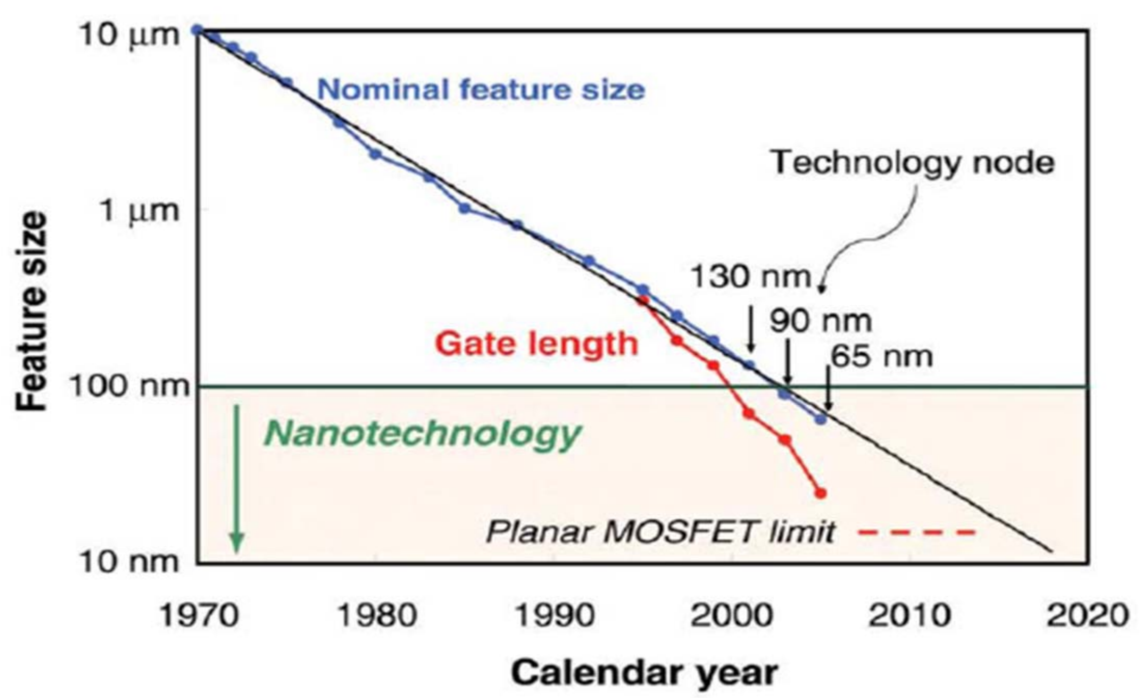


Fig. 1 Logic technology node and transistor gate length versus calendar year. Note mainstream Si technology is nanotechnology. (Published at the International Electron Devices Meeting.)

Figure 5. Semiconductor feature size reduction aspect [40].

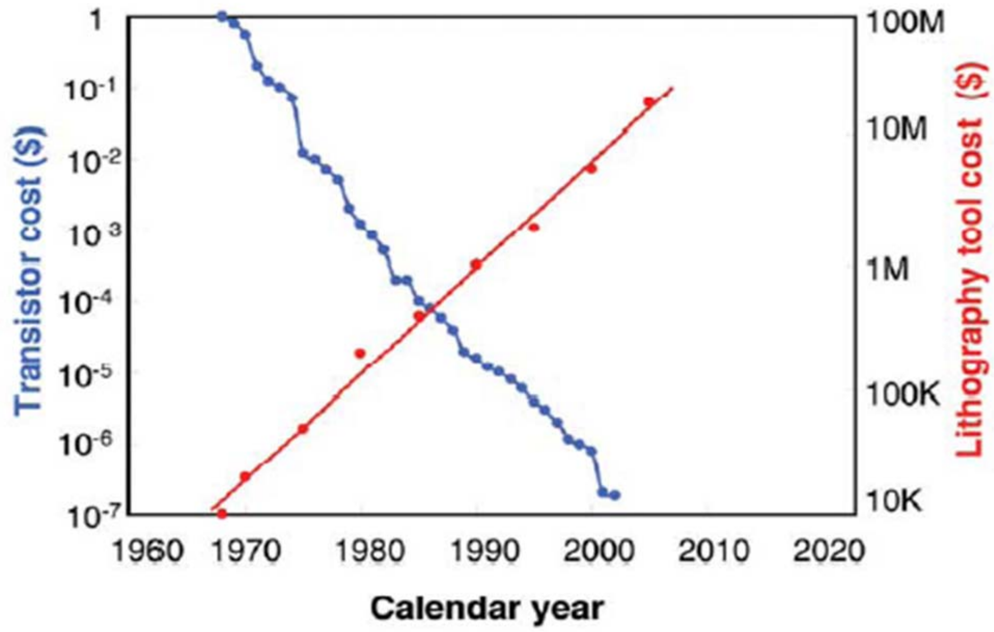


Fig. 2 Transistor cost and lithographic tool cost versus years. Note transistor cost has decreased seven orders of magnitude even while tool cost has increased.

Figure 6. Semiconductor price decrease and tool cost increase [40].

Regarding the relationship between NT and BT, NT provides the tools and the technical platform for BT [41] in showing the way to find the basic methods of biological processes, including self-assembly, cell processes, and the working of bio systems. Measurements based on NT have allowed for understanding the bio-cell as a molecular information machine, capable of highly organized self-maintenance and self-replication, so that critical progress becomes possible in BT [41]. NT also provides new solutions for developing applied technologies in such disciplines as bio-processing and molecular pharmaceuticals [41].

2.2. Impacts of IT, BT, and NT: Economic and Social Perspectives

Industry's computerization and digitalization have changed the industrial structure, resulting in faster and more efficient production [21]. Convergence in existing industrial technology and IT is improving many industries, including automobile, machinery, and shipbuilding [42]. The sharing of tactical knowledge has also become smooth via IT-driven networks; hence, efficiency improvement in the craft production methods of traditional industry areas is expected as well [43].

IT technology has resulted in products and services previously unknown to traditional industry, and new industries have begun, known as IT manufacturing or IT services. This new industry group has created brand new needs and/or expanded existing needs: examples are the identity management system, following Internet access expansion [44], and the online music market growth, following development of the mp3 player.

