Knowledge-based Economy and Intellectual Capital: The Impact of National Intellectual and Information Capitals on Economic Growth in Korea

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Abstract

The purpose of this study is to examine the impact of national intellectual and information technology capital on economic growth and the productivity in Korea during the period 1971-2003. The growth contributions from standard input factors, information technology (IT) capital inputs, and the business cycle effect are calculated on the basis of the growth accounting framework. This study also investigates the source of productivity growth by OLS estimation, using the extended growth model and drawing attention to the role that national intellectual and IT capital may have played. The results show that national intellectual and IT capital have strongly positive effects on the growth of labor productivity in the long run.
Keywords: economic growth; national intellectual capital; IT; productivity; Korea

1. Introduction

The last decade of the 20th century represented a turning point in the global development process. It is known that knowledge has become the engine of social, economic, and cultural development in today's world. Knowledge, as embodied in human beings (as “human capital”) and in technology, has always been central to economic development. Knowledge-based economic activities are now a factor of production with strategic importance in the leading countries. These have also become the main indicator of the level of development and the readiness of every country for further economic and cultural growth in the 21st century.

The term knowledge-based economy stems from a fuller recognition of the role of knowledge and technology in economic growth. Several characteristics define a knowledge-based economy: (1) it is focused on intangible resources rather than tangible resources [Edvinsson and Malone, 1997]; (2) it has a very powerful technological driving force; i.e., the rapid growth of information technologies (IT); (3) it is stimulated by the rapid growth of ITs with telecommunication and networking, which have penetrated all spheres of human activity, forcing the ITs to work in a new mode and creating new spheres; and (4) knowledge has become an independent force and the most decisive factor in social, economic, technological, and cultural transformation [UNECE, 2002]. In a knowledge-based economy, intellectual capital is a core factor, therefore, in the competitiveness of a nation, and its role has been increasing not only from a national perspective, but also in terms of individual firms. Despite the increasingly important role of intellectual capital in national performance, its importance has been recognized in only the last few years. Most countries, therefore, still assess their performance in terms of the traditional factors of production.

Korea is well known for having established specific types of hi-tech industries, such as memory chips and computing equipment (hardwares and softwares), telecommunication equipment, and other IT-related products. Development of these industries has been based largely, however, on borrowed
technologies, which have been combined with relatively low wages, thus enabling Korea to compete in global markets for such products. Newly industrialized countries (NICs) in general and Korea, in particular, do not yet have fully developed "knowledge-based" economies, which are characterized by knowledge-intensive industries and a service economy that focuses on information-based intellectual capital. Since the early 1990s, however, efforts such as direct and indirect government incentive policies designed to encourage investment in the IT industries have helped NICs and Korea catch up with advanced countries with respect to the new knowledge-intensive industries. In Korea, investments in these industries have been made largely by the private sector, which has responded positively to government initiatives.

As more capital is channeled into the new IT industries in Korea and other NICs, economists are keeping an eye on the debate about seemingly "paradoxical" issues surrounding slow productivity growth in the United States and other advanced countries. This debate centers on the observation that, despite the introduction of IT in the 1970s and 1980s with massive capital investments, total factory productivity (TFP) has continued to decline.

Until the 1990s, Korea had a significant increase in both labor participation and IT investments, and there was little empirical evidence that substitution was accompanied with technological change in the Korean economy. Perhaps as an alarm to the economy, new evidence suggests that the increase of per capita capital (K/L) has been subject to diminishing returns, with a visible decline in the marginal productivity of capital [Hsieh, 1999]. If this proves to be the case, the Korean economy will need to seek a way for productivity growth that will offset the declining contribution of accumulated capital and other factors. A reasonable way to deal with these issues would be to introduce national intellectual and IT capital into economy.

Parallel with the importance of IT industries, national intellectual capital has been receiving the increased attention of company CEOs and national policy makers, as the driver of national wealth and the driver of innovation, learning, and productivity growth. National intellectual capital is becoming a cornerstone, therefore, of corporate success in a "knowledge-based economy."

Although research on national intellectual capital has been conducted in a variety of international settings, none seems to have been made in Korea. The purpose of this study, therefore, is to examine the impact of national intellectual
IT capital on economic growth and productivity in Korea during the period 1971-2003. In this study, growth contributions from standard input factors as well as from IT capital inputs are calculated on the basis of the growth accounting framework. We also examine the growth contribution from the business cycle effect. In addition, this study investigates the source of productivity growth by OLS estimation in the long run, using an extended growth model and drawing attention to the role that national intellectual and IT capital may have played. The study examines whether productivity growth is attributable to national intellectual and IT capital directly from the production function instead of the calculation from income shares, and it also investigates the possible relationship between R&D and TFP.

Following this introduction, Section 2 presents a brief description of national intellectual capital. Section 3 describes the role of national intellectual and IT capital in productivity growth. Section 4 provides the empirical framework for measuring the sources of economic growth and productivity. The empirical results of the study are presented in Section 5, and our concluding remarks are made in Section 6.

