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Knowledge Capital in Economic Growth: A Panel Analysis of 120 Countries[*]

Dong-Geon Lim[**], Jin Hwa Jung[***]

Abstract This paper approaches knowledge capital as social infrastructure and analyzes its impact on economic growth. To this end, we constructed a panel dataset for 120 countries for the years 2000-2014 and estimated the economic growth function using the panel analysis. As proxies for knowledge capital, we used the R&D expenditure per capita and the number of patent applications per thousand people in each country, both measured in stock. Economic growth was measured in terms of real GDP per capita and real value added per capita at the industry level. The empirical findings demonstrate that knowledge capital accumulated in a society significantly promotes economic growth. Especially R&D stock increases real value added per capita in all industries-not only manufacturing, but also services and agriculture-implying substantial inter-industry spillover effects. The findings of this study suggest that knowledge capital boosts economic growth as core social infrastructure.

Keywords Knowledge capital, social infrastructure, economic growth, spillover effect, panel analysis

I. Introduction

With the unprecedented speed of advances in technology, characterized by the Fourth Industrial Revolution, increasing attention has been paid to the role of knowledge capital in economic growth. Knowledge capital can be perceived as core social infrastructure in that its accumulation lowers fixed cost of production and its benefits spread over the entire economy. Furthermore, traditional infrastructure, such as paved road and electricity, has

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[**] Department of Agricultural Economics and Rural Development, Seoul National University, 1 Gwanak-ro, Gwan-ak Gu, Seoul, Korea; cu8907@snu.ac.kr

[***] Corresponding, Department of Agriculture Economics and Rural Development, Research Institute for Agriculture and Life Sciences, Seoul National University, 1 Gwanak-ro, Gwan-ak Gu, Seoul, Korea; jhjung@snu.ac.kr

reached saturation in many countries, rarefying its function as social infrastructure. In this context, the present paper focuses on the role of knowledge capital as social infrastructure in economic growth.

Knowledge capital is an intangible asset, representing the technological capability of the state. Therefore, many previous studies have used R&D expenditures and/or the number of patent applications as proxy variables for knowledge capital. While R&D investment is a key input factor to form knowledge capital, the number of patent applications is the representative output variable obtained from the use of knowledge capital.

In this study, we applied the panel analysis to investigate how knowledge capital affects economic growth, whereas knowledge capital was defined as the stock of R&D investment and the number of filed patents.[1] For the economic growth model, we extended the concept of social infrastructure in the endogenous growth model proposed by Romer (1987) and Bougheas et al. (2000). For the empirical analysis, to estimate the effects of knowledge capital on real GDP per capita and real value added per capita of different industries, we adopted the economic growth model of Levine and Renelt (1992). For the data, we collected national macro data from various international organizations. By doing so, we constructed the panel dataset for 120 countries in the world for the period from 2000 to 2014. To control for the two-way causality problem, we set the time lag between the dependent variables and the explanatory variables.

The major contribution of this paper is that it explicitly considers knowledge capital as social infrastructure in the era of rapid technological change and empirically investigates how it affects economic growth using the worldwide panel data. We constructed the panel data for the national-level knowledge capital for over one-hundred countries for most recent years; we measured the stock variables to reflect the nature of knowledge capital as social infrastructure. Furthermore, to investigate if knowledge capital-social infrastructure nexus differs by industry and how inter-industry spillover effects work, we conducted a comparative analysis of the role of knowledge capital in economic growth for different industries.

The remainder of this paper is organized as follows. Section II overviews the trend of global economic growth and accumulation of knowledge capital. Section III provides a theoretical underpinning and related literature for the nexus between knowledge capital and economic growth. Section IV explains

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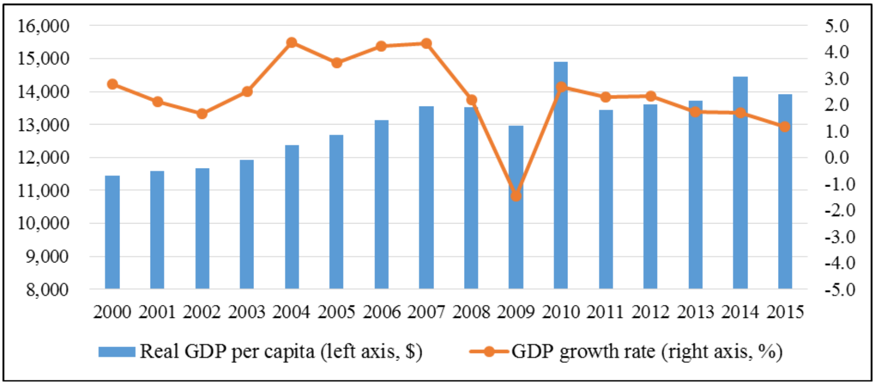
[1] The measurement of R&D investment varies across studies. In this paper, we used the data of R&D expenditure from UNESCO. R&D expenditure in this dataset encompasses both public and private sectors; it reflects substantial R&D investment that increases knowledge capital, including expenditures in human resources, new product development, technology development, and basic research, etc.

the empirical model and the data used in this study, while Section V reports the empirical results. Section VI concludes the paper.