BT contributes to productivity increase and added value in the various traditional industries through process replacement or technology convergence. BT improves efficiency in a wide range of industrial areas through the increasing introduction of GM crops; application of molecular biology in remedial agents, diagnostic agents, or pharmacogenomics; and substitution of fermentation technology for chemical synthesis [8].

For example, in two acryl-amide production methods, one produced by a traditional chemical method and the other by a BT-based method, the latter is found to have higher concentration in a bioreactor with lighter conditions and to use only 20% of the energy needed for the traditional method [45]. Through gene synthesis, chemical substances and materials can be produced more effectively at a lower cost than when using traditional approaches [46].

NT is also expected to deliver efficiencies and productivity improvement to traditional industries in most applicable areas, such as the manufacturing business [34] and in all processes of the food industry [47]. It is expected to be profitably applied to sustainable development issues involving water, energy, health, the environment, and agriculture [48]. Convergence of traditional industrial technology and NT is expected to enhance such industries as chemical processing, machinery, and consumer products.

Among the new industrial areas created by IT, BT, and NT, those based on convergent technology are particularly promising. Examples include bio-informatics based on BT-IT convergence, bio-chips based on BT-NT convergence, nano-sensors based on IT-NT convergence, and bio-sensors and bio-chips in which BT-IT-NT converge. A high demand is expected in wellness-related products because of economic growth and population ageing, and the supply will be enabled by BT-IT-NT convergence: among MIT projections for future technologies are nanomedicine, personalized medical monitors, and cheap genome analysis.

2.3. New Humankind: Digital Natives and Active Seniors

With regard to the social characteristics of a knowledge-based society, two new human groups have appeared: the Digital Native [49] and the Active Senior [50]. These two economically active groups with their new characteristics have appeared with the aging trend, along with the digital revolution and economic growth caused by IT industry development. These groups, which are highly influential in technology innovation, productivity improvement, and increased demand, are highly significant to the economic growth of a knowledge-based society.

At the beginning of the 21st century, with the change from analog to digital, the big-bang of digital media was completed, and human life was changed. The new generation was variously called the Net Generation, Generation Y, or the Digital Native. The Digital Native grew up in the middle of the digital revolution, marked by the popularization of the personal computer in 1980s and the spread of mobile phones and the Internet in the 1990s [49]. Each researcher defines this generation slightly differently; however, in general, most of the members were born after 1980, had sent and received at least 200,000 messages in texts and e-mails, according to one estimate from 2003, and had spent at least 100 hours using mobile phones and playing video games [51]. Digital Natives comprise about 27% of the U.S. population [52]. This group accepts information rapidly, performs different tasks simultaneously, expects instantaneous compensation, and tends to think that work should be more fun than serious [53]. The digital generation is portrayed in Table 1, and the resulting economic impact will be reviewed in discussing the impact on expanded reproduction.

On the other hand, Active Seniors, who comprise an elderly population with new characteristics, have appeared due to the birth rate decrease and the aging phenomenon from the extension of the average life span. Unlike the traditional concept of seniors, Active Seniors, sometimes also referred to as the 'New-Age Elderly' are the over-60, economically active population with economic power, self-confidence, and high control of their own lives [50]. In the United States, this group comes mostly from the baby-boomer generation, which differs from the 'silent generation'. The latter, born between 1925 and 1944, had lower income, labour participation rate, and consumption along with more children than the Active Senior generation. The baby boomer generation, born between 1945 and 1964, has a high economic influence because of higher income and labour participation rate [50].

The baby boomer generation is divided to three groups—the confident, the vulnerable, and the disadvantaged—according to their attitudes and prospects. The confident group is financially well prepared for the future and has positive attitudes. Research has shown that this group is richer, healthier, and better educated than other groups, comprising 46% of the baby boomer generation [54].

Globally, the senior population shows the fastest growth: with an expected population growth rate of 223% from 1970 to 2025, their numbers are expected to reach 1.2 billion persons in 2025 and 2 billion in 2050 [55]. The development of sanitation, public health, food science, pharmaceuticals, and surgical techniques has also promoted the aging of the population not only in the U.S. but also in the whole world [56].

Several negative impacts may be realized from the Digital Native generation. First, because this generation places great value on the individual's right to privacy and has relatively less interest in community issues and activities, its tendency might have a negative effect on the circulation speed of technological innovation, productivity improvement, and value creation system. Some research results show that the digital generation is unconcerned about social issues, resulting in less trust of government, lack of participation in politics, and weaker civil consciousness compared to other groups [57]. Both social trust and interpersonal trust have decreased in this generation as well [58].

Second, Digital Natives frequently cause distrust, disconnection, and conflict between individuals, between individuals and corporations, and between individuals and governments by their addiction to games, entertainment, chatting, and text messaging—in short, their obsession with digital devices. Other negative phenomena include the spread of pornographic and violent materials, cyber-terror, cyber-crimes, electronic stalking, and invasion of privacy, lending to lack of societal integration and hindering social development [59] [60]. The new values and life styles of the digital generation are not supported by existing laws and codes, and gaps in technological and institutional environments produce confusion in values and inhibit the positive aspects that would enhance society's development and evolution [57] [58].

Another characteristic of the Digital Native generation is its excessive consumption, which inhibits capital accumulation and market balance. The Digital Native believes that one's position and status is determined by possession of brand-name products that reflect one's self. For example, 82% of U.S. high school students own iPods, indicating the product's position as a representative icon. Strong buying frenzies of such items, caused by the imitation mentality, has promoted an unnecessary consumption boom, inhibiting capital accumulation and upsetting the market balance [53].

Despite drawbacks, the existing literature points out six comprehensive features of Digital Natives and Active Seniors that are a positive societal influence. Positive characteristics of Digital Natives include innovativeness, collaboration, cyber-space respect, fun, customization, and immediate response. The active senior has such characteristics as a healthy life, wealth, personal development, value consumption, desire to work, and relationship skills (see Table 1).

Table 1. Characteristics of digital native and active senior.