2. Intellectual Capital of a Nation

Intellectual capital resources are now largely recognized as the most important source of an organization’s competitive advantage. In his description of post-capitalist society, Drucker [1993] highlights the importance and arrival of a society dominated by knowledge resources and a competitive landscape dominated by intellectual capital allocation. Machlup [1962] coined the term intellectual capital and used it to emphasize the importance of general knowledge as a vital element in the growth and development of nation.\(^1\)

The theory of intellectual capital and its accompanying framework, construction, and measurement were initially developed as the focal level of analysis of a firm. Although hints of the theory can be found while learning the

\(^1\) The term intellectual capital has many complex connotations and is often used as a synonym for intellectual property. Intellectual property, however, is legally defined and represents property rights to such things as patents, trademarks and copyrights. These assets are the only form of intellectual capital that is regularly recognized for accounting purposes.
organization, the resource-based theory of the firm, even Tobin's Q literature streams, and the real impetus for growth came in the early 1990s. In the case of physical capital, present and future benefits are made comparable through the use of discount rates, while costs are measured by depreciation. In the case of intellectual capital, however, there is no way to count cost and benefits over any period of time except the immediate accounting period.

Many of those who have done research in this area are interested in answering two questions: (1) What causes firms to be worth so much more than their book value? And, (2) What specifically are those intangible assets? Stewart [1997] defines intellectual capital as those intellectual materials — knowledge, information, intellectual property, and experience — that have been formalized, captured, and leveraged to create wealth by producing a higher-valued asset. Following some researchers [Bontis, 1998, 2001; Roos, et al., 1998; Sveiby, 1997; Edvinsson and Malone, 1997; Saint-Onge, 1996; and Sullivan and Edvinsson, 1996], intellectual capital at the firm level is defined as encompassing: (i) human capital, (ii) structural capital, and (iii) relational capital.

Theorists soon extrapolated the initial conceptual level to also include nations. Accordingly, researchers have moved to assessments of the stock of intellectual capital at the national level. The basic idea is, therefore, that a comparative advantage may accrue from a relatively greater level of intellectual capital, providing impetus to a nation's international competitiveness if it can be appropriately employed [Edvinsson, 2002]. Malhotra [2000] argues that leaders of national economies are trying to find reliable ways to measure intellectual capital in order to understand how it relates to the future performance. The expectation is that such measures may help governments better manage the intangible resources that increasingly determine the success of their economies.

National intellectual capital can be described as the assets that underpin the growth and development of a country. In this context, the intellectual capital of a nation may include the hidden values of individuals, enterprises, institutions, communities, and regions, which are current and potential sources for the creation of wealth. These hidden values are the roots for nourishment and cultivation of a country’s future well-being. In this sense, intellectual capital also includes those collective intangible assets that can be identified and measured.

Measuring national intellectual capital is relevant to the value, growth, monitoring, and management of these intangible assets [Malhotra, 2000]. Such
assets include constructs such as information, knowledge, ideas, innovation, creativity, and other derivatives. These constructs were not treated as assets in traditional accounting standards. In many cases, however, high growth rates were often attributed to national investment in knowledge-based and information-based infrastructure, goods, and services. In this respect, national intellectual capital represents the identifiable aspects of a nation, in which "intangible" can be considered as specific types of additional values. Nowadays, intellectual capital is the primary source of production. Although much of the research on intellectual capital spans only a decade, the national view of this phenomenon is in its infancy.

3. Role of National Intellectual and IT Capital in Productivity Growth

Traditional assessment of national economic performance has relied on an understanding of the gross domestic product (GDP) in terms of traditional factors of production — land, labor, and capital. National intellectual and IT capital can be distinguished from the traditional factors of production in that it is governed by what has been described as the “law of increasing returns.” In contrast to the traditional factors of production, which are governed by diminishing returns, every additional unit of national intellectual and IT capital that is used effectively results in a marginal increase in economic performance.

We here present the role of national intellectual and IT capital in the growth of an economy. The first step in this discussion is to begin with an extended Cobb-Douglas production function [Sichel, 1999] as

\[ Y = T(K_{NIC} + K_{IT} + K_{OT})^\alpha L^{1-\alpha} \]

where \( Y \) is output, \( T \) is a multiplicative technology parameter, and total capital is decomposed into national intellectual capital \( (K_{NIC}) \), IT capital \( (K_{IT}) \), and other capital \( (K_{OT}) \), and \( L \) is labor, respectively. \( \alpha \) is the capital share of output and \( (1-\alpha) \) is the labor share of output. The technological progress \( T \) is also known as the Solow Residual, and the total factor productivity (TFP) is externally determined. The contribution of national intellectual and IT capital to productivity growth may be disembodied or embodied. In an embodied approach, national
intellectual and IT capital contributes to productivity by raising the TFP, which makes all factor inputs more proportionately productive.

In this formulation, total factor productivity (TFP) is defined as follows:

\[
TFP = Y/(K_{NIC} + K_{IT} + K_{OT})^\alpha L^{(1-\alpha)} = T
\]  

(2)

Because productivity is defined as the ratio of total output to total input, and because national intellectual capital and IT capital are inputs, one would expect the growth in intellectual and IT intensity to raise productivity. It is also possible that national intellectual capital may have this effect if its principal function were to improve coordination. One way to represent embodied technical progress is to model production function as:

\[
Y = T[K_{OT} + (1+\phi_1)K_{NIC} + (1+\phi_2)K_{IT}]^\alpha L^{(1-\alpha)}
\]  

(3)

where \(\phi_1\) and \(\phi_2\) are parameters that measure the excess productivity (i.e., spillovers or externalities) of national intellectual and IT capital relative to other types of capital.² Substituting \((K-K_{NIC}-K_{IT})\) for \(K_{OT}\) and rearranging the equation, we can express the share of national intellectual and IT capital in the total capital stock as

\[
Y = T[K\{1 + \phi_1(K_{NIC}/K) + \phi_2(K_{IT}/K)\}]^\alpha L^{(1-\alpha)}
\]  

(4)

