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The Gene of an Accelerating Industrial Society: Expansive Reproduction

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Abstract

This study reviewed broad theories of economics and case studies to explain the phenomenon of accelerating economic growth in industrial society. Based on economic literature of economic growth theories, the causes of the acceleration of economic growth in industrial society are identified, and reference the genetic properties of economic growth represented as the virtuous cycle of expansive reproduction. Expansive reproduction is a unique growth structure of industrial society with an economy that expands through capital accumulation and technological innovation. The model suggested in this study is supported by major economic growth theories, such as Smith's theory of the division of labor, Marshall's theory of returns to scale, Chandler's theory of increasing returns, Myrdal's theory of cumulative causation, endogenous growth theory, and learning by doing, and also by empirical data, such as historical trends in per capita GDP and production efficiency. This study attempts to explain accurately economic growth in industrial society and forms a guide to the critical pathway leading to economic development, providing a theoretical background in determining industrial policies. This study also provides implications for advancing toward becoming a knowledge-based economy, an extension of postindustrial society.

Keywords: Expansive reproduction • Accelerating industrial society • Growth accelerations • Technical change • Economic growth • Exponential growth

JEL Classification Numbers: *L16, O11, O47, O14*

1. Introduction

The origins of the word "industrial society" are the Latin word "*industria*," which means "diligent," "education," "talent," and "technology," and another Latin word, "*societas*," which means "union," "organization," and "society." Together, "industrial society" can be interpreted as a "union of diligent people," "organization of educated people," and "society of technologies." An historical understanding of industrial society provides a connection to the essence of industrial society. This study intends to clarify the connection.

The agricultural revolution was a blessing that transformed the primitive human race into the true leader of all creatures, and began the age of civilization. However, in a pure agricultural society[1] (Stavenhagen 1982; Kim et al. 2009), in which productivity decelerates and economic growth slows, the creation of agricultural economic value, such as food production, could not surpass the rate at which population increased. This implied that the human race could not overcome the Malthusian trap, the survival limits of the human race (Clark 2007). The fact that the human population, which must have increased theoretically in geometric progression according to the law of nature, stagnated for millennia (Fig. 1a) is proof to the contrary—that the vicious cycle of decelerating food production in a pure agricultural society leads to limited livelihood without any surplus production and food insufficiency, hindering an increase in the population.

In contrast, industrial society is a marvelous society, simultaneously achieving both exponential growth in wealth and explosive population growth.

Fig. 1 (a) illustrates changes in the world's population, and Fig. 1 (b) illustrates per capita GDP. The population and per capita income were stagnant during the agricultural society. However, in the industrial society, population and per capita income increased sharply. Since industrial society entirely accommodated and supported a geometrically increasing population, and per capita income increased geometrically at the same time, theoretically this implies that value creation in industrial society occurred at the square of the rate of the geometric increase. The fact that the population and per capita GDP both experienced accelerating growth with the advent of the industrial society provides sufficient evidence that economic growth, which is the index for measuring the creation of value in industrial society, does accelerate.

[1] Stavenhagen (1982) defined agricultural society as that in which the majority of a country's population lives in rural communities and that has an agriculture-based economy. In agricultural society, activities mainly cover agricultural production, where farmland and farmers are the most important resources of the national economy. In addition to this definition, we define a "pure agricultural society" as one in which the economy is based entirely upon agriculture before industrial revolution.

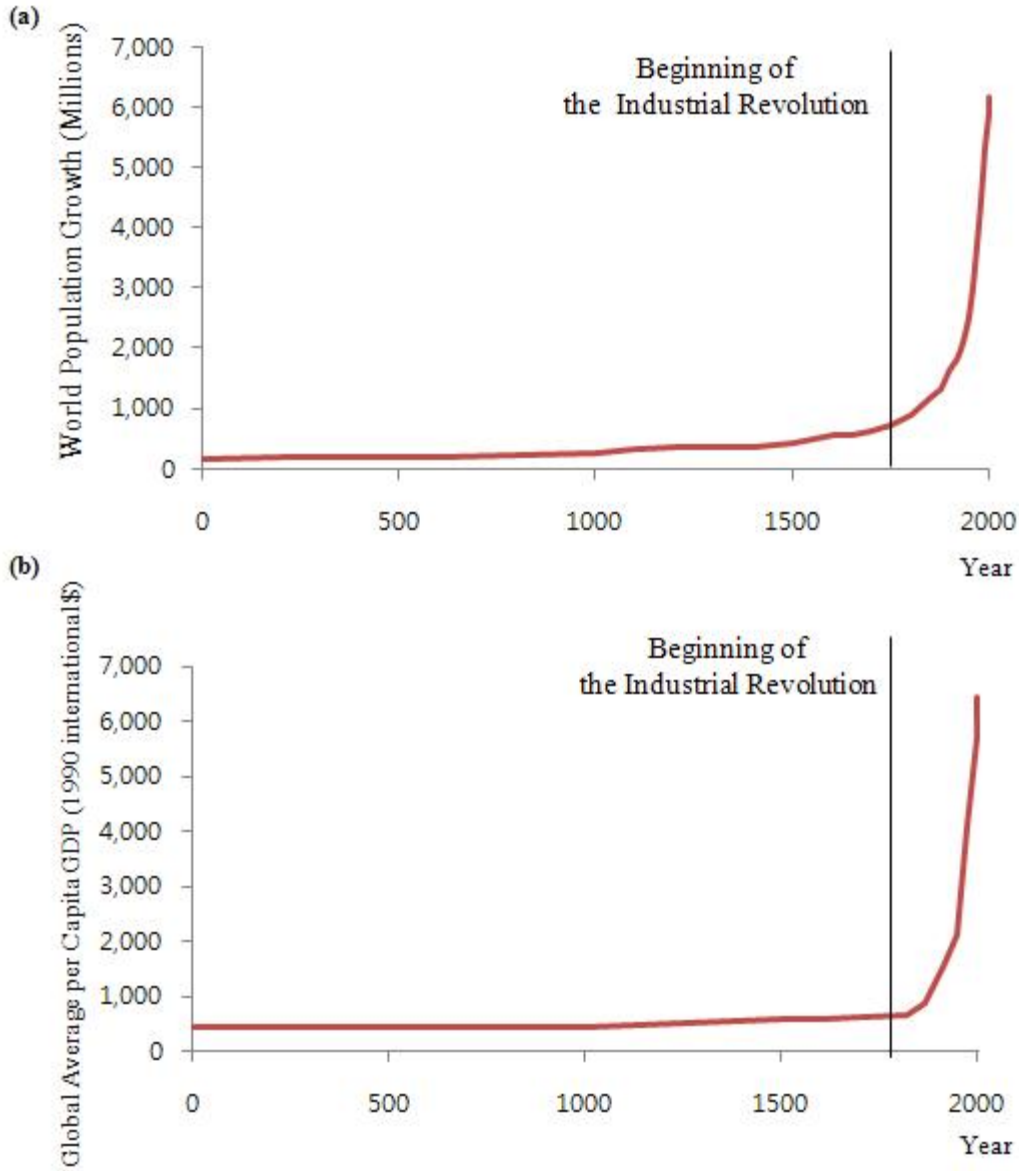

Fig. 1 (a) World Population Growth. (b) Global Average per Capita GDP.

Data Source: (a) Kremer, M. (1993). Population Growth and Technological Change: one million B.C. to 1990. The Quarterly Journal of Economics, 180(3), 681–716.

(b) OECD Development Centre (2001). The World Economy: A Millennial Perspective. Paris, France.

OECD Development Centre (2003). The World Economy: Historical Statistics. Paris, France.

However, wholly unearthing accelerating economic growth trends is not simple, as such trends can be grounded by a number of obstacles to growth originating from within industrial society, such as the economy's business cycle, financial crises, and the

Great Depression. In particular, existing economic growth studies that summarize such growth in a functional form or that looked for growth patterns based on macroscopic economic indices, did not successfully trace the growth process of all of industrial society regardless of their notable academic achievements. The reason is that analyzing an entire industrial society that has existed for over three centuries is difficult in the current paradigm of economic growth theory. Such obstacles include difficulty in developing a function that dynamically reflects technological development in the whole industrial society, unavailability of data over a very long term, and difficulties in developing data to eliminate noises that may influence short-term and casual economic growth. In other words, a diachronic approach is needed primarily to piece together the entire industrial society to examine its unique growth patterns based on the new production modes that such a society brings. This study defines this approach as the historic and hyper-long-run approach, where the expression "hyper-long-run" refers to the lengthy period required for a fundamental change in a society's unique production modes to move into a new production mode—sufficiently long to observe the overall development trends in a society. For example, the period during which an entire agricultural society moves from an agricultural revolution into an industrial revolution, or the period during which an entire industrial society moves from an industrial revolution into modern postindustrial society, comprises a hyper-long term.

This study does not intend to take a position for or against any issue concerning growth theory. Instead, it intends to prove that accelerating economic growth in industrial society is the manifestation of unique genetic properties[2] of the production mode of such a society based on a value creation system, wherein existing theories that explain economic growth have yet to refer to it. In other words, this study explains economic growth centering on the outcome of the expansive reproduction cycle, which is the backbone of economic growth in industrial society. It also develops differing viewpoints and scopes from existing studies on economic growth, including the major principles developed in existing economic growth theories.

The purposes of this study are threefold. First, it is intended to verify through theories and actual evidence the economic growth patterns of industrial society, which are fundamentally different from those of agricultural society. While people in agricultural society could not escape from the vicious cycle of starvation and poverty as a result of the simple reproduction that continued for thousands of years, industrial

[2] The term "genetic properties of industrial society" was used in this study to emphasize the fundamental difference between agricultural society and industrial society. Industrial society is a society with very different properties, clearly distinguishing it from agricultural society. Agricultural society emerged naturally all around the world and was developed individually, whereas industrial society can only be established and developed through propagation, starting with steam engines in England.

society achieved the popularization of material affluence for the first time in human history in only a few centuries. Therefore, it is necessary to theoretically identify the secret industrial society experiences an accelerating economic growth tendency that is fundamentally different from the decelerating economic growth tendency of agricultural society (Kim et al. 2009).

Second, this study intends to contribute to establishing economic policies for the development of countries that have yet to benefit from the public affluence offered by industrial society. The standards of living in countries yet to be industrialized remain at the level of those of a pure agricultural society before an industrial revolution, and the people in the least developed among developing countries are harmed by economic policy failures resulting from an insufficient understanding of the expansive reproduction cycle, e.g., the value creating structure of industrial society. This study intends to be useful as a theoretical basis for all developing countries when they select appropriate economic policies, as this can enable their people to enjoy the popular affluence found in developed industrial countries.

Third, this study intends to provide a theoretical framework for understanding the characteristics of a postindustrial society. As industrial society has fundamentally different characteristics from the agricultural societies in the past, the economic growth patterns of a postindustrial society may be very different from those of industrial society. A study of the economic growth of industrial society is essential for preparing for a knowledge-based society in the future or for any other postindustrial society.

To achieve these purposes, this study theoretically analyzes the phenomenon wherein output accelerates over time by expanding the study of the growth theory, and by proving that the accelerating growth rate of industrial society originates from the virtuous cycle of expansive reproduction. This study also demonstrates, through historical statistical figures, that an accelerating economic growth trend did, does, and will appear in an industrialized society in the past, present, and future. This study looks for trends in pure economic growth based on the unique value creation system of industrial society, and eliminates the effect of disturbance factors such as changes in national policy directions aimed at welfare and distribution rather than economic growth, economic crises, war, and other one-off events. To do this, the study limits the society or country studied to a typical industrial country that mainly engages in manufacturing and manufacturing-based service industries, in which most of the national wealth is created through industrial production and sales. In other words, the economy of a society or country mentioned in this study is assumed to be an economic unit that does not mainly depend on international trade or the production of natural resources, and has

a territory and population that can, to a certain degree, support an independent economy.

The remainder of the paper is organized as follows. Section 2 clarifies the meaning of the accelerating industrial society that this study intends to discuss by comparing existing studies most relevant in context. It also reviews existing economic growth theories, which provides clues to the principle of accelerating economic growth despite differing viewpoints. Section 3 suggests an economic model of an accelerating industrial society and examines the factors that enable this model to work are examined via the expansive reproduction cycle. In section 4, a number of examples are considered that support the proposed model. Section 5 concludes.