II. Trend of Economic Growth and Knowledge Capital

The world's economic growth has been unprecedentedly promoted by the IT revolution in the 1990s and the continuing technology development afterward; however, it has also been suppressed by the collapse of the IT bubble and the global financial crisis. As illustrated in Figure 1, the average real GDP per capita in the world amounted to $13,908 in 2015, which is 21.5% higher than $11,449 in 2000. Then, real GDP per capita fell sharply due to the collapse of the IT bubble and the outbreak of the global financial crisis in the early 2000s and 2009, respectively. The growth rate of real GDP per capita bounced back in 2010, but has been steadily declining in recent years.



Source: World Bank, *National Account Data*, 2016.

Figure 1 The trend of real GDP per capita growth (world average)

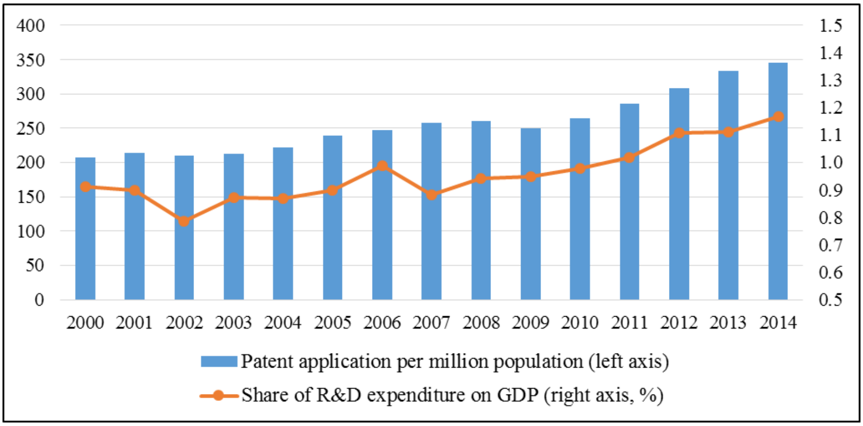
Table 1 reports the trend of real value added per capita for different countries from 2000 onwards. The level of real value added per capita was kept far higher in the service sector than in manufacturing, with agriculture being the lowest. The real value added per capita in service industries has significantly increased, while the growth of manufacturing has been less substantial for the period of 2000-2015. For agriculture, the economic growth has stagnated throughout all observed years.

Table 1 The real value added and annual growth rate: sectoral comparison

	Manufacturing		Services		Agriculture	
	Value added ($)	Annual growth rate (%)	Value added ($)	Annual growth rate (%)	Value added ($)	Annual growth rate (%)
2000 (B)	1,512	4.5	6,716	4.3	391	1.7
2005	1,655	3.6	7,564	5.2	399	1.9
2010	1,609	5.6	8,286	4.4	388	1.6
2015 (A)	1,580	2.2	7,693	3.4	398	2.0
(A-B)/B×100 (%)	4.50		14.55		1.79	

Note: Total value added was divided by population, and real value is based on 2010 price.
Source: World Bank, *National Accounts Data*, 2016.

Along with the growth of the global economy, the accumulation of knowledge capital in each country has been actively carried out. Figure 2 shows the annual trend of R&D expenditure as a ratio of GDP and patent applications. The number of patent applications per million population has steadily increased, especially from 2010 onwards. The ratio of R&D expenditure in GDP has also grown, except for in 2002 and 2007.



Note: The patent applications are the sum of patent applications of residents and non-residents, following the definition of WIPO.
Source: World Intellectual Property Organization, 2016.

Figure 2 Accumulation of knowledge capital (world average)

III. Theoretical Background

1. Knowledge Capital as Social Infrastructure

Following earlier studies by Ayres (1953) and Arrow (1962), the effect of knowledge capital on economic growth has been widely discussed in the literature. For instance, Griliches (1992) noted that the spillover effect of knowledge capital is larger than that of other types of capital. Furthermore, Levin and Reiss (1984) argued that the accumulation of knowledge capital contributes to economic growth by improving the cost structure of national production. In this context, we can define knowledge capital as a new social infrastructure of the states.