When the logarithm is taken in both sides of Eq. (4), it can be written as

\[
\ln Y = \ln T + \alpha \ln K + \alpha \ln (1 + \phi_1 \nabla NIC + \phi_2 \nabla IT + (1-\alpha) \ln L
\]  

(5)

where \(\nabla NIC\equiv(K_{NIC}/K)\) and \(\nabla IT\equiv(K_{IT}/K)\), which are the share of national intellectual and IT capital in the total capital stock. Then, the forms for TFP and labor productivity can be written as

\[
\ln TFP\equiv \ln T + \alpha \ln (1+\phi_1 \nabla NIC+\phi_2 \nabla IT
\]  

(6)

\[
\ln (Y/L)\equiv \ln T + \alpha \ln (K/L) + \alpha \ln (1 + \phi_1 \nabla NIC + \phi_2 \nabla IT)
\]  

(7)

Eq. (6) represents the increase of national intellectual intensity (\(\nabla NIC\)) and IT intensity (\(\nabla IT\)) that would be expected to increase the TFP as long as \(\alpha>0\) and \(\phi_1+\phi_2\geq 1\). The national intellectual and IT capital may contribute to the technical progress directly, because they are more productive than other types of

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² The concepts of spillover and externality may be different aspects of one phenomenon in that spillover focuses on the physical aspect of the unpaid side effects of producers’ or consumers’ actions whereas externality focuses on the price-distortion effects.
factor inputs. Regarding the productivity issue, labor productivity may be discussed rather than TFP. Eq. (7) describes the dependence of labor productivity on overall per capita capital input \((K/L)\) and the share of national intellectual and IT capital in the total capital stock. In this sense, labor productivity would not decrease as long as national intellectual capital and IT capital deepen, but there is no necessity for TFP to rise. Although high gross investment is likely to be offset by the rapid depreciation of IT, the increase in the productivity of these types of capital would probably offset, or more than offset, the diminishing marginal returns to other physical capital per capita.

This may be true in the case of the rapidly increasing stock of IT capital, but the growth of the stock of other capital has been sluggish. The rapid diffusion of IT has led to a continuing decline in its price and that of related equipment, which, in turn, has led to a continuing substitution of IT equipment for other forms of capital and labor. In addition, national intellectual capital enables both the creation of new goods and services and the exploitation of new technologies to improve products and processes. Thus, every additional unit of national intellectual capital that is used effectively results in a marginal increase in productivity. In particular, computers and related equipment in the IT industries have been much indebted for the application of intellectual activities. The increase in national intellectual capital and IT capital will probably offset diminishing marginal returns to physical capital per capita. Thus, investment in both national intellectual and IT capital may be the right way to boost productivity growth.

4. Empirical Framework

This section includes a discussion of growth accounting, sources of product growth, and R&D investment and TFP.

4.1. Growth Accounting

In order to investigate the role of IT capital in overall economic growth, we begin our analysis with the neoclassical growth accounting framework.\(^3\) Thus, the

\(^3\) The neoclassical growth accounting expression used here was pioneered by Edward Denison [1985] and is the same as that used in Oliner and Sichel [1994, 2000], Sichel [1997, 1999], and Schreyer [2000].
growth rate of the output in Eq. (1) can be expressed as

\[ \triangle \ln Y = S_L \triangle \ln L + S_{IT} \triangle \ln K_{IT} + S_{OT} \triangle \ln K_{OT} + \triangle \ln TFP \] (8)

where \( S_L \) indicates labor income shares, \( S_{IT} \) is IT capital income share, and \( S_{OT} \) is other capital (non-IT capital) income share, respectively. The term \( S_L \triangle \ln L \) is the growth contribution of aggregate labor input, \( S_{IT} \triangle \ln K_{IT} \) is the contribution of IT capital input, \( S_{OT} \triangle \ln K_{OT} \) is the contribution of all other types of capital other than IT capital, and TFP is the growth contribution of total factor productivity. The total factor productivity term identifies the portion of output growth after accounting for the growth of capital and labor. It reflects the technological or organizational improvements of the efficiency in translating input into output.

The contribution of IT capital depends critically on the income share, \( S_{IT} \), which is unobservable. To compute \( S_{IT} \), the present study follows the method used by the U.S. Bureau of Labor Statistics (BLS) to calculate income shares for other types of capital.\(^4\) With this procedure, the income share for IT capital is

\[ S_{IT} = (i + \delta_{IT} - P^*_{IT})P_{IT}K_{IT} / PY \] (9)

where \( i \) is a measure of the nominal rate of return common to all types of capital, \( \delta_{IT} \) is the depreciation rate on IT capital, and \( P_{IT} \) is the price index for IT capital and its rate of change, \( P^*_{IT} \). The term \( P_{IT}K_{IT} \) represents the nominal capital stock, and \( PY \) represents the total nominal output or income. TFP reflects the change in output that cannot be accounted for by the change in combined inputs. As a result, TFP measures reflect the joint effects of many factors including new technology, economies of scale, managerial skills, and changes in the organization of production. If the performance of TFP improves over time, it could be interpreted as a sign of an additional growth contribution from IT; but the rise of TFP growth is neither a necessary nor a sufficient condition to show positive externalities of IT capital, because many factors influence TFP growth and can compensate for positive effects from IT.