Digital Native			Active Senior		
Characteristics		References	Characteristics		References
Y1) Innovativeness	-Active in using new technology, challenging -Open and horizontal thinking	[61] [62]	**O1) Healthy life**	-Pursues healthy life -High demand for food/exercise control and health care services	[10] [66]
Y2) Collaboration	-Active cooperation through various media -Cooperation with firm for better products and services	[62] [6]	**O2) Wealthy**	-High income level -Well prepared for elderly life -High purchasing power	[67] [54] [68]
Y3) Cyberspace Respect	-Shows respect in cyberspace -Regards online experience as important as offline	[63] [64]	**O3) Personal development**	-Tries to continue an independent life -Lifelong education -High interest in cultural life and youth	[69] [10]
Y4) Fun	-Pursues entertainment and pleasure -Regards life quality highly	[62]	**O4) Value consumption**	-Positive consumption tendency for perceived valuables	[70] [71] [72] [9] [73]
Y5) Customization	- Pursues differentiated products and services -Pursues various projects and customization	[65] [62]	**O5) Working desire**	-Desires continuous labour activity	[54]
Y6) Immediate Response	-Fast information exchange through instant interaction and real time response -Favours information sharing	[62] [60]	**O6) Relation**	-Tries to build relationships with new people -Increases leisure activities, such as religion/hobby/friendship	[69] [50]

3. The Faster-Accelerating Growth of the Knowledge-based Society

The value creation system of the traditional industrial society is the virtuous cycle of expanded reproduction: it expands every cycle by capital accumulation and technology innovation, increasing supply and demand. This expanded reproduction structure creates accelerating economic growth [74]. This structure is fundamentally different from the simple reproduction system of the agricultural society, which is based on primary production, thereby resulting in stagnation of production and demand [75]. Transformation of the indigenous value creation system of the industrial society is expected to create new value through increasing dependence on IT, BT, and NT.

3.1 The Value Creation System of the Knowledge-based Society: The Change from the Industrial Society

3.1.1. New Humankind: Digital Natives and Active Seniors

New product development and productivity improvement, mass production, existing demand growth, and new demand creation all allow the expanded reproduction system of the industrial society to expand more every cycle (inner cycle shown in Fig. 7). As explained in the previous section, IT, BT, and NT in a knowledge-based society encourage technology innovation and knowledge accumulation through converging with the existing industrial technologies in the traditional industrial society (see link between inner and outer cycle in Fig. 7). These technologies also create new demand, previously non-existent in the traditional industrial society, by creating new industries and new knowledge-based products. Such productivity improvements in the existing industries and creation of new industries through the development of IT, BT, and NT have a positive effect on the supply and demand expansion in every cycle of the value creation system (see outer cycle in Fig. 7).

The simultaneous growth of demand and supply and capital accumulation in the value creation system of the knowledge-based society is similar in terms of function to the expanded reproduction system of the industrial society. The fundamental difference between the value creation system driven by IT, BT, and NT in a knowledge-based society and that of the traditional industrial society is the introduction of a new type of production function by the increasing rate of intangible factors, especially knowledge input. The following numbers demonstrate the substitution of intangible knowledge input for material input: in 2006, high-tech industries had more than a 52% share of total manufacturing in OECD countries [76]. R&D investment by U.S. bio-firms has been increasing by 11% annually for 10 years since 1996 [11]. NT is expected to contribute to weight decrease in the auto industry by 10-15% and in spacecraft by 3% [77].

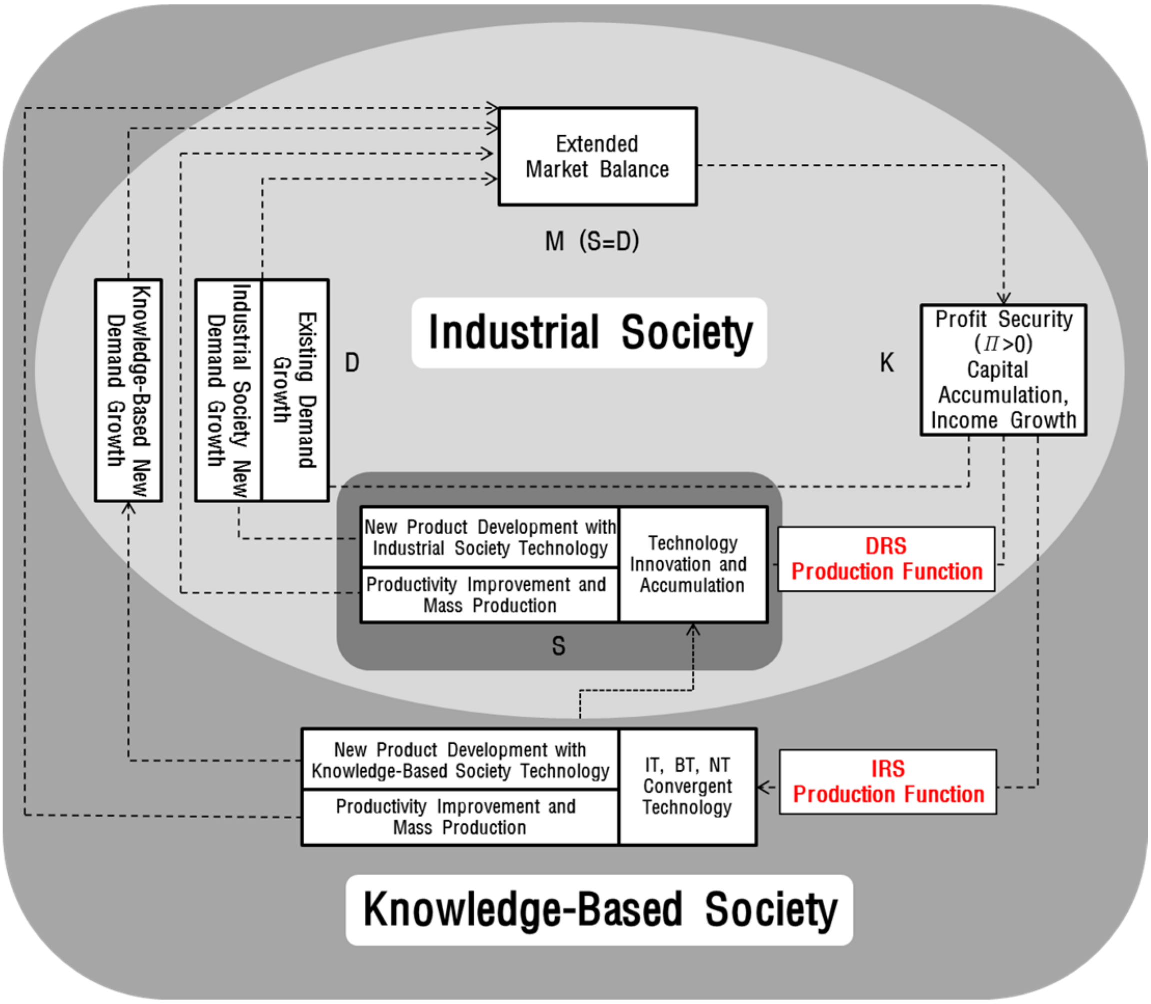


Figure 7. Expanded reproduction system of the knowledge-based society[3].