Romer (1987) and Bougheas et al. (2000) provided the theoretical underpinning for the role of knowledge capital as social infrastructure in economic growth. According to Romer (1987), the degree of specialization reduces fixed costs of production and thereby increases national productivity. Extending this discussion, Bougheas et al. (2000) showed that social infrastructure increases the degree of specialization and thus promotes economic growth, while the enhancement of social infrastructure accelerates economic growth with the decreasing marginal effect.

According to Romer (1987), the degree of specialization is proportional to final output, as presented by the production function (see Eq. (1)).

$$Y(L,x) = L\int_{R+} g\left(\frac{x(i)}{L}\right) di \quad (1)$$

where Y is final output and L is labor input; x(i) is the amount of intermediate good i used. If function g is specified as power function, g(x)=x^α, with 0<α<1, Eq. (1) can be rewritten as Eq. (2).

$$Y(L,x) = L^{1-\alpha}\int_{R+} x(i)^{\alpha}\, di \quad (2)$$

Suppose that $x(i)$ is represented by the functions of M and N, which measure the range of intermediate good and the total quantity of intermediate good, respectively. Let $x(i) = \frac{N}{M}$ for $i \in [0, M]$. Then Eq. (2) can be rewritten as follows (see Eq. (3)):

$$Y(L,\{M,N\}) = M^{1-\alpha}(L^{1-\alpha}N^{\alpha}) \quad (3)$$

Assume that $x(i)$ is produced by initial input Z through an average cost function, $h,$ which is represented and ranged as Eq. (4). With this restriction, the feasible range of intermediate input is finite.

$$\int_{R+} h\big(x(i)\big)di \leq Z \quad (4)$$

In equilibrium and on a set of inputs i of length $M = Z(2-\alpha)$, intermediate good $x(i)$ has the following form (see Eq. (5)), with the assumption that $h(x) = \frac{1+x^2}{2}$:

$$x(i) = \bar{x} = \left(\frac{\alpha}{2-\alpha}\right)^{\frac{1}{2}} \quad (5)$$

Based on Romer's (1987) theoretical discussion outlined above, Bougheas et al. (2000) dynamically extended the model and added social infrastructure as an endogenous variable in the cost function. Specifically, they derived the equilibrium from long-run economic growth and social infrastructure that changes the average cost function, $h(x)$, as shown in Eq. (6).

$$h\left(x(i), \frac{G}{Y}\right) = \frac{C\left(\frac{G}{Y}\right)+x(i)^2}{2} \quad \forall i \qquad (6)$$

where G is government spending, which, in turn, produces social infrastructure. We can then derive Eq. (7) as an objective function for the government that maximizes the profit, given the price of intermediate good, $p(i),$ and proportional tax rate, τ.

$$\int_{R+}(1-\tau)x(i)^{\alpha}di - \int_{R+} p(i)x(i)di \quad (7)$$

By solving the maximization problem, we obtain the following solutions for $\bar{x},\ M,$ and R as functions of the policy parameter, τ (see Eq. (8)):

$$\bar{x} = \left(\frac{\alpha C(\tau)}{2-\alpha}\right)^{\frac{1}{2}}, \quad M = \frac{Z(2-\alpha)}{C(\tau)}\ , \quad R = (1-\tau)\alpha^2\left(\frac{\alpha C(\tau)}{2-\alpha}\right)^{\frac{\alpha-2}{2}} \quad (8)$$

where R is the unit price of the primary resource, measured in units of final output.

The balanced growth rate of the economy, r, is then derived as Eq. (9).[2]

$$\mathrm{r} \equiv [(1-\tau)\lambda f(\tau)^{1-\alpha}-\rho]\frac{1}{\sigma} \quad (9)$$

where $f(\tau)=\frac{G}{Y}$, $f'^{(\tau)} < 0$; σ is the parameter of the CES utility function, with $0 < \sigma < \infty$. Eq. (8) and (9) imply that social infrastructure enhances specialization and thereby promotes economic growth; however, there is an inverted-U relationship between the long-run growth rate and the stock of social infrastructure.

2. Knowledge Capital, R&D and Patent

Knowledge capital acts as an accelerator of innovation activities (Schumpeter, 1950; Arrow, 1962). Although there is no scholarly consensus on how to measure knowledge capital, most frequently used proxy variables for knowledge capital are R&D investment and patent application. R&D investment enhances the innovativeness of enterprises and nations, with the spillover effects larger than other types of investment (Jaffe, 1986; Benstein and Nadiri, 1988; Bernstein, 1989; Griliches, 1992; López-Pueyo et al., 2008; Pöschl et al., 2016). Patents also bring innovation outcomes through the emergence of new products and services, with the spillover effects (Heller and Eisenberg, 1998; Sakakibara and Branstetter, 2001; Allred and Park, 2007; Battke et al., 2016).