The key assumption underlying the neoclassical approach, however, encounters several potential difficulties regarding implementation of the theory. First, the total input is characterized by constant returns to scale. Second, businesses always make optimal investment decisions, and all types of capital

\(^4\) In contrast to the BLS, the present study omits tax terms, for the purposes of simplicity.
earn the same competitive rate of return at the margin. Third, the absence of externality eliminates any potential division between private and social marginal products. Introducing additional production factors or allowing for quality changes in factor inputs often extends this standard growth accounting approach. The critical weakness of this method, however, is its dependence on factor income shares, which are not only directly observable, but also difficult to measure.

4.2. Sources of Productivity Growth

One way to overcome this problem is to use growth regression, which allows one to estimate the output elasticities of the factors directly from the regression of the production function, instead of calculating them from factor income shares. Now, the production function of Eq. (1) can be extended by introducing other input factors in addition to labor and three types of capital by allowing for quality changes in the inputs. We control the national intellectual and IT capital inputs that have an important bearing on the source of productivity growth. Thus, the production function of Eq. (1) can be written as

\[ Y = F(L_h, L_q, K_{IT}, K_{NIC}, K_{OT}, B, TFP) \] (10)

where the labor input is decomposed into labor hours \(L_h\) and labor qualities \(L_q\) to reflect changes in working hours and the qualities of labor such as experience, gender, and the education mixture of the workforce. Introducing labor quality as a production factor also brings the growth model, which relies on the high output elasticities of reproducible capital, more in accordance with the income distribution. Capital input is also decomposed into national intellectual capital \(K_{NIC}\), IT capital \(K_{IT}\), and all other types of capital \(K_{OT}\). In addition, the indicator of the business cycle \(B\) reflecting the factor utilization was introduced into the production function to correct for inefficiencies associated with productivity growth and the business cycle. The business cycles not only capture the repeated expansion and contraction around the sustained trends of the macroeconomic variables (i.e., GDP, consumption, investment, employment, export, and import) but also imply their simultaneous movements. Finally, \(TFP\) is included in order to examine the presence of the externalities generated by IT, intellectual activities, and the overall rate of technical change.

To examine labor productivity for national intellectual capital, IT capital, and other types of capital, Eq. (10) can be transformed to the growth rate by dividing
the growth rate of the total hours worked out on both sides of the equation, then
\[ \ln(\frac{\Delta Y}{L_{h}}) = F[\ln(\frac{\Delta L_{q,t}}{L_{h}}), \ln(\frac{\Delta L_{IT,t}}{L_{h}}), \ln(\frac{\Delta L_{OT,t}}{L_{h}}), \ln(\frac{\Delta L_{NIC,t}}{L_{h}}), \ln(TFP), e] \] (11)
where \( e \) is the error term.\(^5\)

4.3. R&D Investment and TFP

The relationship between R&D investment and productivity growth has been a subject of considerable interest in economics literature, as well as to policy analysts.\(^6\) In general, the producer of a technology benefits not only from its R&D effort but also from technology spillovers. IT itself is thus both a result of continuous innovation and a source of further innovation in the other areas of production in that sector. To analyze the relationship between innovation and the diffusion of innovation and growth, we now examine the effect of R&D investment on TFP.

The analytical tool often used to link productivity growth to R&D is usually based on a Cobb–Douglas production function that includes the stock of R&D capital as a separable factor of production [Nadiri, 1993]. Another way of saying this is that R&D can be used as an explanatory variable of the TFP. As discussed in the previous section, the “standard” TFP can be measured in terms of the quality-adjusted labor and capital in the views of the Solow residual. Although a measure of TFP that controls for human capital would be more appropriate in this context, a cruder measure is used here because some appropriate data are available. On the assumption of the constant returns to the scale with respect to conventional inputs, equilibrium in input and output markets, and a zero depreciation rate of the R&D capital stock, TFP is related to the R&D expenditure by

\[ \ln(TFP) = F[(R&D/Y), (IT/non-IT)] \] (12)

where \( Y \) is output, and the ratio of IT to non-IT capital is included to examine whether IT contributes to GDP growth by the increase in FTP growth or by the capital depth. Although several econometric and estimation issues are involved in these estimates, the discussion in Section 5 touches only the brief results that have

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\(^5\) This labor-intensive form may also reduce the problems of heteroscedasticity and multicollinearity.

\(^6\) For recent studies, see Los and Verspagen [2000], Bassanini et al. [2000], and Greenam et al. [2001].
emerged from this line of research.

5. **Empirical Results**

The empirical investigation used data for the years of 1971 through 2003. Most of the data, except for the capital stock, were directly obtained from *National Account* and the *Economic Statistics Yearbook*, both published by the Bank of Korea, and the *Korea Statistical Yearbook*, published by the Korea National Statistical Office. The capital stocks were taken from Pyo [1998], in spite of some criticisms of these data, because they were estimated by both the perpetual inventory method and the polynomial-benchmark method, using the National Wealth Survey for the years of 1968, 1977, and 1987, together with the total fixed capital formation from the National Accounts. Because these data provided only the estimated capital stocks for 28 sub-sector industries in manufacturing industries and of 10 major sector industries for the other industries, net IT capital stocks were approximately constructed by multiplying the net capital stock of the major or sub-sector industries in terms of the tangible fixed asset ratios that related to the IT industry from the *Enterprise Business Analysis*, published by the Bank of Korea, and the *Report on Mining and Manufacturing Survey*, from the Korea National Statistical Office. The number of intellectual properties (patents, utility models, designs, and trademarks) multiplied by its registration and maintenance fee was used as a proxy for the intellectual capital stock. Data on intellectual properties and fees were available in the *Major Statistics of Intellectual Property*, published by the Korea Intellectual Property Office. The labor income share was directly obtained from the *Korea Statistical Yearbook*. The growth rate of output, the interest rate, and the producer price

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7 The data set in Pyo was criticized because of the use of a constant depreciation rate between benchmark years and the use of the inconsistent National Wealth Survey, in which data for the 1970s and 1980s have different trends. Because the data for net capital stocks were provided in Pyo only for the period 1970–96, the present study extended the data through 2003 using the perpetual inventory method.