2. Meaning of an Accelerating Industrial Society and a Review of Related Economic Theories

2.1 Meaning of an Accelerating Industrial Society

Industrial society refers to a manufacturing industry-based society with a modernized economic structure, as defined in the previous section. This study verifies the characteristics of industrial society, which essentially differentiate it from an existing pure agricultural society in terms of economic growth from the perspective of the creation of value or changes of per capita GDP from a historic and hyper-long-run viewpoint. The most significant characteristic of this study is that it proves that qualitative changes—in other words, the genetic characteristics of the value creation structure of industrial society (expansive reproduction)—are the major causes of the acceleration of economic growth rather than simply determining that the cause of acceleration from quantitative changes manifests as a consequence thereof.

However, to the authors' knowledge, no previous studies have been done in this direction, and the choice of previous studies that can be directly helpful to this study or that are useful for comparing or evaluating the study results is restricted. When existing studies on economic growth are examined within a broader scope, it is possible to expect certain similarities between this study and other studies that intended to explain changes in economic growth through time-outcome changes. Studies on tracking economic growth through time include the Business Cycle (Schumpeter 1939), Sudden Stop and Output Drops (Calvo 1998; Chari et al. 2005), and Growth Accelerations (Hausmann et al. 2005; Ben-David et al. 1998; Perron 1989).

First, the business cycle theory investigates the phenomenon wherein economic activity repeats patterns over a fixed cycle (Schumpeter 1939). "Business" refers to the

level of an economy's overall activities or the comprehensive movement of macroeconomic indexes, including those for the real economy, the financial sector, and the export sector. Typical individual business indicator indexes are the GDP and a composite index of business indicators including the composite index and the diffusion index. The business cycle refers to a phenomenon wherein overall economic activities repeat a pattern of depression, recovery, prosperity, and recession, and centers on long-term growth tendencies. Typical business cycles are the kitchen cycle over two to six years, the Juglar cycle over 10 years, and the longest, the Kondratyev cycle, which spans 50 to 60 years. The purpose of the business cycle theory is to identify an economy's cycle, which repeats over certain periods, rather than the long-term tendencies of economic growth beyond the cycle. This theory and this study do not share the same goal.

Second, the purpose of studies on the sudden stop and output drops is to verify the relationship between sudden stops in capital flows[3]; in other words, abrupt declines in capital inflows, and large declines in output, known as two features of financial crises that take place in emerging markets (Chari et al. 2005). Studies concerned with the sudden stop examine the reasons why an economy that maintained continuous growth suddenly faces a financial crisis such as insolvency, and the cases and solutions for Mexico's Tequila Crisis in 1994 and the Asian Financial Crisis in 1997/98 are targets of these studies. Given that the countries that faced sudden stops enjoyed relatively high growth rates, these studies can easily be misunderstood as counterexamples for the sustained accelerating growth pattern in industrial society, as discussed in this study, or are presented as obstacles to accelerating growth.

However, such studies do not contradict this study in two aspects but simply offer differing perspectives. First, the study on the phenomenon of sudden stops analyzes the financial economy in relation to cash inflow of capital markets. It does not contradict the analysis of the value creation system emphasized by this study, namely that pertaining to the real economy in terms of supply and demand. Second, the periods of financial crises caused by sudden stops were not sufficiently long to affect the hyper-long-run point of view, which is the basis of this study. In other words, a sudden stop is considered a short-term shock from the viewpoint of this study.[4]

The studies mentioned relate strictly to short-term shocks brought to economic growth by incidents that hamper the normal operation of the value creation system of industrial society. They have no common context or similarities to this study, and have a

[3] The term "sudden stop" was inspired by the following adage among bankers: "It is not speed that kills, it is the sudden stop" (Dornbusch et al. 1995).

[4] A short-term shock refers to a one-time event that does not have a significant impact on development when economic growth is examined from the hyper-long-run point of view.

tremendous complementary relationship with this study.

Lastly, Growth Accelerations (Hausmann et al. 2005) can cause confusion with the term "Growth Accelerations"[5] that we use in this study that means "Accelerating Economic Growth." The two terms are not the same.

In this study, while accelerating economic growth refers to economic growth whose rate of increase expands continuously from the hyper-long-run point of view, Hausmann et al. (2005) refer to acceleration as the state in which the average economic growth rate during the recent eight or more years is 2% higher than the average growth rate of the previous eight years. Acceleration defined by Hausmann et al. is different from acceleration in this study in three ways, as follows.

First, the span of accelerating growth differs. Accelerating growth in this study is economic growth from the hyper-long-run point of view based on the fundamental nature of industrial society appearing in the entire cycle of industrial society, whereas Growth Acceleration is an event measured in a relatively short period, and examines whether the average rate of economic growth during the most recent eight years has increased by 2% or more. In other words, it is impossible to check whether accelerating growth is a unique characteristic of industrial society from the point of view of Hausmann et al. (2005).

Second, a difference exists in the direction of verifying the cause of accelerating growth. This study sees industrial society as a system with an output structure represented as expansive reproduction, and examines endogenous causes for growth that enable a virtuous cycle of expansive reproduction. In contrast, Hausmann et al. (2005) estimated the correlation between economic growth and three types of predictors, external context, domestic economic policies, and political circumstances. Lastly, this study deals with industrialized countries, whereas Hausmann et al. (2005) dealt with various countries during 1957–1992. Even unindustrialized countries were included in the study of Growth Acceleration when trends in their short-term economic growth satisfied the conditions. Therefore, the study analyzed all economic and social elements that enabled rapid economic growth as causes of accelerating growth, rather than industrial society's unique penchant for economic growth.

Eventually, Hausmann et al. (2005) shows a significant difference from this study, as it intends to verify the cause of growth acceleration from the results, which comprehensively reflect all noneconomic contingencies on economic growth. In other

[5] Growth Acceleration has the following meaning according to the definition of Hausmann et al. (2005): "We define growth acceleration as an increase in per-capita growth of 2 percentage points or more (with most of the episodes we identify exceeding this threshold by a wide margin). To qualify as acceleration, the increase in growth has to be sustained for at least eight years and the post-acceleration growth rate has to be at least 3.5 percent per year. In addition, to rule out cases of pure recovery, we require that post-acceleration output exceed the pre-episode peak level

words, it is in line with this study, as it attempted to verify the cause of growth among economic phenomena, albeit using different approaches and directions. Also, the acceleration appearing in a short period of eight years reflects all short-term macroeconomic indices. This makes understanding the characteristics of economic growth from the hyper-long-run point of view difficult given the impact of the noise inside and outside the boundaries of the economy, in contrast to examining the essence of industrial society that can be identified from the hyper-long-run point of view. Under these circumstances, this study is a new study that verifies that the accelerating growth of the economy is a unique characteristic of industrial society, and is therefore different from the study of Hausmann et al. (2005).

The previous studies examined above are fundamentally different from this study in the following way. This study intends to prove, through theories and empirical examples, that industrial society inevitably shows a trend in accelerating economic growth from the hyper-long-run point of view as a result of the genetic property of industrial society, expansive reproduction. It intends to verify the quantitative change in long-term economic growth based on the essential characteristics of industrial society. On the contrary, existing studies attempt to determine the characteristics of industrial society based on quantitative changes in short-term economic growth that reflect the influence of the economy, society, politics, and even casual events. Given noise in the data, approaching sustained accelerating growth from the hyper-long-run point of view based on the methodologies used in existing studies necessarily creates limitations in correctly deriving the fundamental causes that lead to hyper-long-run accelerating growth.

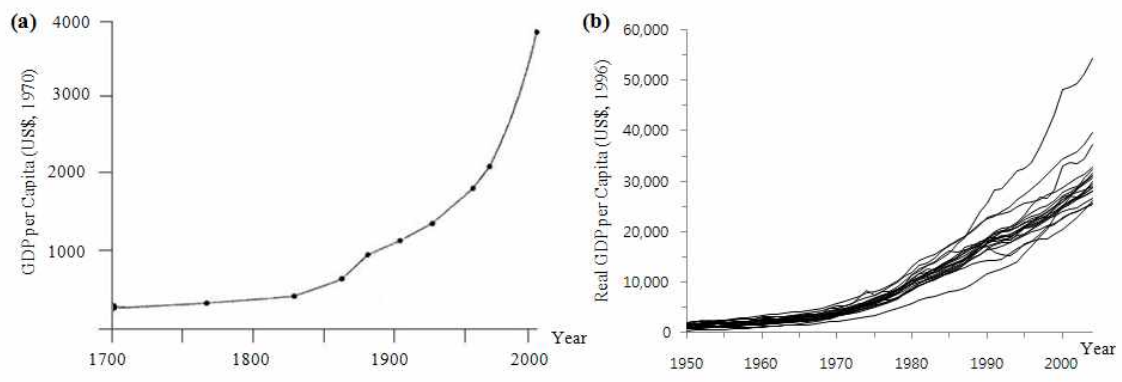

Fig. 2 (a) GDP per Capita in England (1970s US$), 1700–2000. (b) GDP per Capita in OECD TOP 20 countries, 1950–2004.

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of income."

Data source:
(a) Maddison, A. (1982). Phase of capitalist development. New York: Oxford University Press.
(b) Heston, A., Summers R., Aten, B. (2002). Penn World Table Version 6.1. Center for International Comparisons at the University of Pennsylvania (CICUP). http://datacentre2.chass.utoronto.ca/pwt61. Accessed 10 March 2009.
Notes: In Fig. 2 (b), the 20 countries are Italy, Finland, New Zealand, Japan, Germany, Belgium, Sweden, France, the Netherlands, the United Kingdom, Iceland, Ireland, Austria, Denmark, Canada, Australia, Switzerland, Norway, the United States, and Luxembourg.

Fig. 2 shows the change in outcomes over time from the hyper-long-run point of view suggested in this study. While existing economic growth theory focuses on the relationship between input and output, this study focuses on long-term input and output, which comprehends the simultaneous growth in production, consumption, and technological advancement—in other words, the interrelationship between the passage of time and the change in the rate of economic growth. It will become possible to understand accurately the characteristics of industrial society by observing patterns of economic growth from the hyper-long-run point of view whenever it requires being described as "historic." As shown in Fig. 2, industrial society shows a slow slope close to the horizon in the beginning of the economic growth stage as a result of the characteristics of accelerating along with expansive reproduction. However, industrial society eventually exhibits accelerating economic growth with a rapidly increasing slope, with per capita GDP also increasing exponentially. Fig. 2 (b) represents the change in per capita GDP after the 1950s, when the current top 20 OECD nations became substantially industrialized. This figure also clearly shows an acceleration trend, without exception.

Skepticism existed about the essence of an industrial revolution as a result of a lack of understanding of the genetic characteristics of industrial society by expansive reproduction. Paradoxically, this emphasizes the need for studies that understand the essential characteristics of industrial society. Wrigley (1989) and Clapham (1926) reported that the growth rate of per capita GDP was very low in England even after the Industrial Revolution, that the use of machinery and fossil fuel failed to spread nationwide, and that resources were distributed through the market even before the Industrial Revolution. However, the industrial revolution of a nation or a society does not refer to the simultaneous industrialization of the national economy. Instead, it refers to the grand beginnings of industrialization when a few industries, centering on

manufacturing, began to be partially industrialized. Existing manual labor was replaced and expansive reproduction occurred, creating new demand that gradually increased the share of accelerating industrial production and consumption areas in GDP. Some early industrial societies inevitably showed exponential economic growth along with progress in industrialization as a result of accelerating genetic characteristics, while the national economic growth rate remained quite low as the industrial sector took very little part in GNP regardless of the geometric growth seen in some industries. As represented in the figure above, the accelerating curve develops a greater slope over time, as economic growth apparently stagnates in the early stages of industrialization and skepticism about the Industrial Revolution (Wrigley 1989; Clapham 1926) grows. This indicates that analogizing the cause from a quantitative index of economic growth without an understanding of the fundamental mechanisms of such growth in industrial society can result in significant risk of error.