As for the effect of R&D investment on economic growth, Weiss (1965) demonstrated that R&D investment increases GNP per capita. Geol and Ram (1994) found the significant growth effect of R&D investment for the developed countries, but no significant effect for the less developed countries. Howitt (1999) argued that, due to the scale effect, the growth effect of R&D investment tends to be overestimated. Davidson and Segerton (1998) stated that, while government subsidies on R&D investment stimulate economic growth, the imitative subsidies to corporate R&D investment suppress economic growth. In addition, Griffith et al. (2004) emphasized technology transfer from the more to the less advanced countries, which enlarges the contribution of R&D investment at the technology frontier to the global economic growth.

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[2] To derive the relationship between the long-run growth rate and social infrastructure as shown in Eq. (9), we need to introduce dynamics into the model. For the full discussion, see Bougheas et al. (2000).

Fagerberg (1996) defined patent applications as innovation and analyzed them as a major factor of economic growth. In a similar fashion, Sakakibara and Branstetter (2001) investigated whether patent applications lead to technology innovation and economic growth and found out that patent applications have promoted economic growth in Japan. Of note, Allred and Park (2007) found that the higher the degree of patent protection, the higher economic growth is achieved.

Still, there is a paucity of research on the effect of knowledge capital on the industry level. Among the few relevant studies, Singh (2004) used R&D investment and intellectual property rights as proxy variables for knowledge capital; the author found that the accumulation of these factors increases the total factor productivity in manufacturing, not only in the industry where knowledge capital is accumulated, but also in all other industries, through the inter-sector technology transfer.

IV. Methodology and Data

1. Methods

The economic growth model used in the present paper draws on the Levine and Renelt's (1992) growth model that tested the robustness of the explanatory variables for long-term economic growth rate through the Extreme Bound Analysis (EBA).[3] In Levine and Renelt's (1992) study, the explanatory variables that proved to be robust are the ratio of total investment to GDP, the initial real GDP, and the enrollment rate in the secondary school in the initial year.[4]

As for the growth variables, we use real GDP per capita to measure the overall economic growth and real value added per capita in each industry for

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[3] Levine and Renelt (1992) tested the robustness of the explanatory variables with the Extreme Bound Analysis (EBA) proposed by Leamer (1983). This analysis sets the maximum range and the minimum range of the regression coefficients by setting the required variables (*i*-variable) and the test variables (*m*-variable). If the regression coefficient of the test variable deviates from this range, it is judged to be not robust. The explanatory variables they tested were fiscal policy indicator, international trade and price distortion indicator, and monetary and political indicators. The EBA method can be applied to the panel analysis as well as the cross-sectional analysis.

[4] Instead of the enrollment rate of secondary school, we use the enrollment rate of primary education (for basic human capital investment) and tertiary education (for high-level human capital investment). The correlation coefficient between these two human capital variables was 0.3.

economic growth on the industry level. The panel analysis is applied to the panel dataset constructed.[5] The empirical model of the growth function is as follows (see Eq. (10)):

$$Y_{i,t} = \alpha I_{i,t-1} + \beta M_{i,t-1} + \gamma M^2{}_{i,t-1} + \delta Z_i + \zeta D_t + \varepsilon_{i,t} \quad (10)$$

To control for the possible two-way causality problem, we put one-year time lag between the dependent variables and explanatory variables. $Y_{i,t}$ represents the i-th nation's real GDP per capita and real value added per capita in each industry, respectively, at time t, both in logarithmic term. $I_{i,t-1}$ refers to the robustness verification variables, which include the ratio of total investment to GDP and enrollment rate in primary school and tertiary school, with one-year time lag.[6] $M_{i,t-1}$ denotes the knowledge capital stock in terms of R&D expenditure per capita and the number of patent applications per thousand population for country i at time t-1.[7] Z_i lists the unobservable time-invariant country-specific characteristics. D_t is the dummy variable for the years 2009 and 2010 to control for any idiosyncrasies related to the outbreak of the global financial crisis. $\varepsilon_{i,t}$ is an error term.

2. Data

The data were collected from various international organizations. Each nation's real GDP per capita and real value added per capita in different industries were obtained from the World Bank; the data on the ratio of total investment were obtained from the IMF. Educational data, such as the enrollment rate in primary school and tertiary school, were extracted from UNESCO. The data of patent applications were drawn from the WIPO database.