8 In growth accounting, although “productive” capital stocks may be a more appropriate measure than net capital stock, for the present study, the net capital stock for IT capital was used because the data were available. See Oliner and Sichel [2000].

9 Where the intellectual properties include patents, utility models, designs, and trademarks.
index at the 1995 constant price were taken from the *Economic Statistics Yearbook*.

To reflect changes in working hours and quality of labor, the number of workers was multiplied by the working hour index and the economy-wide labor quality index in Hong and Kim [1996].

The *Report on Monthly Labor Survey*, published by the Ministry of Labor, provided the number of workers, labor hours, and average monthly earnings. For business cycle indicators, the average value of the capital and labor utilization was used. The index of manufacturing operation ratios, taken from the *Manufacturing Production Capacity and Operation Ratio Survey* published by the Korea National Statistical Office, and the one-minus (1–) unemployment rate were used for the capital and labor utilization, respectively.

### 5.1 Contributions to Output Growth

The contribution of each input to output growth was calculated on the basis of the standard growth accounting framework. Table 1 shows the decomposition of the growth of the real output. For the calculation of the income share of IT capital, the short-term interest rate (the interest rate on loans for up to one year of general funds for general enterprises) was used as a measure of the nominal rate of the return common to all capitals. Data for the depreciation rate of IT capital stock were from Pyo [1998], where 13.1% was used for the period 1970-1977, 14.2% for 1977-1987, and 22.4% for 1988-2003.

The price index of IT capital was approximately measured as a weighted average value from the producer price index indexes of major IT industries. To examine the effect of the business

10 Because the data were provided only during 1992, all the necessary series were extended to 2003.
11 Up to the year of 2000, the Korean economy had experienced six business cycles. At the end of 2000, it was in its seventh cycle. See *Korean Economic Trend* [Seoul: Samsung Economic Research Institute, December 2000].
12 The depreciation rates in Pyo [1998] were estimated at 13.1% during 1970-1977 and 14.2% for the period 1978-1987. These rates are somewhat smaller than Shin's [2000] study, where the estimated rate was 22.4%. For the period 1988-2003, the present study uses 22.4% depreciation rate.
13 The weighted average values of the producer price indexes come from five IT-related sectors, including electronic motors-electronic generators-electronic transformers, insulated wires and cables, electronic valve and tube components, communication equipment and apparatuses, and TV-radio-sound and video recording and reproduction apparatuses. The weight, on a scale of 1 through 5, was based on the number of items in each sector.
cycle, the growth accounting model was allowed for the factor utilization. The contribution of each input to growth was computed on a year-by-year basis, and then the annual figures were averaged to measure contributions over longer time spans. In Table 1, the first row shows the growth rate of output, and rows between two and six outline this growth rate among the contributions from the five inputs: labor, other capital, IT capital, the business cycle, and TFP. The last row explains the only trend of TFP of manufacturing industries.

<table>
<thead>
<tr>
<th>Table 1. Contributions to Output Growth (Unit: %)</th>
<th>1971-80</th>
<th>1981-90</th>
<th>1991-95</th>
<th>1996-00</th>
<th>2001-03</th>
<th>1971-03</th>
</tr>
</thead>
<tbody>
<tr>
<td>Growth Rate of Output</td>
<td>7.30&lt;100.0&gt;</td>
<td>8.74&lt;100.0&gt;</td>
<td>7.82&lt;100.0&gt;</td>
<td>4.56&lt;100.0&gt;</td>
<td>4.63&lt;100.0&gt;</td>
<td>6.96&lt;100.0&gt;</td>
</tr>
<tr>
<td>Contributions from Labor</td>
<td>1.47&lt;20.1&gt;</td>
<td>1.14&lt;13.0&gt;</td>
<td>-0.20&lt;--2.6&gt;</td>
<td>-0.10&lt;--2.1&gt;</td>
<td>-0.15&lt;--3.3&gt;</td>
<td>0.64&lt;9.2&gt;</td>
</tr>
<tr>
<td>Other Capital</td>
<td>6.26&lt;85.8&gt;</td>
<td>3.53&lt;40.4&gt;</td>
<td>3.58&lt;45.8&gt;</td>
<td>1.07&lt;43.2&gt;</td>
<td>1.93&lt;41.7&gt;</td>
<td>3.49&lt;50.1&gt;</td>
</tr>
<tr>
<td>IT Capital</td>
<td>0.91&lt;12.5&gt;</td>
<td>1.24&lt;14.2&gt;</td>
<td>2.01&lt;25.7&gt;</td>
<td>1.29&lt;28.3&gt;</td>
<td>1.63&lt;35.1&gt;</td>
<td>1.42&lt;20.4&gt;</td>
</tr>
<tr>
<td>Business Cycle</td>
<td>1.01&lt;13.8&gt;</td>
<td>0.70&lt;8.0&gt;</td>
<td>0.69&lt;8.8&gt;</td>
<td>0.15&lt;3.2&gt;</td>
<td>-0.11&lt;--2.3&gt;</td>
<td>0.33&lt;4.7&gt;</td>
</tr>
<tr>
<td>TFP</td>
<td>-2.35&lt;--32.2&gt;</td>
<td>2.13&lt;24.4&gt;</td>
<td>1.74&lt;22.3&gt;</td>
<td>1.25&lt;27.4&gt;</td>
<td>1.33&lt;28.8&gt;</td>
<td>1.08&lt;15.6&gt;</td>
</tr>
</tbody>
</table>

Note: Figures in angle brackets <> are the weights in the output growth.
*The number did not allow for the business cycle. IT = information technology; TFP = total factor productivity.