The increasing rate of intangible factors will expand increasing returns-to-scale (IRS) production in the knowledge-based society for various reasons. First, with knowledge input as the main factor of production, the tangible physical factors governing production conditions will change. Romer [78] has insisted that production function with knowledge input shows IRS production because of the increasing marginal productivity of the stock of the knowledge input. An endogenous economic growth model is established with the

[3] Expanded reproduction is first mentioned by Karl Marx (1967) to explain economic growth in an industrial society: the new surplus value created by wage-labour is reinvested in production so that accumulation and reproduction takes place on an Extended Scale. In this paper, we have added the value of "technology advancement" so that we can explain not only expansion of quantity in scale but also expansion of quality of product by advanced technology. The expanded reproduction system of the knowledge-based society includes the value creation structure of the industrial society. If the value creation structure of the industrial society should be separated, the traditional industrial society and knowledge based industrial society can be segregated from each other according to the mode of production.

assumption of an increasing marginal return of knowledge stock, compared to the diminishing marginal return of traditional capital stock.

Adams [79] established an economic growth model with the assumption that conventional decreasing returns-to-scale (DRS) production functions will be changed to the IRS production functions because of knowledge spill over. The OECD [3] highlights the knowledge factor as a tool to offset the decreasing return from physical capital. Bontis et al. [80] indicated that an economy based on intangible factors, such as knowledge or information, has a non-zero-sum effect and increasing returns to scale, compared to the decreasing returns of land, labour, or physical capital, i.e., traditional economic resources.

Arthur [81] has insisted that while the traditional sectors in the economy are governed by the law of decreasing marginal returns, new industrial sectors—especially knowledge-based industries—are governed by increasing marginal returns. He also noted that the economy has been changed from mass production to technology design and use, from resource process to information process, and from raw energy application to idea application. From the perspective that the position of the knowledge-based society is in continuous change from a DRS to an IRS economy, allowing the flexibility of production functions, Ray et al. [82] prove theoretically that characteristics of capital stock transform to an increasing marginal return above the threshold level of the rate of intangible capital in the total capital stock.

Industries that produce knowledge—for example, in bio-industry the research laboratory-based industry that produces mere knowledge—show IRS production naturally because most of the production cost is fixed capital, and as the number of users increases, average cost decreases [83]. Computer or software industries are representative examples of IRS production function in the real economy, because of the decreasing marginal cost. In the case of software industries, the marginal production cost is regarded as converging almost to zero[84].

The production function of the knowledge-based society based on IT, BT, and NT will be IRS because of the increasing knowledge input, compared to the DRS function of the industrial society, dependent as it is on tangible physical factors. Outputs from IRS production, such as technology-intensive products or services provided by biotechnology laboratories or software development companies, influence technology innovation and knowledge accumulation in the DRS economy of traditional industry through convergence and integration with traditional technologies. Therefore, the expanded reproduction structure of a knowledge-based society will result in greater expansion than can exist in the industrial society each cycle. For this reason, IT, BT, and NT need to be regarded as new technology classes, separate from traditional industrial technologies, for properly understanding the expanded reproduction structure of the knowledge-based society.

3.1.2. The Economic Force of the New Humankind upon the Knowledge-Based Society

The positive impact to the expanded production system from the Digital Native and Active Senior is shown in Figure 8.