The absence of studies on growth patterns based on the fundamental characteristics of industrial society and the possibility of misunderstanding the approach may explain why studies on the long-term growth of industrial society could not be accomplished. Nonetheless, existing economic growth theories developed by a number of great scholars provide numerous clues that support the economic growth of an accelerating industrial society. In other words, finding implications about accelerating economic growth in existing economic growth theory and deploying this study's growth model based thereon may solidify the theoretical foundations of this study and clearly demonstrate its appropriateness.

2.2 Supporting Theories of Accelerating Economic Growth in Industrial Society

Existing economic growth theories supporting the theoretical feasibility of accelerating economic growth include: (i) the division of labor by Smith (1776), (ii) the theory of returns to scale by Marshall (1920), (iii) the theory of increasing returns by Chandler (1990), (iv) the theory of cumulative causation by Myrdal (1957), (v) endogenous economic growth theory, which explains the phenomenon of acceleration in quantitative and qualitative aspects, and (vi) the theory of learning by doing.

The division of labor by Smith

The Wealth of Nations by Adam Smith (1776), which contains the theory of the division of labor, describes the case of the pin manufacturing process. The pin manufacturing process illustrates a very basic idea about accelerating economic growth. To manufacture pins manually, each worker must participate in the entire manufacturing process. However, when each worker specializes in just one task, production noticeably

increases through time savings and developing skills by repeating the same task. The division of labor reduces production costs, resulting in improved productivity and eventual expansion of market size. Thus, production in this case has the characteristics of an accelerating society (Blaug 1979).

Marshall's theory of returns to scale

The theory of returns to scale is divided into three types: increasing returns to scale, constant returns to scale, and diminishing returns to scale. Returns to scale refer to the increase of output in proportion to inputs.

Marshall (1920) indicates the difference between internal and external economies of scale. When a company reduces costs and increases production through scale economies, internal economies of scale are achieved. External economies of scale are not achieved at the company level but at the industry level. In addition, Marshall (1920) insists that increasing returns to scale are found at the industry level, not at the firm level, implying that the external economy and not the internal economy, can be affected by increasing returns to scale. Therefore, when industry- or country-level output is analyzed, an increasing returns to scale effect can be detected. Therefore, a sustained increasing returns to scale effect in industrial society can be detected through external economics of scale, or accelerating economic growth. In this aspect, this theory gives us one possible explanation for accelerating economic growth.

Chandler's theory of increasing returns

Chandler (1990) studied the scale and scope of production by analyzing the liquidity of industrial capitalism. As for the scale of production, for example, mass production in industrial society reduces the cost of manufacturing products. In the case of the scope of production, economy of scope appears in this joint production and takes place when fixed inputs, joint inputs, or an interdependent relationship between production and technology exist. For example, different crops cannot be produced on the same field in agricultural society, whereas the same manufacturing facility can be used for many purposes or the same machine parts can be used to manufacture a variety of products. As a result, final cost of production decreases through economies of scope in industrial society.

In other words, economies of scale and scope in production increase productivity per unit, which reduces costs. Therefore, when the utilization of manufacturing elements increase and mass production is achieved, production efficiency increases. This principle can become the basis for supporting the accelerating growth of industrial society.

Myrdal's theory of cumulative causation

The principle of circular and cumulative causation, or CC theory (Salvadori and Panico 2006), also has implications for the accelerating economic growth of industrial society. The most significant characteristic of CC theory is that it does not recognize the self-stabilization function of a social system. Myrdal (1957) found that the system continuously moves to break the balance of power rather than find a balance.

Two effects explain this phenomenon: the backwash effect and the spread effect. The backwash effect has four characteristics. First, a society concentrates its economic activities in certain areas and neglects other areas deemed vulnerable. Second, labor moves toward areas with more active economic activities. Third, most economic activities and advanced cultural forms prosper more in areas with higher levels of development as society reaches higher levels of development and have more resources to provide better infrastructure and services for companies and the public. Lastly, developed and wealthy societies attract entrepreneurs, technical workers, and new opportunities. New opportunities for growth appear more in advanced environments of a rich country than in a poor country with a low-wage environment.

The other effect, the spread effect, has two characteristics. First, developed areas tend to expand economic activities to new areas for an increase in density, high wages, and high rents. Second, this tendency appears more strongly in richer countries than in poor countries, and the beneficiary areas are those closer to developed areas.

Generally, the backwash effect leads the spread effect and is especially stronger in a less developed economy (Salvadori and Panico 2006). In other words, the overall tendency moves in the direction of increasing the imbalance in the distribution of development and growth. However, a neutralizing force always exists to artificially find balance, such as taxation or redistribution policy.

Myrdal's CC theory is supported by a number of follow-up studies. Kaldor (1978) states that production growth induces growth in productivity through increasing returns. Salvadori and Panico (2006) also show CC effects in similar ways. Increasing returns to scale demonstrate more positive effects in developed countries than in less developed countries, and increasing returns as a result of the CC effect are considered to contribute more to the economic development of advanced nations. According to CC theory, the expansive reproduction of industrial society will circulate and eventually accelerate.

Endogenous economic growth theory

Other theories supporting accelerating industrial society include the endogenous

economic growth theory. Unlike neoclassical theories of economic growth, the endogenous economic growth theory put forth by Romer (1990) sees economic growth as an endogenous rather than exogenous outcome of an economic system. Endogenous forces refer to technological development. In other words, the indices of technological development are included in the production function and are reflected in economic growth.

When using this new production function to describe economic growth, economic growth can be achieved through enhanced technological innovations, the expansion of a number of intermediate inputs invested, and the qualitative improvement of each intermediate material (Barro and Sala-i-Martin 2004). Industrial society continuously creates demand by developing new products based on the accumulation of technology and capital. Economic growth can also accelerate from this point of view. Concerning the qualitative improvement of intermediates, according to the quality ladder model of Grossman and Helpman (1991), when technological development enhances the quality of a single intermediate input, it influences other intermediates (the spillover effect) to gradually increase input–output efficiency. In other words, accelerating economic growth can be achieved through continuous technological development in industrial society.

The theory of learning by doing

The theory of learning by doing is based on the learning curve. It also proves that sustainable productivity enhancement is possible. According to Arrow (1962), technological know-how, skillfulness of labor, operation methods of organization, etc., are learned and the cost curve shifts down as a result.

Arrow (1962) was the first to apply the concept of learning by doing to economic theories. According to him, learning by doing refers to improvements in technology, function, and organization in a narrow sense, and technological advancement in a broader sense. The learning-by-doing theory is similar to the theory of endogenous growth, which considers technological advancement as an endogenous factor of economic growth.

In the learning-by-doing model, technology is considered more an endogenous than exogenous variable. Moreover, accumulated production is used as the index of experience, and it is never reduced over time. Since the accumulated value never declines, the production function always moves upward and production efficiency is necessarily enhanced unless production stops.

Eventually, the learning in the learning-by-doing theory causes an *ex post facto* marginal cost decrease, considered a unique form of economics. It describes the

accelerating development of industrial society through decreases in expenses.

Implications from literature

The accelerating economic growth phenomenon can find a direct and indirect basis even within existing major economic growth theories. This becomes the basis upon which the study of the accelerating growth of industrial society has a connection with existing theories. A new point of view (the hyper-long-run point of view) on economic growth of industrial society is also adopted, rather than being simple imagination or sophistication.

In this vein, the following section starts with the economic growth theory to theoretically prove an accelerating industrial society from the hyper-long-term point of view. While existing economic growth theory focuses on the cause and effect relationship between inputs and outputs, this study takes the analysis one step further to clarify changes in national income over time, which includes the processes of expansive reproduction such as an increase in input elements, the accumulation of capital, the accumulation of technology, an increase in production, and an increase in demand. The starting points of this study are the neoclassical growth model by Solow (1957) and the induced innovation model of Ruttan (2001). The existing theory was briefly summarized in each point of view and expanded in this study. Also, the entire economic cycle of expansive reinvestment and expansive reproduction was examined to analyze how expansive reproduction operates. The next section discusses in depth the concept of the expansive reinvestment and expansive reproduction.

3. Model of an Accelerating Industrial Society and Principles

3.1 Model of an Accelerating Industrial Society

This section demonstrates the accelerating economic growth model of industrial society by starting from the neoclassical production function of Solow (1957) and the theory of induced innovation by Ruttan (2001), and then expanding them into hyper-long-run period points of view.

This section will commence the discussion from the production function, which shows the relationship between input and output to induce the production change path from the hyper-long-run point of view. Solow (1957) divided into two stages the characteristics of the movement of the production function in relation to exogenous

technological changes based on the neoclassical production function.[6] Solow (1957) stated that aggregate production is affected by the degree of technological changes, as outlined in Fig. 3, thereby shifting the production function in accordance with the technology level of the corresponding period. The bottom curve in Fig. 3 represents the production function of investing k1[7] during the period t=1 and producing q1, and the top curve represents the production function of investing k2 during the period t=2 and producing q2. The production function used here is the production function of the neoclassical model, and the curve was shifted by the technical change between t1 and t2. Solow (1957) named each production function at t=1 and t=2 the aggregate production function (APF). He also defined the APF shifts at t=1 and t=2 as "technical change."

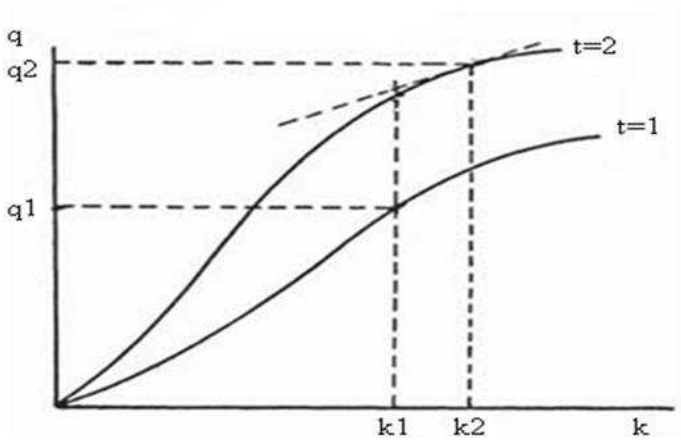

Fig. 3 Shift of APF According to Exogenous Technological Development.
Source: Solow, R.M. (1957). Technical change and the aggregate production function. The Review of Economics and Statistics, 39(3), Figure 1, p. 313.

Another production model that can be used as a starting point for this discussion is the induced technological innovation model. The basic concept of this model is that relative expenses between input elements change over time, and the company develops production technology that uses input elements costing relatively less (Ruttan 2001). According to Ruttan (2001), when a company puts in less expensive input elements as a result of a change in relative prices between input elements for cost-effective production, if the production technology does not change or evolve, the input ratio required to achieve maximum production levels does not change. This eliminates the possible options required to pursue maximum production with minimum cost through factor

[6] For this study, we use the neoclassical production function model according to Debertin (1986).

[7] k is the ratio of capital input per unit labor input (K/L), where K is capital input and L is labor input.

substitution. Such a limitation stimulates the development of new technology for improving the input ratio, meaning a shift toward a new production isoquant. The envelope around the shifted production isoquants is introduced as the meta-production function in the induced technological innovation model (Hayami and Ruttan 1970). The induced technological innovation model also hypothesizes a shift in the production function. This does not endogenize the technology into the production function, as it was not in the Solow (1957) model, and it can be applied to agricultural society and industrial society at different speeds of production technology development and different scales of increases in production. This can be done by deriving new production functions as a result of changes in technology.

It is possible to derive accelerating production curves in the historic and hyper-long-run points of view based on the characteristics of the said production functions. Reflecting the characteristics of technological changes is very important, as they determine the shift range of the production function to derive the production curve of industrial society from the hyper-long-run point of view. Industrial society is a society that enables a virtuous cycle of economic growth in which capital accumulation and technological development increase production and consumption geometrically and simultaneously through the repetition of expansive reproduction. The next section includes a more in-depth discussion on this topic. Technological development accelerates in industrial society, and similar evidence is found in Solow (1957) and Crafts and Mills (1997). Solow analyzed the entire industrial data of America by dividing them into Period 1 (1909–1929) and Period 2 (1930–1949), and found greater evidence of technical change in Period 2 than in Period 1. He also showed that the increase in GDP per man-hour influenced by technical change was greater in Period 2 ($0.395) than in Period 1 ($0.275). Crafts and Mills (1997) also reported that the manufacturing industry's production growth rate gradually increased until 1900, centering on the period of the Industrial Revolution in England.