The full sample period was divided into five shorter periods -- 1971-80, 1981-90, 1991-95, 1996-2000, and 2001-2003 -- to highlight the separate phases of economic growth. The first two columns cover 1971-80 and 1981-90, and the early stages of IT industrialization. During those two periods, the output grew on average 7.3% and 8.7% per year, respectively. Labor accounted for about 20.1% and 13.0% of the growth, whereas the contribution to other types of capital was

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14 This effect can be accommodated by assuming that the rate of factor utilization differs depending on the business cycle; thus, Eq. (1) will be \( Y = T (\tau L)^{\alpha} (\lambda K_{OT})^{\beta} (\lambda K_{IT})^{(\alpha + \beta)} \). After taking logs and rearrangement, the output growth will be given by \( \Delta Y = \Delta Y + \theta L + \alpha \Delta L + \beta \Delta K_{IT} + (1 - (\alpha + \beta)) \Delta K_{OT} \), where \( \tau \) is the rate of labor utilization, \( \lambda \) the rate of the capital utilization, on the assumption that IT and other capital are the same, and the last term reflects the indicator of the business cycle.
much larger, about 85.8% and 40.4%, respectively. In 1971-80, the contribution to output growth of IT capital was modest, accounting for 12.5% of the output growth rate. Then, this rate increased slightly to 14.2% in the 1980s, whereas other capital made a much larger contribution of 40.4%. Put another way, the contribution of non-IT capital to output growth was more than twice that of IT capital. Such calculations were based on the claim that IT capital had fairly contributed to the growth rate of the output in Korea during 1970s and 1980s, although the ratio of the IT to non-IT capital was less than 1%.15

On the other hand, TFP accounted for –32.2% of the output growth in 1971-80, which may reflect the great eagerness for industrialization characteristic of this period in Korea. The Korean government provided massive investment to build up the heavy and chemical industries with a huge inflow of oil dollars in the mid-1970s, which brought a rapid build-up of capital. This rapid accumulation of capital stock distorted prices and led to technological backwardness, as well as to allocation inefficiencies in the Korean economy [Yuhn and Kwon, 2000]. Thus, the inefficiencies in the Korean economy increasingly became evident during this period so that the minus growth of TFP is not surprising. This observation implies that much of the economic growth during the 1970s in Korea was attributable to the growth of the factor inputs, rather than to the technological progress. Because the government’s huge investment in the heavy and chemical industries in the 1970s was accompanied by the great inefficiency in the industries, in the early of 1980s, the government carried out its policy with a program of structural reform of the industry.

In the same period, output growth noticeably increased simultaneously with a mild inflation rate. This combination might have affected the growth rate of TFP, which recovered to 24.4% of the output growth in the 1980s. During the 1970s and 1980s, the business cycle accounted for 13.9% and 8.0%, respectively, of the output growth. The figure for the 1970s is a little bigger than that of IT capital, but its contribution rate decreased to 8.0% in the 1980s. This figure implies that the accumulation of IT capital was extremely small in the 1970s, but in the 1980s, when the accumulation of IT capital increased, its contribution to output growth also increased while that of the business cycle decreased.

15 The data show that the ratio of IT to non-IT capital stock was 0.3% in 1970, 0.7% in 1980, and 6.1% in 2000.
In the first half of the 1990s, the situation differed little from that of the early stages. The average growth rate of output dropped to 7.8%, which was less than about 1% annually that of the previous period. Non-IT capital stayed around 3.6%, and IT capital increased to 2.0%, accounting for about 25.7% of output growth. The growth contribution of IT capital amounted to about half of the entire growth contribution of other types of capital. At the same time, the TFP growth rate dropped to 1.7%. In contrast to the earlier stages, the first half of the 1990s was characterized as less selective, with more liberal industrial policies and an increased role for the big business group, known as jaebol, in the resource allocation. The civilian government at this time began to emphasize economic growth, rather than stabilization, whereas the big business group promoted over-capitalization and overlapping in several major industries, which led to technological inefficiencies. Nevertheless, the contribution of IT capital to output growth was significant and has been rising.

In the second half of the 1990s (1996-2000), the average growth rate of output dropped even more, to about 4.5% per year. The contribution of labor input to output growth also decreased to -0.1%, accounting for -2.1% of the total growth rate, whereas non-IT capital grew on average 1.1%, accounting for 43.2% of the output growth. However, the contribution from IT capital to output growth also increased during this period. The contribution from IT capital jumped to 28.3% of output growth. These relatively larger contributions since the mid-1990s may reflect faster growth in the real stock of IT equipment in comparison with the average pace before 1995, and the increased importance of IT capital in the economy. Also since the mid-1990s, the contribution from TFP to output growth increased to 27.4%, while the growth rate of output was increased by the business cycle to only 3.2%. In comparison to the previous period, TFP did not increase so much but, rather, it was stable, probably because the environment in which the policy of the structural reform introduced did not adequately support the anticipated improvements. In particular, although the Korean government had announced various programs of economic reform including the liberalization policy since the financial crisis late in 1997, none of them had been completed. Furthermore, increased competition owing to the beginning of economic liberalization did not appear improve the innovative capacity or productivity of either firm.
In 2001-2003, the contribution of labor capital to output growth showed –3.3%, whereas the contribution from IT capital to output growth increased to 35.1%. Also the contribution of TFP increased to 28.8%, whereas the growth rate of output was perturbed by the business cycle to –2.3%.