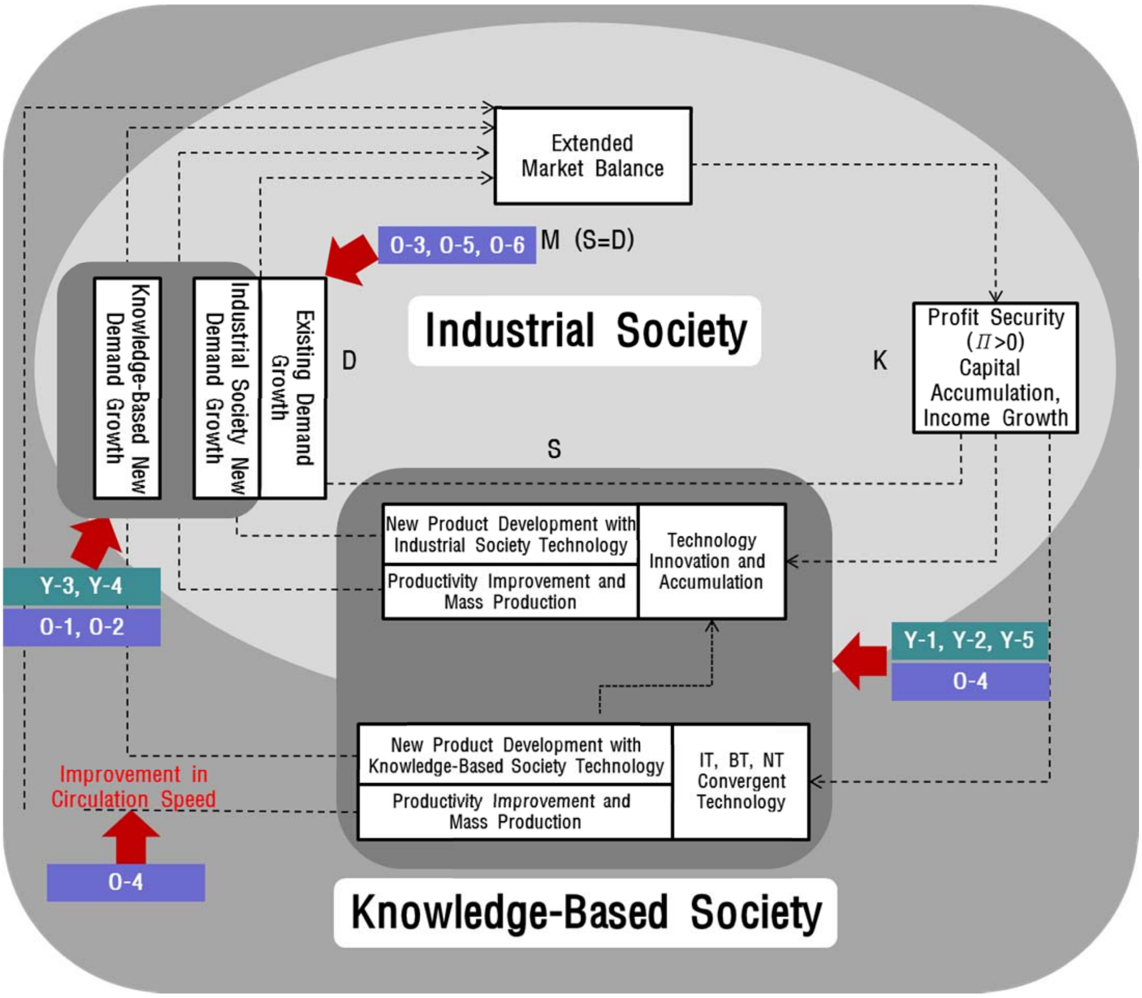


Figure 8. The impact caused by each characteristic of new humankind to the expanded production system.

1) Technology Innovation and Productivity Improvement

The Digital Native's characteristics of innovativeness, collaboration, and customization and the Active Senior's characteristic of value consumption positively influence technology innovation and productivity improvement. Due to innovativeness, the Digital Native is enthusiastic about new technologies and products, quick to adapt new products, and desirous of having the newest and best products. This characteristic produces a faster corporate productivity improvement and innovative development cycle. According to recent articles, the mobile phone replacement market in 2011 is expected to be worth 990 million won, a 37.4% increase from 2010. 'The replacement cycle, in comparison to 82 months in 2009 and 2010, is forecasted to be shortened to 79 months in 2011. Therefore, led by electronic devices, the product replacement cycle is shown to be reduced[4].

The Digital Native's collaborative characteristic provides opportunities for sharing thoughts, resulting in a positive impact on the acceleration of technology innovation and accumulation by reducing the time required for new product development. Online space is full of information on products and services uploaded by the innovative Digital Native, who is simultaneously a consumer and a producer. About 83% of Digital Natives tend to research their intended purchases online; hence, companies should market more attractive products online [5] [49]. In addition, because of the Digital Native's customization characteristic, companies have developed mass production skills that, nonetheless, can individualize products for their customers, resulting in a positive impact on technology innovation [85].

On the other hand, the Active Senior's value consumption characteristic means that, since product quality and long-term investment are important, the companies' technology innovations and product quality improvements can be realized. The donation culture, more noticeable in the senior population, is expected to have a positive impact on technology innovation: for example, a fund might be established for donations to provide technological development and research for human life quality improvement. Such projects result in overall technology innovation.

2) Existing Demand Expansion

The Active Senior's characteristics of working desire, personal development, and relation may have a positive impact on existing and new demand. First, the working desire characteristic relates to the Active Seniors' desire for continuous work in order to maintain their existing consumption levels and to interact with society [54]. Japan's job maintenance policy, Silver Business in Japan [68], and WHO's active aging policy [55] are the best known policies in the world relating to job maintenance. Le Tip and Nano Corp are projects that were developed to support private business activities. Nano Corp, unlike traditional business organizations, helps individuals to run businesses of a manageable size. With this kind of support, the number of middle-aged people and seniors who open businesses after retirement has recently been growing [66]. If Active Seniors maintain a continuous income through their business activity, unlike the existing Silent Senior generation whose consumption had to be reduced after retirement, this generation is expected to enhance the existing consumption increase.

The personal development characteristic refers to maintaining a life in which self-respect and self-sufficiency are possible through lifetime learning and self-development [10]. The Active Senior desires activities for self-development, such as lectures and lifetime education courses. Therefore, the demand for education and related various services is expected to increase [50]. A representative example is 'Elder Hostel' (now called 'Road Scholar'), a U.S. institution that is the world's largest lifetime education centre for seniors with more than 200,000 participants worldwide. The participants learn

[4] http://www.mt.co.kr/view

various cultural subjects and experiences from hosts and instructors with expert knowledge [66].

The relation characteristic is reflected in a strong desire to meet new people and form relationships [69]. The Active Senior generation responds by broadening relationships through religion, socialization, meetings for hobbies, etc.; family relations are considered very important as well, so the demand for existing industries, such as leisure, recreation, and travelling, is expected to increase. The travel industry that caters to the healthy post-retirement senior class is already enjoying a great deal of profit. According to research from Austria in 1999, 75% of the over-60 population had travelled domestically in the prior year, spending $985 million [73].

3) New Demand Creation

New demand from the Digital Native tends to arise out of two characteristics, cyberspace respect and fun. Not having experienced so much real need as either of the two previous generations, the Digital Native can be considered according to Maslow's 5-level Pyramid of Human Desire. According to Maslow [86] human desire can be divided into five levels, consisting of physiological desire, the most basic level; the desire for safety; the desire for a sense of belonging and for love; the desire for respect; and the desire of self-realization. After fulfilment of the basic desires, the human wants satisfaction for the higher levels of desires.

The Digital New Humankind uses digital technology for personal fulfilment. Through community activity and interaction with others, New Humankind fulfils the desires for a sense of belonging, love, and respect, the third and the fourth levels of desire. In addition, through cyberspace and the avatar, this generation's fifth level of desire, the desire for self-realization, becomes to be satisfied. According to Basso [64], U.S. cyberspace users are motivated by accomplishment, amity, the experience of immersion, escapism, and market manipulation. Basso has noted that users want to learn meaningful human relationships, strong emotional experiences, and leadership skills from the cyber world that may be applicable to reality. In other words, the generation attempts to fulfil the higher level desires of Maslow's human desire levels through games, as well as through the rest of the cyber world. From these factors, new demands are introduced, and new industries to fulfil the new demand are rapidly growing.