When the rate of accelerating technological progress in industrial society is applied to the two types of production function models hypothesized above, it is possible to obtain an accelerating production curve for industrial society.

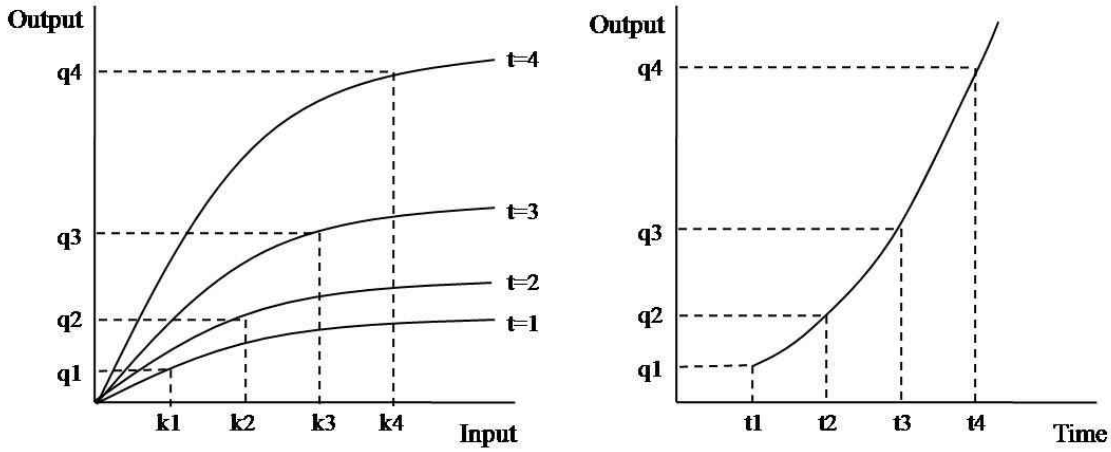

Fig. 4 Time–Output Relations per Solow's APF Shifts.

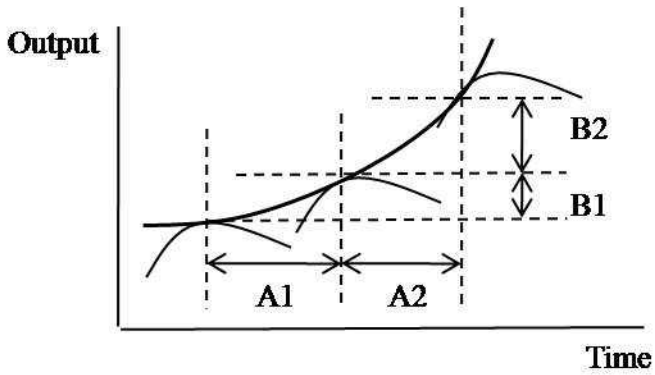

Fig. 5 Time–Output Relations in Industrial Society from the Point of View of the Induced Innovation Model.

Fig. 4 shows the inducement of the shift of Solow's APF from the hyper-long-run point of view. As the speed of technological development accelerates in industrial society, APF's shifting range also increases. However, the point where actual production takes place on the APF is one point in each period ((k1, p1), (k2, p2), (k3, p3), (k4, p4), etc.), meaning that it is possible to derive the production curve in terms of time-output on the right by connecting these points. Also, it is possible to see that an increase in production accelerates from the long-term point of view.

Fig. 5 shows the meta production function over time from the induced innovation model's perspective. As the meta-production function envelops the production functions that represent different production functions, the accelerating production curve will be derived as per the diagram when the evolving production technologies of industrial society are reflected. A1 and A2 are the times used to establish each technological development, and B1 and B2 indicate increased production through technological development. Technological development will increase further

over time given the value creation system represented as the expansive reproduction cycle of industrial society, and the impact of this system is manifested as acceleration in production.

Technology advances so slowly in a pure agricultural society that it can result in the deceleration of economic growth (Clark 2007; Kim et al. 2009), whereas technology evolves rapidly enough for economic growth to accelerate. When production curves of industrial society from the hyper-long-run point of view were derived based on the characteristics of the two production functions of Solow (1957) and the induced innovation model (Ruttan 2001), the same type of accelerating curves was induced in both cases. An accelerating production curve represents the change of production over time from the hyper-long-run point of view and, thus, it can be defined as the "production expansion path," as it expanded the existing production function in terms of time. In the next section, we discuss expansive reproduction as endogenous genetic properties of industrial society that accelerate the production expansion path. The acceleration of economic growth is manifested in the economic growth of industrialized countries without exception, and the next subsection explains the key principles of accelerating economic growth.

3.2. Expansive Reproduction Structure of an Accelerating Economy

Accelerating growth in industrial society is manifested by the virtuous cycle of expansive reproduction, which repeats the simultaneous growth of supply and demand. This structure is buttressed by capital accumulation and technological development. This subsection proves the growth mechanism of an accelerating industrial society by showing the characteristics of the expansive reproduction cycle at each stage as the genes of accelerating economic growth of industrial society and the evidence thereof.

Expansive reproduction refers to the phenomenon in which the gross production scale expands as most of the surplus secured by a company, capitalists, or society through economic activities is accumulated as capital and reinvested into production (Jalee 1977). Expanded capital, an increase in the income of workers participating in production, a decrease of prices resulting from higher productivity, and new demand created by new products released through technological innovation will create synergy effects and elevate supply and demand at the same time. A society with a continuously repeating virtuous cycle of economic growth is the very industrial society to which we refer, with accelerating economic growth.

Table 1 Main Characteristics of Industrial Society in Europe

Characteristic	Industrial Society
Period:	From the mid 1700s to the mid 1900s
Key institutions:	The state, firms, unions, banks, the nuclear family, political parties
Principal resources:	Means of production, primary materials, patents, productivity
Determinant economic sector:	Production of goods: manufacturing, transformation, and distribution Secondary sector
Workplace:	Mill, factory, office, cities, urbanism
Instrumentation:	Energy, production line, machine-made
Advantages:	Mass consumption, geographical and social mobility, control of nature, egalitarianism
Disadvantages:	Alienation, competition, waste, anomie, psychophysical fatigue, exploitation

Source: Modified from Masi, D. (1987). L'avvento post-industriale. Milano: Franco Angeli.

Compared with the simple reproduction cycle of a pure agricultural society (Kim et al. 2009), expansive reproduction was enabled through a fundamental change in production modes. Agricultural society had limits to its economic growth as a result of simple reproduction. Capital accumulation and technological development stagnated while production decelerated as a result of natural environmental limitations (e.g., area of land for cultivation, quantity of sown seeds per constant land, etc.) and the stagnation of demand resulting from product characteristics (e.g., low income elasticity of agricultural products). The accelerating industrial society overcame these limits to growth through the accumulation of capital and technological advancement resulting from mass production, continuous creation of demand, and mass consumption, and enabled the structural change represented as expansive reproduction. The industrial society is one that has undergone fundamental changes in production technology, such as mechanization, the use of fossil energy, and factory-oriented production modes. The development of this type of system overcame the millenniums-old Malthusian Trap of agricultural society (Clark 2007). Table 1 shows the economic characteristics of industrial society as differentiated from those of agricultural society. The expansive

reproduction cycle originates from the unique production mode of the industrial society and demonstrates accelerating economic growth by continuously achieving new market balances with expanded supply and demand resulting from the accumulation of capital and the development of technology.

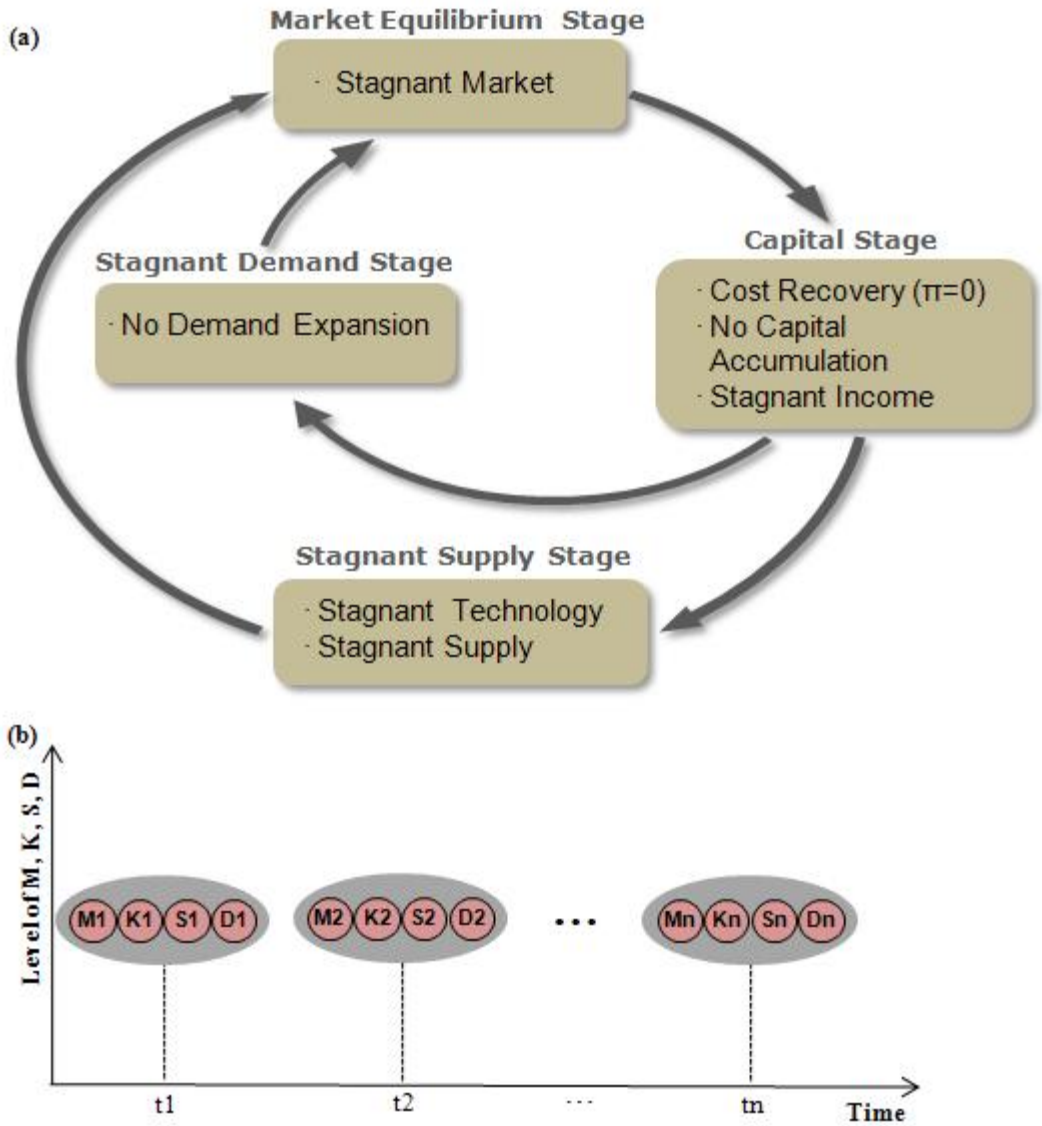

Fig. 6 (a) Simple Reproduction Structure in an Agricultural Decelerating Society. (b) Stagnant Level in Each Stage of the Circulation of Simple Reproduction.
Notes: In Fig. 1 (b),
M: Market size, K: Capital accumulation, S: Net supply, D: Net demand

Before discussing the expansive reproduction cycle, Fig. 6 illustrates the simple reproduction cycle of a pure agricultural society (Fig. 6 (a)) and the change in each element by the circulation of simple reproduction (Fig. 6 (b)). The simple reproduction

cycle shows the circulation of the economy through the balance of supply and demand. However, this is quite different from the expansive reproduction cycle, as supply and demand do not increase and economic growth remains stagnant. The production of primary industrial products decelerates in a decelerating agricultural society, resulting in a small yield of surplus production and a small value added for small profits. Profits that could be secured cannot be accumulated as capital, exhibiting a stagnant economic growth tendency that repeats simple reproduction. The reason for this phenomenon in terms of supply is that primary industrial products, such as agricultural products, have the characteristic whereby the input to outcome ratio decelerates in production. Agricultural production has a number of variables, such as the weather, that affects yield, and technological development is very slow (Clark 2007; Kim et al. 2009). Therefore, it is difficult to expect productivity to be enhanced. In terms of demand, since the major products such as food are necessities, demand does not increase above a fixed level. Moreover, the demand for even some luxurious goods such as special products and items of personal preference can only stagnate after they become popular. In particular, the absence of new products through new technology representing incapacity in creating new demand is the biggest cause for stagnant demand in agricultural society. The simultaneous stagnation of supply and demand is why a pure agricultural society cannot find a way out of the vicious cycle of simple reproduction, and remained stagnant for millenniums in human history until the Industrial Revolution.