The last column of the table shows the growth rate of each element for the entire period 1971-2003. Output grew 6.9% per year. The average contribution of labor input to output growth was about 9.2%. Other capital and IT capital were important sources of the economic growth, accounting for 50.1% and 20.4%, respectively, whereas the business cycle accounted for 4.7% and TFP accounted for the remaining 15.6%. Although TFP accounted for about 15.6% of the output growth, if there were no business cycle effect, the average annual growth rate of TFP during this period would have been about 1.41%. This growth rate was relatively low, which was similar to the average rate without the effect of the business cycle during 1996-2003, and this was fairly stable. Much of this output growth may, therefore, have been due to the growth of factor input rather than to actual technical progress.

In addition, although the TFP growth rate was slightly increased since the second half of the 1990s, the picture of TFP growth is subtly different from the growth output. Most of the slowdown in output growth in the 1990s can be attributed to a collapse in TFP growth, but the smaller increase of 0.08% in TFP growth during the period 2001-03 seems to be due to the increase in the growth of IT capital inputs. Although the neoclassical model used here does not attribute the pickup in TFP growth to IT, many earlier studies have suggested that the rapid spread of IT has played an important role in the improved performance of TFP since 1996 [see Oliner and Sichel, 2000; Jorgenson and Stiroh, 2000; and the U.S. Department of Commerce, 2000. Finally, the average growth rate of TFP in the manufacturing industries was 3.0% between 1971 and 2003, which was similar to what was found in earlier studies [see Yuhn and Kwon, 2000; Roberts, 2000; Cho and Bae, 2000; and Cho, 2000].

5.2. Sources of Productivity Growth

This section presents the estimated results of the sources of productivity growth in the long run. The log-linear forms were estimated by the ordinary least-square method on the basis of Eqs. (11) and (12). Table 2 shows the results of both the standard and the extended growth models, which explain the results of
labor productivity growth and TFP. Surprisingly, the results yield a quite reasonable estimate of the elasticity of productivity with respect to capitals although the R-squares are between 0.31 and 0.39. The first row in the table represents labor productivity from the standard growth model, which is assumed to be constant returns to the scale of the exogenous technical change. The second equation includes the changes of the factor utilization as an indicator of the business cycle. These results give a quite reasonable estimate of the elasticity of productivity growth with respect to both capital intensity and changes of factor utilization. In particular, the coefficient of the business cycle indicator is highly significant, reflecting that the change of the factor utilization is an important determinant of productivity growth. Its inclusion reduces not only the standard errors of the coefficient of capital intensity but also the problem of the omitted variables.

The next three rows show the results of the extended growth model. In general, a time series analysis gives pure results for the long-run trend of labor productivity growth. The result, however, is relatively reasonable for the explanatory variables in the equation, which provide valuable insights into the productivity analysis even though their explanatory power is low. Labor quality was included as an explanatory variable that might reflect the importance of human capital. Although the coefficient tended to be insignificantly different from zero, the result indicated that labor quality had a positive effect on productivity growth as a physical capital. Thus, in the long run, the productivity growth of more highly qualified workers will be higher. Although Korea lacks natural resources, its productivity growth is indebted to the improvement in the quality of labor. Its excellent human resources are well known as one of the strong points of Korea’s economy.
The estimated average coefficients of IT and other (non-IT) capital intensity, 0.03 and 0.35, respectively, are statistically significant. The small coefficient of IT capital intensity can be explained by two hypotheses. The first is the hypothesis of capital stock, which reflects the fact that IT capital remains as a relatively small share of total capital stock because of the short period of IT investment. In the United States, investment in IT industries has been steady since the 1970s. Korea, on the other hand, began to build the underpinnings of IT industries only in the mid-1990s. This later start has made for a relatively small capital accumulation for these industries, and the effects of IT investment seem to appear in the late 1990s. As mentioned in Section 5.1., the ratio of IT to non-IT capital stock was only 6.1% in the year 2000. The second is the hypothesis of long learning lags. According to this hypothesis, new technologies gradually diffuse because a long period is needed to learn how to use new resources. Further, truly revolutionary applications such as IT applications often require a major reorganization of

Table 2. Estimates of Productivity Growth and TFP

<table>
<thead>
<tr>
<th>$\Delta \ln (K/L)_t$</th>
<th>$\Delta \ln B_t$</th>
<th>$R^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.327 (1.99)</td>
<td>-</td>
<td>0.31</td>
</tr>
<tr>
<td>0.316 (2.11)</td>
<td>0.052 (3.45)</td>
<td>0.33</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>$\Delta \ln (Y/L)_t$</th>
<th>$\Delta \ln (K_{IT}/L)_t$</th>
<th>$\Delta \ln (K_{IT}/L)_t$</th>
<th>$\Delta \ln K_{NGC}$</th>
<th>$\Delta \ln B_t$</th>
<th>$\Delta \ln TFP_t$</th>
<th>$R^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.087 (1.14)</td>
<td>0.027 (1.24)</td>
<td>0.354 (2.12)</td>
<td>0.016 (1.21)</td>
<td>0.058 (3.46)</td>
<td>-</td>
<td>0.38</td>
</tr>
<tr>
<td>0.077 (1.25)</td>
<td>-</td>
<td>0.375 (2.23)</td>
<td>0.018 (1.571)</td>
<td>0.059 (3.37)</td>
<td>0.001 (1.11)</td>
<td>0.39</td>
</tr>
<tr>
<td>0.084 (1.22)</td>
<td>0.026 (1.98)</td>
<td>0.363 (2.62)</td>
<td>-</td>
<td>0.048 (2.42)</td>
<td>0.002 (1.18)</td>
<td>0.37</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>$\Delta \ln (R&amp;D/Y)$</th>
<th>$\Delta \ln (IT/non-IT)$</th>
<th>$R^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.281 (2.70)</td>
<td>-</td>
<td>0.32</td>
</tr>
<tr>
<td>0.259 (1.67)</td>
<td>0.0061</td>
<td>0.34</td>
</tr>
</tbody>
</table>