The most noticeable examples of the new demand are the game industry and SNS (Social Network Services). These industries have growing quickly. The global game market is forecasted to expand 5.5% per year on average (CAGR) to become 143 billion in 2010 to 420 million dollar in 2014 [87]. In the case of SNS, the number of U.S. teenage users (12–17 year-olds) was projected to grow from 11.5 million in 2006 to 17.7 million in 2011. Advertising for SNS has grown rapidly as well, from $480 million in 2006 to $1.2 billion in 2007, with projected growth to $4.1 billion in 2011 [87].

On the other hand, the Active Senior characteristics that influence new demand creation are healthy life and wealthy. The Active Senior's higher interest in health and lower endurance against disease compared to former generations, in combination with the generation's average yearly household income of $50,000, will create a high demand for applied biotechnology in healthcare services and in the pharmaceutical and other industries [54].

According to a report from the Korea Institute for Health and Social Affairs, Koreans' expected life span is 78.6 years, whereas the healthy lifespan is only 68.6, with the remaining 10 years subject to pains, physical discomforts, and emotional uneasiness caused by diseases or accidents. Therefore, expansion of the healthy lifespan is likely to become the core of national health policy [88]. Such concerns will necessarily also lead to an increased demand for BT to address a variety of declining physiological functions, such as degenerative arthritis, osteoporosis, and sexual dysfunction. In 2008, the senior population, which comprises 9.8% of the whole population, accounted for 29.9% of the medical expenditure. Thus, as demonstrated here, the Active Senior's pursuit for a healthy life will become a large driving force in creating new needs [89]. In the U.S., as well, the health and medical industry has produced 1.7 million jobs in manufacturing since 2001, giving rise to 'Health Belts' in various area of the nation. The industry's positive role is noticeable in the entire national economy.

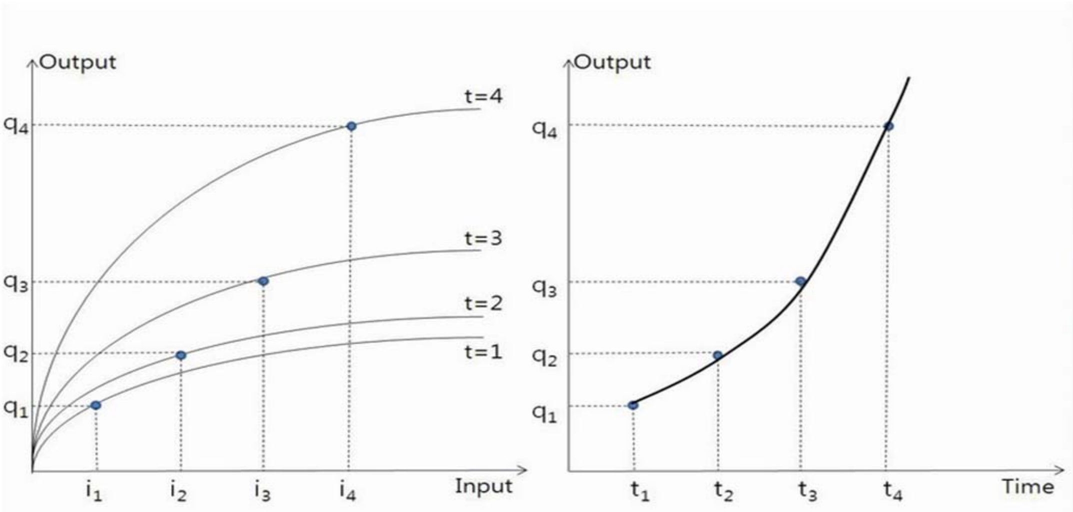
4) Expanded Reproduction System Circulation Speeds Improvement

The Digital Native's immediate response characteristic translates into instant response to products and public opinions cooperatively through the networks. Therefore, consumers' needs and feedback on products are delivered to companies quickly enough that the time needed for developing new products and improving existing ones is greatly reduced. Rapid and accurate information exchange establishes a business environment wherein a company cannot survive without maintaining the high standards and efficiency necessary to compete with other companies. The change will increase the speed of the overall extended reproduction system's circulation consisting of an expanded market balance, capital accumulation, and supply expansion of the company.

3.2. The Time-output Relationship in the Knowledge-based Society

The fundamental difference between the value creation system of the knowledge-based society and that of the industrial society is the introduction of IRS production functions from IT, BT, NT, and their convergent technologies, as mentioned in 3.1.1. Therefore, the economic growth pattern of a knowledge-based society can be understood by analyzing the shift of input-output relationship as observed from different DRS and IRS production functions over time.

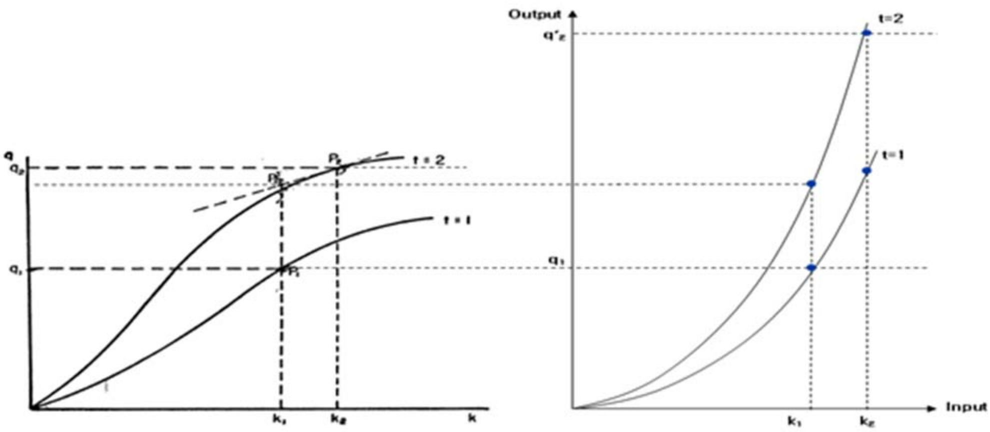
Prior to understanding the shift of IRS production functions, we describe the shift of DRS functions over time, which is generally considered for explaining the economic growth patterns of an industrial society. Kim et al. [74] have explained the economic growth pattern of the industrial society with DRS production function and technological progress (Fig. 9). The economic growth pattern, represented by a line linked between the points over different production functions that are shifted by technical progress, appears to be accelerating [74].