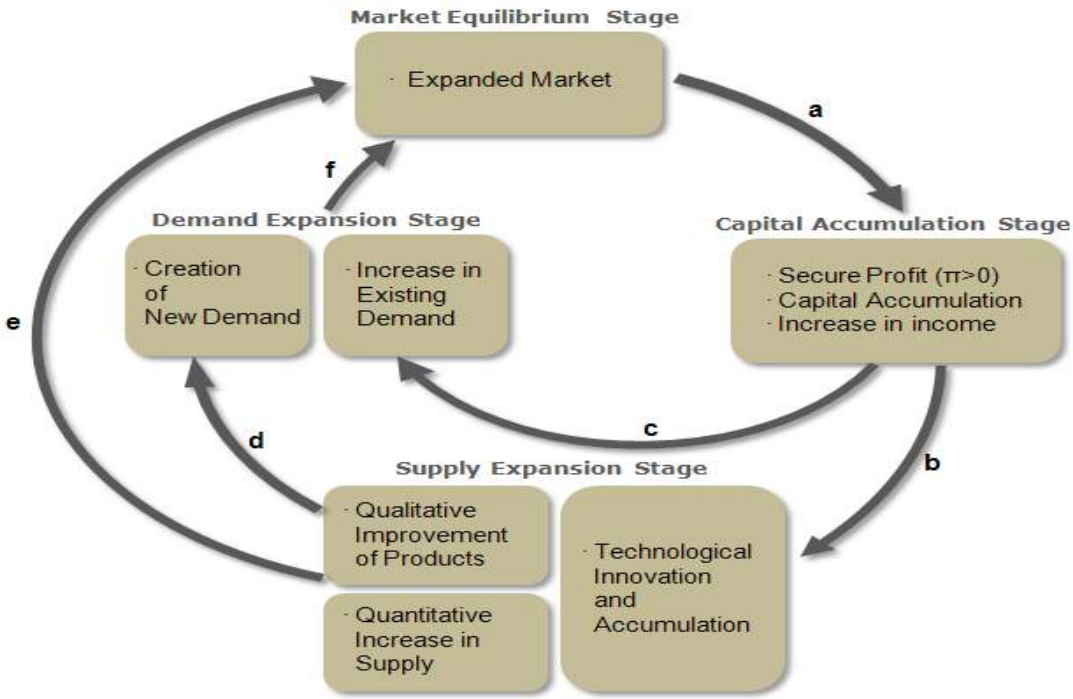

Fig. 7 Expansive Reproduction Structure in an Accelerating Industrial Society.

Notes: Paths a to f refer to the following descriptions.

Path a: Given market equilibrium, capitalists can secure profits, their accumulation becomes significant capital for reinvestment, and income increases.

Path b: Capital accumulation and an increase in income induce the expansion of existing demand.

Path c: Accumulated capital is reinvested for technological innovation and production expansion.

Path d: A launch of quality-enhanced new products from technology innovation creates new demand.

Path e: Existing expansion of demand and new demand creation increase net demand in the market.

Path f: Production expansion through expanded production capacity and productivity improvements, and the launch of new products by technology innovation, increase the net supply to the market.

Fig. 7 illustrates the detailed stages of expansive reproduction in industrial society and Fig. 8 shows the change in economic growth and related indicators that increase over time in an accelerating manner. Fig. 7 represents the structure of expansive reproduction, and shows a virtuous cycle in which supply and demand increase through the accumulation of capital and the economy grows through an expanded market equilibrium in industrial society. In relating to this, Fig. 8 shows that the economic indicators constituting the expansive reproduction cycle also increase in an accelerating manner, along with economic growth when the virtuous cycle of expansive reproduction is established from the hyper-long-run point of view.

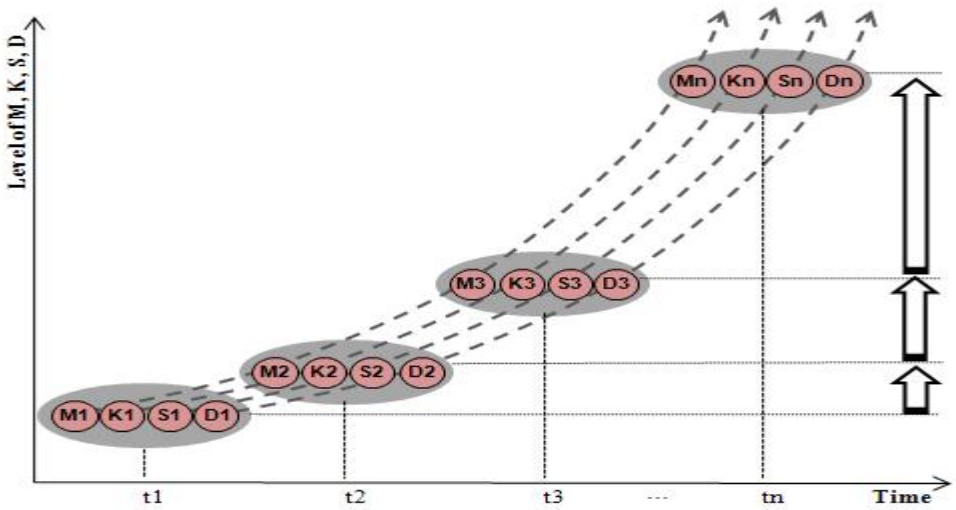

Fig. 8 Accelerating Trends at Each Stage Created by the Circulation of Expansive Reproduction (per Fig. 7).

Notes: M: Market size, K: Capital accumulation, S: Net supply, D: Net demand

Capital-intensive and technology-intensive products in industrial society generated much higher profits compared with existing agricultural or handmade products, and the increase in profits enabled the accumulation of capital and technology. This enabled mass production through productivity improvements and economies of scale in terms of supply. Also, in terms of demand, the increase in profits expanded existing demand through the accumulation of capital and an increase in income. The advancement of industrial structures and products through the accumulation of technology released new products and created new demand that did not exist in the past. Supply and demand grew simultaneously especially with the geometric growth of economy resulting from unique capitalistic and innovative technological characteristics of industrial society, especially with the geometric growth of the economy. A compound increase in capital through expansive reinvestment created synergy and enabled continuously accelerating economic growth through a balance between supply and demand. This is the virtuous cycle of expansive reproduction and the secret of accelerating economic growth in industrial society, which escaped the millenniums-old Malthusian Trap in a few short centuries. This matches the accelerating growth patterns of the figure on the right in Fig. 4 and Fig. 5 as derived from the theories of Solow (1957) and Ruttan (2001) that were discussed above. The growth level of each stage in expansive reproduction as enabling factors of accelerating growth will accelerate with economic growth as the overall output.

This study named this virtuous cycle of accelerating economic growth the expansive reproduction cycle. It may be divided into the following four stages: the Market Equilibrium stage, the Capital Accumulation stage, the Supply Expansion by Technological Innovation stage, and the Demand Expansion stage.

Market Equilibrium stage

In the Market Equilibrium stage, the expanded production resulting from the expansion of supply capacity and the expanded consumption that originated from the increase in demand that created equilibrium in the market, represented the scale of the economy or market. Concerning economic growth in industrial society, the increase in production (GDP) and consumption accelerates as the expansive reproduction cycle continues the virtuous cycle. In other words, an increase in the production scale, as in Fig. 8, gradually increases through the repetition of reproduction, accelerating growth.

This phenomenon of acceleration can be verified in a few preceding studies. Gras (1939) reported that the industrial capitalist era is one in which excessive demand

and the expansion of supply took place. In particular, the opinion of Knowles (1924), Hammond (1925), and Hobson (1965) that the existence of a market that can consume increases in industrial output is an essential condition for the development of capitalism. This is reflected in the advancement of industrial capitalism made through the expansion of supply and the market; in other words, the expansion of demand. The continuous expansion of market scale through the expansion of supply and demand shows accelerating economic growth from the hyper-long-run point of view. The examples of accelerating growth in Section 4 will highlight this further.

Capital Accumulation stage

Capital accumulation enables reinvestment for expansion by accumulating capital for the company and by increasing income for individual consumers.

First, the company can expand its capital or corporate scale by accumulating some of the profits secured through the sale of products or services. The capital accumulated here is used as investment for increasing the amount of existing products, or for developing products with higher values in a qualitative sense. In industrial society, most of the investment is used for facility and technology development. When the company or the nation obtains greater profits through the accumulation of capital and technology, there will be greater accumulation and reinvestment of capital in the subsequent cycle of expansive reproduction. Through the repetition of these cycles, the accumulation and reinvestment of capital will accelerate. As a basis for this theory, a study by Lewis (1955) reported that the reinvestment rate, which was under 5% before industrialization, increased to 10% or higher through industrialization. In particular, this rate was driven by the cotton and steel industries in the early stages of the industrial society (Stanley 1970). The case study by Wilson (1957) demonstrates this in more detail.[8]

Individual consumers will naturally have more income when the scale of the economy expands and the company's profits increase as a result of an increase in earned income and capital income. The capital accumulated by companies also causes an expansion of employment and an increase in wages, which contributes to enhancing the income level of individual consumers. The expansion of the economy and an increase in corporate profits also brings about direct investment by individuals, indirect investment through stock markets, and an increase in income by enhancing returns on equity

[8] According to Wilson (1957), William H. Lever, who was engaged in the soap industry, made 50,000 pounds in profit per year in the 1880s, and reinvested most of it (he kept 400 pounds) every year. This case of expansive reproduction in an early industrial society demonstrates how huge amounts of capital have been accumulated in this modern industrial society.

through related financial institutes.

The profits secured in industrial society provide companies with the opportunity to accumulate capital, and provide individual consumers with the opportunity to increase their income levels.

Supply Expansion by Technological Innovation stage

In this stage, supply will increase by reinvesting into industry the capital accumulated in the previous stage. First, the reinvestment of capital accumulated in the previous stage can be divided into quantitative facility expansion investment and qualitative technology development investment. The quantitative facility expansion investment intends to increase only production while maintaining existing levels of production technology. This usually refers to the quantitative expansion of supply to satisfy the expansion of demand for existing products given an increase in consumers' income levels. A qualitative technology development investment tends to create value added through the development of new products based on technological innovation. This refers to investment in the technological development that satisfies the creation of new demand resulting from the release of new products.

This stage is in line with the theory of endogenous growth (Romer 1990). Romer (1990) chose technological development as well as the quantitative expansion of intermediates and qualitative improvement (Grossman and Helpman 1991) as the elements of economic growth, quite similarly to an increase in product supply through a qualitative enhancement of products, expansion of facilities, and an increase in productivity based on technological innovation and accumulation in this study. The theory of learning by doing by Arrow (1962) also supports the logic of this stage, as it mentioned the enhancement of productivity as a result of the effect of the intangible accumulation of technology and know-how. This stage describes more clearly the mechanisms of expansive reproduction, in line with existing economic growth but deals with qualitative development investment for the qualitative improvement of products.

Technological accumulation generally appears in two patterns: through the advancement of products and the advancement of industrial structure. The advancement of products refers to the relatively short-term phenomenon of technological innovation, where products are enhanced, functions are diversified, and new technologies are combined to develop new products within the same industry. The advancement of industrial structure refers to the phenomenon of a more fundamental technological innovation over the relatively long term, such as a shift in the center of the industrial structure in industrial society from labor-intensive light industry to capital-intensive heavy and chemical industries, and again to a more technology-intensive electronic and

advanced information industrial structure.