Note: Figures in parentheses are $t$-statistics.
production, which may take a long time to occur. If these hypotheses are correct, it will take a long time to reap the benefits of the effects of the productivity growth.

The estimation results of national intellectual capital, however, are unsatisfactory, indicating coefficients of fairly small magnitudes averaging 0.017 (not significant), even though they provide positive signs. This result reflects the continuing weakness of the knowledge base in Korea. The number of patent applications remains half that of advanced countries, and the number of published theses is only one-fifth that of those countries. In addition, because the capacity to organize the knowledge-based activities of economic bodies remains weak, the Korean economy has not made effective use of its national intellectual capital to improve productivity growth. Furthermore, some of Korea’s newly created and learned knowledge remains unused and, therefore, has not contributed to the creation of high-value-added industry areas.

The business cycle also is an important determinant in both the long and short run, and it significantly affects productivity growth in Korea. The estimated average coefficient is about 0.05, and that is statistically significant. This magnitude is fairly large in comparison with other factors such as IT and national intellectual capital in productivity growth. From this result, it can be considered that economic activity and productivity growth are complementary; hence, economic expansion will increase productivity in the long run. Since the 1970s, when statistics on business cycles were first collected, the Korean economy has experienced six business cycles. Consequently, all economic aspects have been greatly affected by changes in the external environment. The results seem to support the analysis of the growth contribution discussed in the previous section.

The fourth and fifth equations include TFP variables to examine the long-run externality effect on the productivity growth. The estimated results show positive effects, but that is statistically insignificant. Since the variable TFP is not measured as the logarithm of the number of establishments because several values take negative, the logarithm of the number plus 1 was used. This alternative estimate did not yield a more or better significant result.
Finally, the last two equations were estimated in terms of the relationship between TFP and the ratio of R&D to output and the ratio of IT to non-IT capital. Although there are a number of econometric and estimation issues concerning these estimates, the result suggests a positive and strong relationship between TFP and R&D investment, accounting for a 27% rate of return. This result may give a prediction that the decrease of R&D investment in Korea during the 1990s has had a major impact on the slowdown of TFP. The ratio of the IT to no-IT capital variable is positive, but statistically insignificant. This result may support that the contribution of IT to GDP growth come from the deepening IT capital rather than the increase of the TFP growth.

6. Concluding Remarks

Over the last 25 years, advanced countries have increasingly become knowledge-based economies. The production, dissemination, and use of knowledge have become crucial factors for enhancing economic growth, job creation, competitiveness, and welfare. National intellectual capital can be both the end result of a knowledge transformation process or the knowledge itself that is transformed into intellectual property or intellectual assets of the nation. The transition of most developing and developed nations to knowledge-based economies has resulted in an increasing awareness of national intellectual capital as a key factor for the economic growth and performance.

This study has discussed the framework for the role and impact of national intellectual and IT capital on economic growth and productivity, and provided an illustrative case study of Korea that has applied this assessment method. Our findings show that national intellectual and IT capital are important factors for economic performance in Korea. In particular, R&D investment was one of the important factors fostering intellectual capital and creating wealth. From these investigations, the study suggests several policy implications for the Korean

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17 Since the performance of TFP have positive effects over time, this might be interpreted as the sign of additional productivity growth from IT and national intellectual capital. However, this remains only a possibility because a rise in TFP growth is neither a necessary nor a sufficient condition to show positive externalities of IT and national intellectual capital.
First, the Korean government needs to build a knowledge-based industrial structure, which would help the private sector to create and use knowledge. Without building such a structure, Korea may regress to the status of an underdeveloped country.

Second, the role of the government will need to change to allow market principles to function more efficiently. In recognizing the importance of national intellectual capital suggested here, Korea should establish itself as a knowledge-based economy. In this way, Korean knowledge-based industries will receive another important boost, which in turn will lead to both economic growth and productivity growth.

Third, the Korean government will need to increase its economic immunity in order to stabilize the economy in the face of external factors such as changes in the exchange rate and global demand for domestic goods and services. To promote its knowledge-based industries, the government will need to develop a strong domestic consumption market.

Last, promising new IT-related industries suitable to Korea need to be established. For this purpose, the focus of investment will need to be on industries that represent the "digital era," for example, semiconductors, digital home appliances, telecommunications, and e-commerce. Furthermore, in order to encourage talented individuals to participate in creative research activities, social and government support systems will be needed as part of a continued exploration of these new fields.

At the turn to the 21st century, Korea faces new challenges. Already, it has lost its comparative advantages in labor-intensive industries to newly emerging countries. In order to survive in the global market, Korea clearly must develop comparative advantages in intellectual capital-intensive industries with the increase of R&D investment.

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