(a) (b)

Figure 9. Time-Output relationships with DRS production function and technical progress.

Kim et al. [42] compared the shift of IRS production functions with the shift of DRS production functions in an industrial society on the assumption of the same speed of technical progress (Fig. 10). The output curve from IRS production functions shows faster accelerating growth than the line from DRS production functions (Fig. 11). As a knowledge-based society includes two types of production function, DRS and IRS, the acceleration of net output increase over time in this society will be faster than the speed observed in the traditional industrial society following only DRS production. The more the economy based on the IRS production function expands, the faster the acceleration of economic growth will be.



(a) (b)

Figure 10. Comparison of the time-output relationships from the shift of DRS and IRS production functions in the case of the same technical progress rate [90].

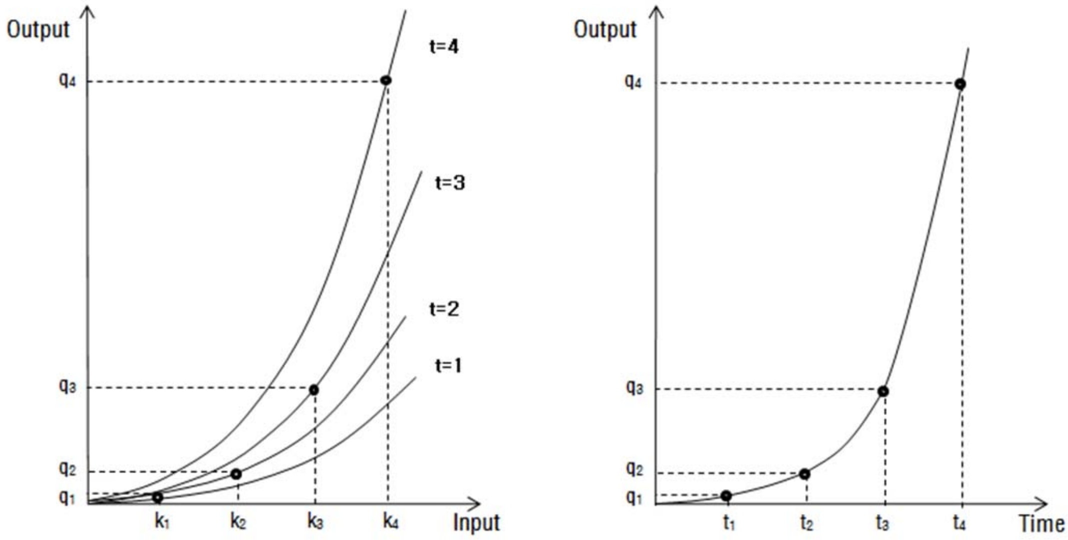


Figure 11. Time-output relationship from the shift of IRS production functions over time.

From several cases, including the ‘new economy’ in the U.S. (from the late 1990s to the early 2000s), the economic pattern of the digital economy appears to be faster accelerating, differing from the economic growth pattern of the traditional industrial economy [42] [91]. IT will overcome the limit of Moore’s law by technical progress and, above all, by IT-NT convergence. The biotechnology progress rate exceeds the IT progress rate of Moore’s law [27]. If convergence technology with BT or NT is industrialized and if its fast progress rate affects the IRS production function shift, the consequent economic growth rate is expected to be higher than that achieved by either the industrial society or the digital economy.

In addition to the technological and production characteristics of the knowledge-based society, the social aspect characterized by the new humankind will accelerate economic growth.

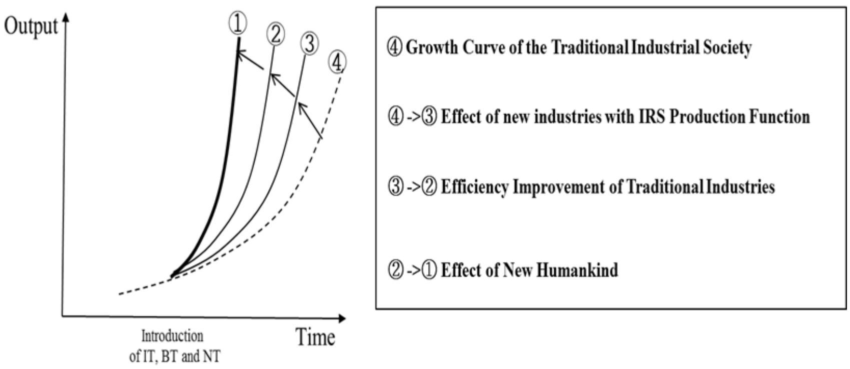


Figure 12. Faster acceleration of output growth in the knowledge-based society.

In Fig. 12, ④ is the economic growth curve of the traditional industrial society. The difference between ④ and ③ can be explained by the creation of new industries with IRS production functions. Improved efficiency in the traditional industries from IT, NT, BT, and their convergence technologies will bend the growth curve inward (③->②) and the new humankind will do so more (②->①). For such reasons, the economic growth pattern of the knowledge-based society will show faster accelerating growth.

The agricultural society and the industrial society have DRS production functions, but technical progress differentiates an accelerating industrial society from a decelerating agricultural society. Meanwhile, an industrial society and a knowledge-based society both show economic growth acceleration, but the speed of acceleration in the knowledge-based society is faster than that in the industrial society because of the fundamental difference in the characteristics of the production functions in terms of returns to scale (Fig. 13).