Expansive reinvestment in quantitative facility expansion and qualitative technological innovation generates synergy effects that simultaneously increase supply and demand compared with the previous cycle. This enables a virtuous cycle of expansive reproduction. Technological innovation through qualitative investment becomes the major driving force for the accelerating economic growth of industrial society, as it creates new demand through the development of new product that did not exist in previous cycles.

First, this theory is supported by the following studies that clearly show continuous technological development in industrial society. Pollard (1965) and Smelser (1959) stated that manpower has been qualitatively improved through an increase in investment in labor training in the industrialized 19th century. Catling (1970) demonstrates the case of technological innovation in the cotton spinning industry and labor productivity thereof, which involved the effect of technological investment in both qualitative and quantitative aspects. (Refer to Table 2.)

Table 2 Labor Productivities in the Cotton Spinning Industry

Types of Cotton Spinning Processors	Required Labor Hours
Indian labor (18th century)	50,000
Crompton's self-actor (1780)	2,000
100 weight self-actor (1790)	1,000
Power aided self-actor (1795)	300
Robert's self-actor (1825)	135
Modern cotton spinning machine	40

Source: Modified from Catling, H. (1970). The spinning mule. Newton Abbot: David and Charles

Also, Mitchell and Dean (1962) surveyed the increase in patents from the 1700s to the 1800s (Fig. 9). In Fig. 9, if number of patents is considered the outcome of investment in technological innovation, the geometric increase in patent registrations shows that investment in qualitative technological innovation increased in an accelerating manner.

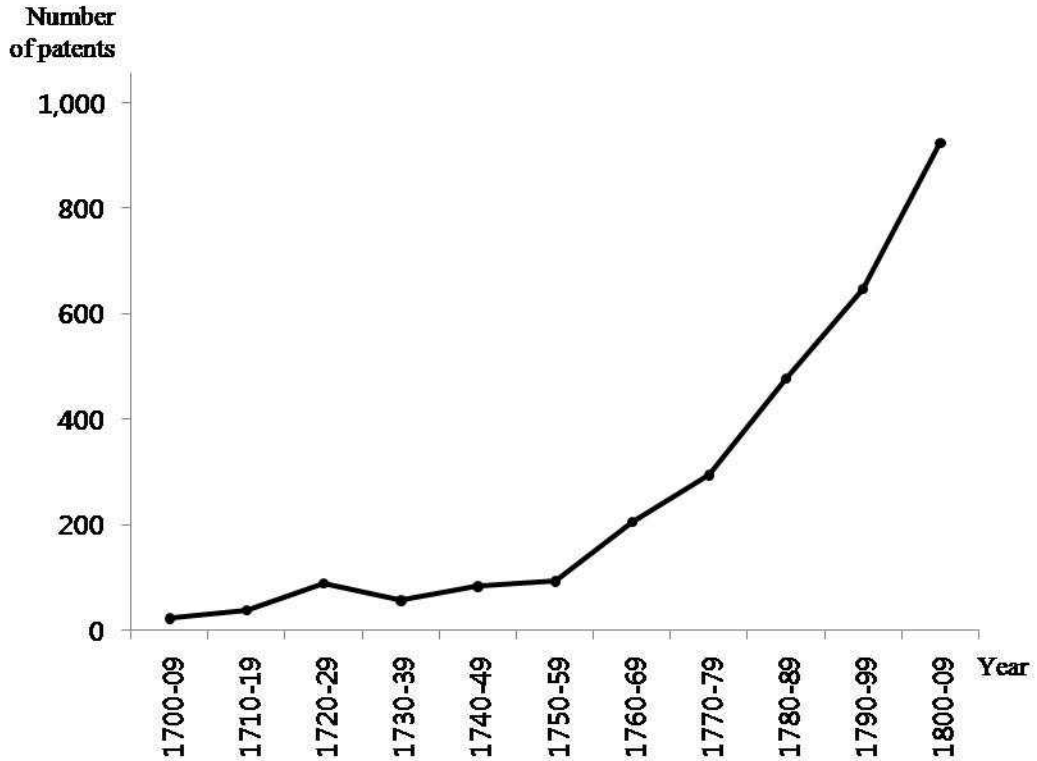

Fig. 9 Patent Registrations in the Industrial Revolution Era, England, 1700–1809.
Source: Mitchell, B., & Dean, P. (1962). Abstract of British historical statistics. Cambridge: Cambridge University Press, Table 13, p. 268.

As industrial society matures, the accumulation of technology in the early stages of industrial society as examined above is becoming more expanded and developed through the accelerating accumulation of technologies.

Second, existing studies also show that technological development is manifested into two patterns, the advancement of products and the advancement of the industrial structure. Fig. 10 schematizes systematically existing studies that interpreted the qualitative growth of the economy into the advancement of products and the advancement of industrial structure.

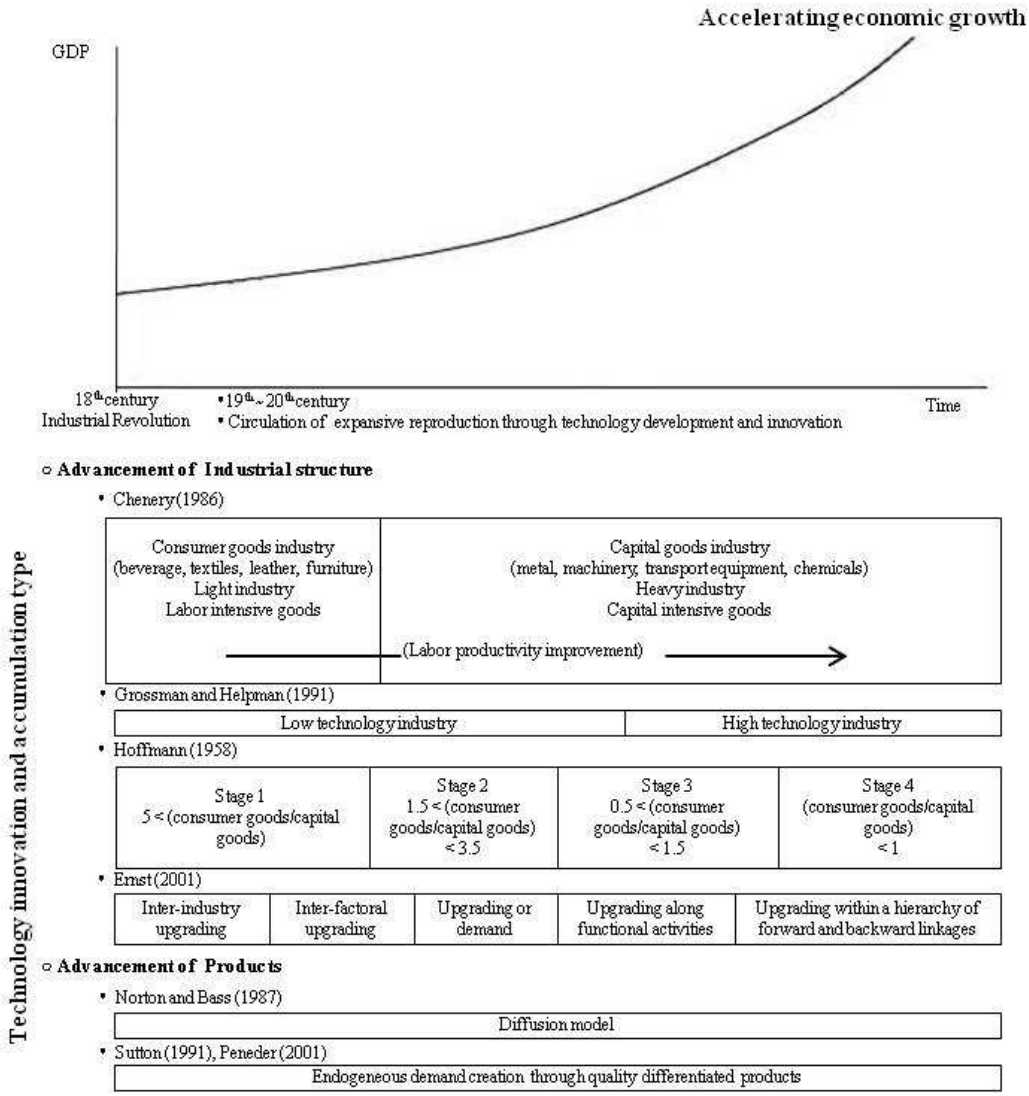

Fig. 10 Qualitative Growth Pattern in Accelerating Societies

From the perspective of the advancement of product, when a product is developed, continuous development of new technologies occurs to replace old technologies. This leads to the commercialization of a previously uncommercialized area, and expanding the market from the perspective of innovative products and discovering markets (Norton and Bass 1987). Sutton (1991) and Peneder (2001) also note that new technologies are developed periodically through the innovation and differentiation of individual products, with profits and output rapidly increasing through the enhancement of a product's performance and by creating endogenously demand and market scale. From the perspective of the advancement of industrial structure, the studies of Hoffman (1958) and Chenery et al. (1986) demonstrate changes in industrial structure over four stages and two stages, respectively, the study of Grossman and Helpman (1991) demonstrates the differences in productivity improvement by industries

specialization: relatively slow productivity improvement by low-tech industries and rapid productivity improvement by high-tech industries, and the studies of Ernst (2001) demonstrates the advancement of industrial structure through four types of industrial upgrading.

Demand Expansion stage

The Demand Expansion stage can be examined in two aspects, similar to the Supply Expansion stage. The two aspects are: (a) an increase in existing demand as a result of an increase in purchasing power from capital accumulation and greater income, and (b) the creation of unprecedented and new demand resulting from the release of new products through technology innovation and its accumulation.

First, an increase in existing demand refers to an increase in the consumption of products with the same quality resulting from an increase in individual income. Second, the creation of new demand refers to the creation of greater demand resulting from the release of new products that did not exist in the market. This becomes an important resource for an increase in demand in industrial society. The advancement of products and industrial structure in the Supply Expansion stage brings a qualitative advancement of existing products or the development of new industrial products. This replaces or expands the demand for existing products or creates new demand for new products.

Before an industrial revolution, commercial expansive reinvestment could increase demand through capital accumulation and an increase in income, but only in the short term. There was no continuous creation of new demand resulting from launches of new products created from technological innovation and its accumulation. This was the fundamental reason the Netherlands, which maintained hegemony in the commercial era, could not help but be outstripped by England, which started the Industrial Revolution. The Netherlands suffered from stagnant demand for agricultural products, such as spices, while England's cotton and steel industries enabled a virtuous cycle of expansive reproduction by continuously creating new demand through new technology.

In relation to this, John (1961, 1965) reports that increases in the population and income in industrial society brought about an increase in demand for food, industrial products, and services, which then created an increased supply and, eventually, initiated economic growth. In particular, Masi (1987) noted enormous demand as an advantage of industrial society.

Circulation of expansive reproduction

As discussed above, industrial society is an accelerating society with a virtuous

cycle of economic growth, represented as expansive reproduction. The four stages: Market Equilibrium, Capital Accumulation, Supply Expansion by Technological Innovation, and Demand Expansion, continue circulation and growth by increasing quantity or enhancing quality through clear causal relationships. In particular, the accumulation of technology through capital accumulation or the launch of new products and the creation of new demand through new technology are areas in which the qualitative enhancement of economic growth, which was absent in the simple reproduction cycle of a pure agricultural society, takes place. This is the most important element that forms expansive reproduction—the gene of industrial society—to continue the virtuous cycle. Qualitative growth through technological innovation and its accumulation represented as an advancement of industrial structure and products plays the role as the core DNA that constitutes the gene of the industrial society—expansive reproduction.

Also, the fact that the implications of growth theories advocated by renowned economists provide clues of this study are in line with a part of the progression in each stage of the virtuous cycle of expansive reproduction, supporting the logic of this study, which has demonstrated accelerating economic growth through the circulation of expansive reproduction. Increased production based on the division of labor by Smith (1776) and an increase in productivity therein explains the progression of the Supply Expansion stage to the Market Equilibrium stage, where the production supplied to the Market Equilibrium stage increases through technological innovation and the expansion of production facilities in the Supply Expansion stage. Marshall's (1920) theory of returns to scale supports ideologically the circulation of paths a, c, and f in the expansive reproduction cycle (Fig. 7), as it states that companies that accumulated profits and capital through market expansion (the Market Expansion Stage) increase facilities quantitatively through large investments (the Capital Accumulation stage) and improve productivity (path f in Fig. 7). Similarly, the theory of increasing returns by Chandler (1990) also becomes the basis for the link between paths c and f, which is a part of the circulation chain suggested by this study. This is similar to Marshall's theory that cites large facility investment (Capital Accumulation stage), an increase in productivity through the mixed use of the same facility due to an increase in technological compatibility (Supply Expansion stage), and an increase in production (Market Expansion stage) in terms of economies of scope. Also, implications on cumulative growth by Myrdal (2006) in line with accelerating economic growth in this study (virtuous circulation of expansive reproduction) suggest that this study does not deviate from the direction of very basic and fundamental studies on economic growth, along with a variety of economic growth theories mentioned above.

Consequently, the establishment of the virtuous cycle of economic growth based on expansive reproduction becomes the driving force for industrial society to achieve accelerating growth from the hyper-long-run point of view. This is regardless of the obstacles faced, such as short-term economic growth resulting from economic, social, political, and casual events.

4. Countries Experiencing Accelerating Growth in Industrial Society

Although previous paragraphs clarified that accelerating growth in industrial society is led by expansive reproduction, it is difficult to find cases in each country that actually demonstrate accelerating economic growth. This is true for a few reasons. First, advanced nations that industrialized early lack data that would prove this theory. England had its Industrial Revolution as early as the 18th century (Deane, 1979), but has almost no consistent historical data to illustrate economic growth. On the other hand, countries that became industrialized in modern times and achieved rapid growth were mostly influenced by the economic elements of short-term shocks (financial crises, trade imbalances, friction with developed countries, etc.), despite the fundamental and structural properties of industrial society. This is because they achieved growth in a relatively short period. Regardless of the limitations in collecting data and the theoretical evidence, the following demonstrates that industrial society has accelerating characteristics from the hyper-long-run point of view. This section examines actual examples of accelerating economic growth from the perspective of per capita GDP, production efficiency, and other elements.

Fig. 2 (a) shows that the increase in the per capita GDP of England accelerated after the Industrial Revolution. Per capita GDP in England (US$, 1970) during the industrial revolution was US$250 in the year 1700 and increased to US$4,000 in 2000.

Fig. 11 shows the accelerating growth of per capita income from 1870 to 2000 in three developed countries (Germany, Japan, America), and two countries that were industrialized later (Argentina and Korea).

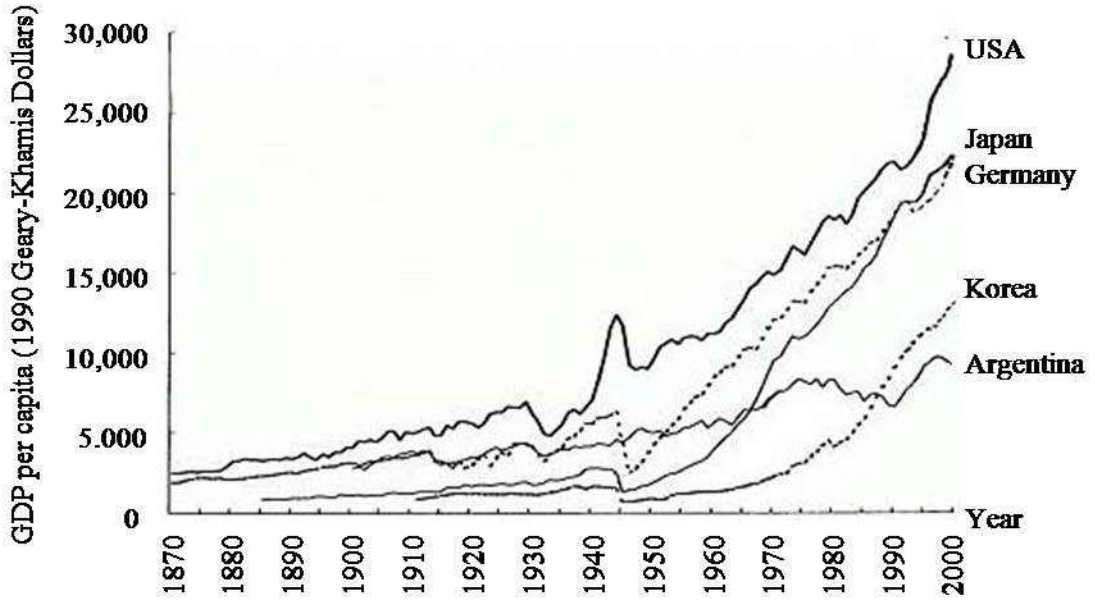

Fig. 11 GDP per Capita in Selected Developed and Developing Countries, 1870–2000.

Data source: Maddison, A. (1995). Organization for Economic Co-operation and Development, National Accounts.
http://www.oecd.org/topicstatsportal/0,2647,en_2825_495684_2759282_1_1_1_1,00.html. Accessed 10 March 2008.

As shown in Fig. 11, America, which became industrialized first among five countries, showed the highest per capita GDP over a 130-year observation period, followed by Japan, Germany, Korea, and Argentina. The irregular section of the graph between 1930 and 1950 is thought to have been influenced by the Second World War. The rise of Japan commenced immediately after the Second World War in 1945, and Korea began rising in 1970. In other words, the accelerating points of the developed countries that industrialized earlier than Korea retained higher continuous GDP than Korea.

The third example, Fig. 12, shows the trend in per capita GDP of the ten Western European countries, the six Asian countries, and the fifty-seven countries in Africa from 1820 to 1990. While the Western European countries and the six Asian countries showed accelerating economic growth, African nations that were not industrialized showed the decelerating economic growth commonly found in agricultural society. However, the characteristics of the accelerating curve show that the gap between the ten early-industrialized European countries and the six later-industrialized Asian countries is growing.

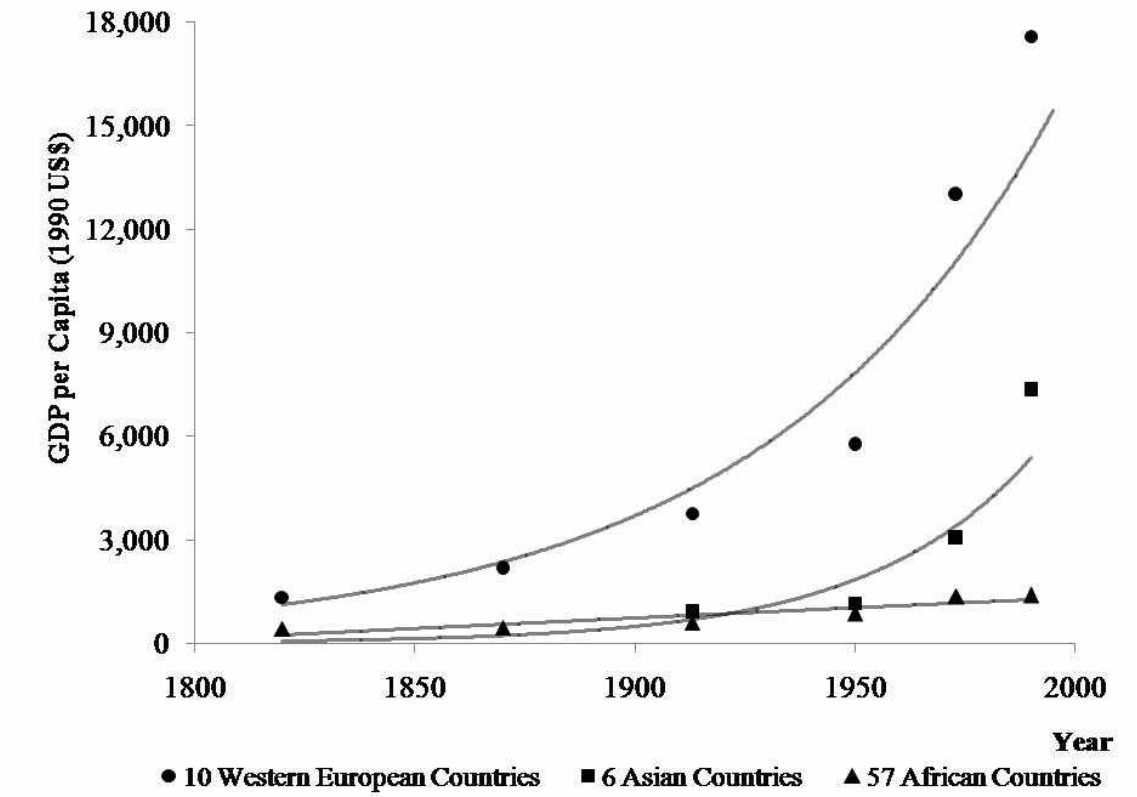

Fig. 12 Trend in GDP per Capita of Country Groups.
Data source: Maddison, A. (2001). The world economy: A millennial perspective. Paris: Development Center of the Organization for Economic Co-operation and Development.
Notes: The ten Western European countries are Austria, Belgium, Denmark, France, Germany, Italy, the Netherlands, Sweden, Switzerland, and the United Kingdom. The six Asian countries include India, Malaysia, Singapore, South Korea, Taiwan, and Thailand. The last group includes 57 African countries.

The fourth example is the world's per capita GDP, which increased rapidly (Maddison 2001). Fig. 13 shows an accelerating trend in the world's per capita GDP from the 1880s, when industrial society emerged, until the 1990s.

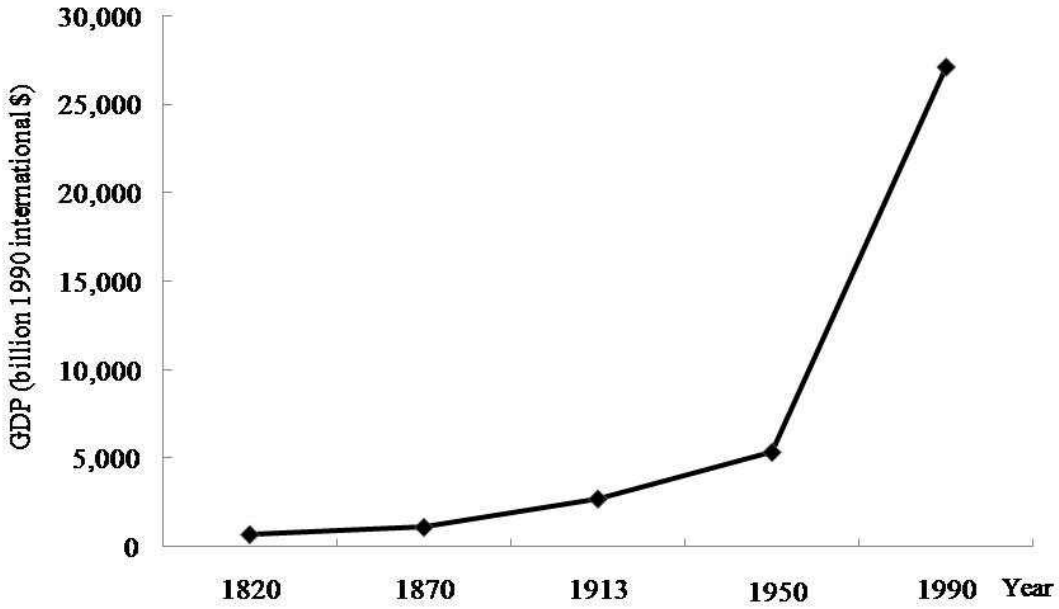

Fig. 13 World GDP per Capita, 1820–1990.
Data source: Maddison, A. (2001). The world economy: A millennial perspective. Paris: Development Center of the Organization for Economic Co-operation and Development.

The fifth example, Fig. 14, shows the changes in labor productivity of 12 industrial countries from 1870 to 1998. Excluding 1870, America showed the highest labor productivity in each year, and Japan showed the lowest figure until 1950. However, Japan's labor productivity increased much faster than America's in the late 20th century. Each graph in the following shows the acceleration of labor productivity in each country.