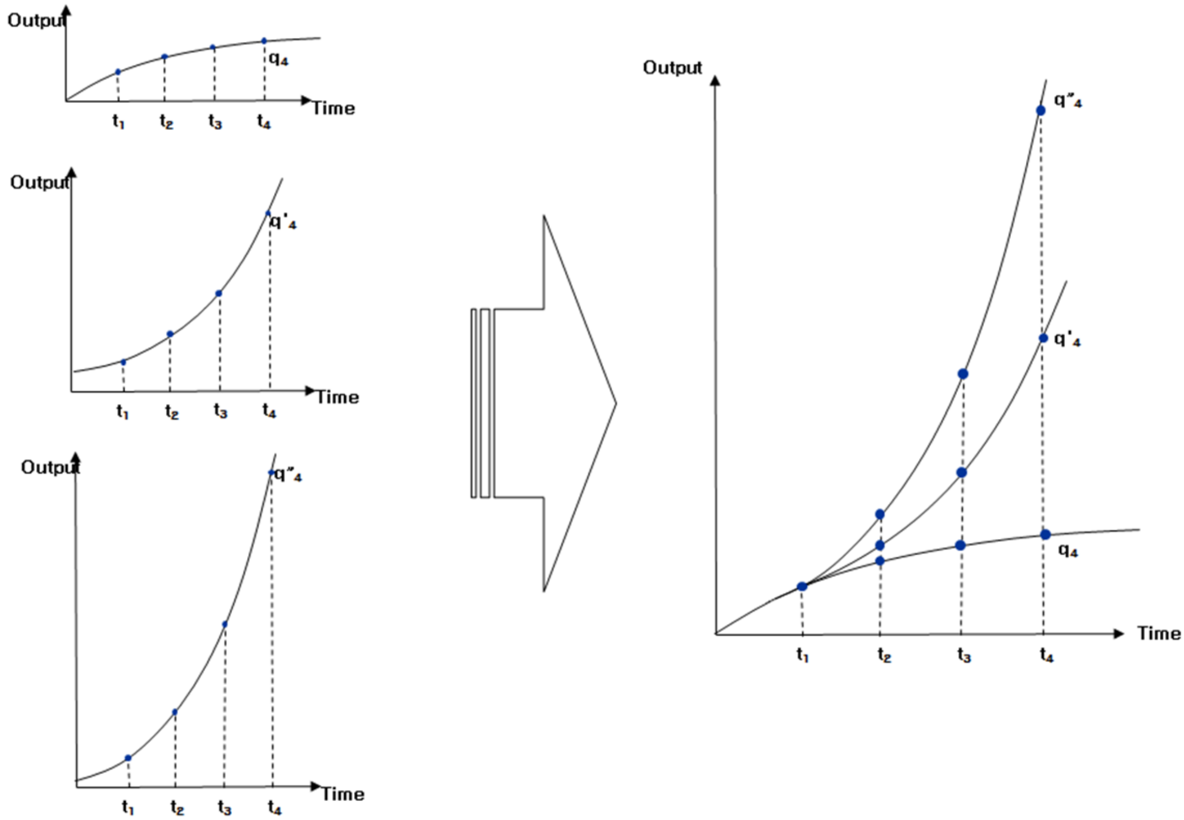


Figure 13. Comparison of output growth between the agricultural society, the industrial society, and the knowledge-based society.

The R&D paradox, the controversial phenomenon of disconnection between economic output or GDP growth and input for knowledge creation—such as R&D investment or education [92]—seems against the faster accelerating growth of the knowledge-based society, as does the IT productivity paradox. As Solow said in 1987, ‘You can see the computer age everywhere but in the productivity statistics’. The process of knowledge accumulation and diffusion requires time [93]. In sectors based on science like BT, there is a considerable time lag before an R&D product materializes [94]. Productivity effects from IT also have a time lag after the technologies are developed [95]. Therefore, the economic effect of knowledge input or IT cannot be represented merely by relationships between R&D expenditure or IT capital and GDP in the same period. A recent study identifying that the R&D paradox is observed in the fastest-growing industries [96] notes that industries investing in the knowledge base have been growing the fastest, therefore supporting the result of this study.

4. Conclusions

From observing the decelerating agricultural society and the accelerating industrial society in terms of economic growth, we learn that the economic growth pattern of a particular society is determined by the inherent value creation structure. An IT-driven digital economy enhances prospects for a new society, with differentiated, faster accelerating economic growth. This study analyzed both the economic and social aspects of future technologies as well as the effect on an expanded reproduction system. Our research clarifies why and how the accelerating economic growth of the traditional industrial society will be transformed in the future knowledge-based society.

Whereas the agricultural society depends on primary products from the land, the industrial society depends on capital accumulation and technology innovation, on creating new demands and expanding the scales of production, thereby accelerating economic growth. Production modes that depend on material inputs, such as fossil energies, plant equipment, or machinery, in the industrial society usually have DRS production functions.

The knowledge-based society is differentiated from the industrial society by the emergence of a fundamentally new mode of production with rapidly increasing intangible input and output. The development of IT, BT, NT, and their convergent technologies improves the efficiency of the traditional industries and encourages the emergence of new industries because of rapid technical progress and IRS production functions, which increase the knowledge input and output in the economy. The foregoing characteristics of the knowledge-based society contribute to the growth and expansion of IRS economy. In addition, the new humankind, enhanced by new technologies and economic growth, enables more accumulation of profit and capital, more technology innovation, more supply and new demand, and faster circulation of the expanded reproduction system, thereby accelerating the economic growth of the knowledge-based society over that of a traditional industrial society.

The contribution of this study is to identify the economic growth patterns of the emerging but immature society of the future, compared to the agricultural society or the industrial society, by analysing the aspects of future technologies and new humans and their effects on the value creation structure. This study is from the same context as some previous studies, aiming to distinguish the industrial society from the agricultural society by modes of production and economic growth patterns [97] [98] [75] [74]. We have verified that a new mode of production based on IT, BT, and NT results in the faster-accelerating economic growth of the future knowledge-based society. Therefore, the results of this study may encourage society to develop more smoothly and faster toward the knowledge-based society, like a compass pointing toward our future.

The second contribution of this study is to highlight the characteristics of the New Humankind in a knowledge-based society. A number of studies related to economic growth from the long and macro perspective have considered only the conventional aspects of individual humans—for example, a rational consumer or a labour supplier—but this study has considered newly emerging groups with different socio-economic characteristics and their effects on the economy and society. This study demonstrates the need to research the effect of the new humankind's co-evolution with technology, the economy, and society in a new economic growth pattern.

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