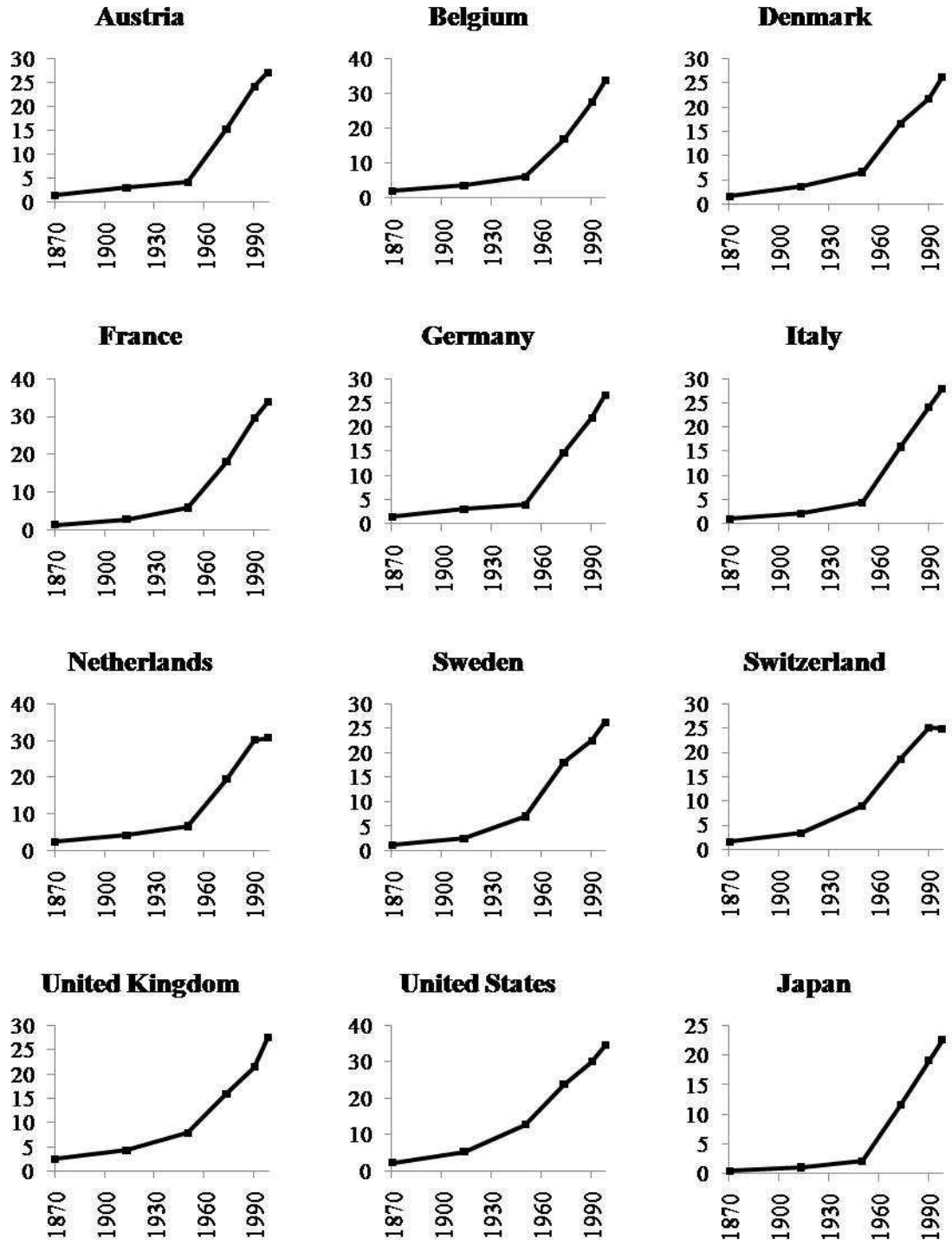

Fig. 14 Twelve Countries' Labor Productivity, 1870–1998.

Data source: Maddison, A. (2001). The world economy: A millennial perspective. Paris: Development Center of the Organization for Economic Co-operation and Development.

Notes: Horizontal axis – Year, Vertical axis – GDP per Hour Worked (1990 international $ per hour).

Finally, the case of Jackson (1992) in Fig. 15 also verifies indirectly the accelerating economic growth theory. Jackson (1992) analyzed the industrial growth of England after the Industrial Revolution, as in the following graph. Fig. 15 shows that the changes in industrial production were small, that large fluctuations occurred before 1750, and that industrial production increased rapidly after 1750.

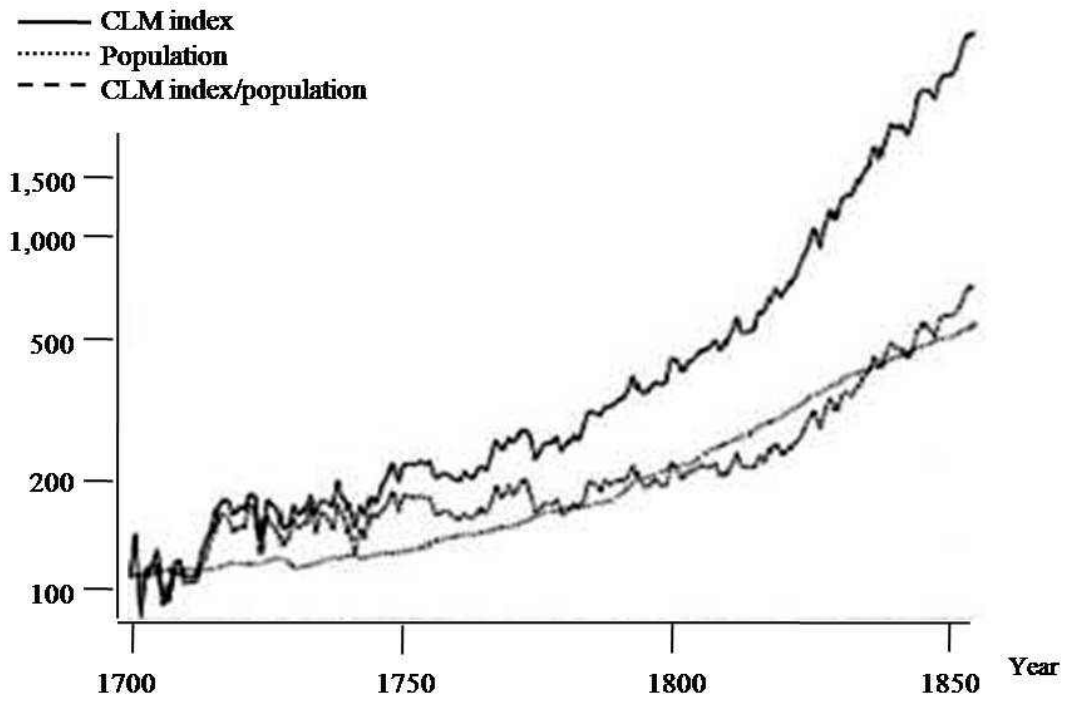

Fig. 15 Industrial Production, Population, and Industrial Production per Capita in England, 1700–1854.

Source: Jackson, R.V. (1992). Rate of industrial growth during the Industrial Revolution, Economic History Review 45(1), Figure 1, p. 5.

The examples presented above directly and indirectly show the accelerating growth of an economy in industrial society from the hyper-long-run point of view, covering a period from the beginning of industrialization to modern times. In other words, they show that both a theoretical basis and actual examples verify the fact that industrial society has accelerating growth characteristics.

5. Conclusion

This study was conducted to answer the question of the secret to the economic growth in industrial society that, unlike in the pure agricultural age, resulted in a continuous

increase in per capita GDP regardless of the geometric increase in worldwide population after the Industrial Revolution. This study theoretically proves that the unique value creation structure of industrial society enables the acceleration of economic growth over time through the input–output relationship of growth theory based on a basic understanding that economic growth is essentially "creating value" that is new and in greater quantity than at existing levels, and that represents expansive reproduction. This study also verified this through actual statistical data from historic and hyper-long-run points of view. This study also proved that industrial society is eventually an accelerating society in which the creation of value increases over time and is maintained by expansive reproduction. Expansive reproduction brings accumulation of capital, which results in technological innovation that becomes the basis for the synergism and virtuous cycle between demand and creation through an increase in supply given productivity enhancements and new product releases. This principle was directly verified through a variety of historical evidence, with the growth theory of a number of economists providing clues to the fact that economic growth accelerates in industrial society.

In other words, the theoretical results and empirical evidence of this study can be summarized with the following two statements: "Industrial society is one in which economic growth accelerates," and "Accelerating economic growth is the manifestation of the genetic property of industrial society, called 'expansive reproduction.'" The true meaning and policy implications of these statements are clear, suggesting the desperate need for more in-depth and profound follow-up studies.

A pure agricultural society with decelerating economic growth and industrial society with accelerating economic growth have witnessed great vertical diversion of human history as well as great horizontal divergence (Similar to this, Pomeranz (2002) defined the increase in the economic gap between China and Western Europe as "The Great Divergence.") between eastern and western civilizations starting from the Industrial Revolution. However, the creation of value in modern agricultural industry using the technology and equipment of industrial society does not always cause a deceleration. Rather, the revolution of biotechnology based on genetic modification or the decoding of a DNA structure can evolve agricultural society into a new, future society that more efficiently executes economic development. However, all of these should be realized through the accumulation of traditional industrial technology and emerging advanced scientific technology, only serving to emphasize the importance of the economic growth of industrial society. From England, which realized an accelerating industrial society through the Industrial Revolution for the first time in human history to Western European countries, countries in the New Continent, and

Asian countries, industrialization has become a worldwide phenomenon beyond the trends of time. However, the industrialization of most countries, excluding a few developed countries, remains unsuccessful. Moreover, countries that have failed to industrialize, even those that partially succeeded, face a number of domestic problems such as economic inequality, political and social unrest, the pollution and destruction of the environment, and an increasing gap from advanced nations. Also, great threats to human civilization, which even developed countries face and cannot resolve, such as global warming, shortage of energy resources, and the global financial crisis (Bernanke 1983; Shiller 2008; Stiglitz 2003) that spread worldwide like the Great Depression, are products of the accelerating economic growth of industrial society. As much as all trials that the human race face today are caused within an accelerating industrial society, solutions to those trials must start from a correct understanding of an accelerating society.

Expansive reproduction—the gene that accelerates economic growth in industrial society—provides more specific policy implications. The limitations to growth in agricultural society that have existed for millenniums were overcome within a few short centuries through the accumulation of capital, which does not exist in the simple reproduction model. This is the first step to enabling the expansion of reproduction, and is a necessary condition for expansive reproduction. The expansive reproduction cycle, which depends on capital accumulation, was formed for the short term even in the commercial era before the Industrial Revolution. However, it could not overcome growth limitations (Mokyr 2000; Vries 2000). Truly overcoming limitations to growth, which enabled popular affluence, was done through technological innovation and its accumulation of expansive reproduction, which the expansive reinvestment system lacked. Technological innovation in the Supply Expansion stage enhanced productivity and enabled mass production. From the perspective of demand, new technology brought about by technological innovation enabled the shipment of new products that created new demand. Also, the market found a new and expanded balance between mass production and increased consumption to complete a cycle of expansive reproduction and start another cycle. Technological innovation can be considered a sufficient condition for expansive reproduction, as technological accumulation, which completes the expansive reproduction cycle, is enabled through accumulated capital invested in technological innovation.

Understanding the progression in the each stage of expansive reproduction will provide the basis for making policy alternatives that directly lead to the critical path of economic growth among very diverse and complicated economic activities that constitute industrial society. This will also prevent the bottleneck phenomenon of

growth to maximize economic efficiency.

Voices exist that define modern industrial society as a post-industrial society or the beginning of a knowledge-based society. Regardless of its definition, the knowledge-based society of the future will certainly be a new form of society that differs from industrial society. The agricultural revolution that gave birth to civilization and started the age of history divided the human race into the ruler who dominates and the ruled that are exploited. The Industrial Revolution overcame the limitations of nature and achieved popular affluence but caused global issues such as economic inequality and environmental destruction. The knowledge revolution will surely overcome a number of challenges that today's human race faces. However, if it is to be the rule of nature and the will of God to place light and darkness together, the human race should to prepare for this. A correct understanding of accelerating industrial society as suggested in this study is anticipated to contribute to the efforts of the human race in its preparation for a better tomorrow.

This study examined the accelerating economic growth trend that integrates industrial society and the endogenous framework. Follow-up studies should theoretically be able to verify the advancement of the industrial structure and its products as a result of technological advancement, which is the most important pivot of expansive reproduction that enables acceleration.

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