The analysis period was 15 years from 2000 to 2014, and the data of 120 countries were used for the analysis. The national data were merged for each year to construct the final dataset which is the unbalanced panel because of

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[5] Either fixed-effect model or random-effect model is applied to the dataset, following the Hausman test results. The null hypothesis is that the random-effect estimator is efficient.

[6] The classification of primary school and tertiary school follows the International Standard Classification of Education (ISCED).

[7] Knowledge capital stock was measured as the weighted sum of the amount of knowledge capital—annual R&D investment and patent applications-newly accumulated in the corresponding year and over the past three years. As for the depreciation rate of knowledge capital, following Kim and Hong (2011), we applied the annual depreciation rate of 15%. Knowledge capital was entered in the growth function with its square term, reflecting the inverted-U relationship between social infrastructure and economic growth.

the missing values. The countries for which the real GDP data were not available were excluded, and so were the small city-states and island nations. The list of countries used for the analysis can be found in Appendix.

The summary statistics of the dependent and independent variables are shown in Table 2. First, the world average of real GDP per capita for years 2000-2014 was $12,809. By industry, the world average of real value added per capita for the same period ranged from $7,642 in services to $422 in agriculture. Regarding the educational attainment level, the average enrollment rate of primary school was 70%, while the average enrollment rate of tertiary school was as low as 31%. For the knowledge capital variables, the annual R&D expenditure per capita was on average $1.02, and the annual number of patent applications per thousand people was on average 1.20.

Table 2 Variable measurement and summary statistics

Variables	Measurement	Mean	S.D.	Source
Dependent				
GDP	Real GDP per capita ($ in 2010 price)	12,809	17,787	World Bank
	Real value added per capita for each industry ($ in 2010 price)			
Value added	Manufacturing	1,763	2,544	
	Services	7,642	11,323	
	Agriculture	422	386	
Independent				
Investment_ratio	The ratio of total investment to GDP (%)	24.26	7.73	IMF
Enrollment_primary	The enrollment rate, primary school (%)	69.66	40.35	UNESCO
Enrollment_tertiary	The enrollment rate, tertiary school (%)	31.05	29.77	UNESCO
R&D stock	R&D stock as measured by the weighted sum of R&D expenditure per capita ($)	1.02	1.25	UNSCSO
Patent stock	Patent stock as measured by the weighted sum of annual patent applications	1.20	1.12	WIPO
Financial Crisis	Dummy variable; 1 for 2009 and 2010			
N		1,287		

Note: The number of observations for R&D expenditure per capita is 567, due to the missing values.

V. Empirical Results

Table 3 reports the fixed-effect panel analysis results for the growth equation, with knowledge capital measured by the R&D stock.[8] As expected, the R&D stock significantly increases real GDP per capita, with the decreasing marginal effect, confirming the inverted-U relationship between knowledge capital as social infrastructure and economic growth. In addition, R&D stock enhances real value added per capita for all industries. Given that, in most countries, R&D activities are disproportionally conducted in manufacturing, the observed growth effect of R&D stock in services and agriculture implies a considerable extent of inter-industry spillover effects of knowledge capital.

Table 3 The effect of R&D expenditure on economic growth

	GDP	Industrial value added		
		Manufacturing	Services	Agriculture
Investment_ratio	0.351 ***	0.385 ***	0.403 ***	0.218 **
	(0.111)	(0.103)	(0.107)	(0.103)
Enrollment_primary	0.003	-0.003	0.005	0.016
	(0.020)	(0.019)	(0.019)	(0.019)
Enrollment_tertiary	0.136 ***	0.093 **	0.138 ***	0.037
	(0.042)	(0.039)	(0.040)	(0.039)
R&D stock	0.281 ***	0.320 ***	0.326 ***	0.157 ***
	(0.049)	(0.046)	(0.047)	(0.046)
*R&D stock_squared*1)	-0.039 ***	-0.050 ***	-0.045 ***	-0.024 ***
	(0.009)	(0.008)	(0.008)	(0.008)
FinancialCrisis	-0.019	-0.047 ***	0.004	-0.015
	(0.012)	(0.011)	(0.011)	(0.011)
Constant	9.038 ***	7.046 ***	8.393 ***	5.854 ***
	(0.048)	(0.044)	(0.046)	(0.044)
Hausman Test(Chi2)	79.87 ***	86.60 ***	88.46 ***	21.98 ***
R-Squared				
within	0.1171	0.1417	0.1518	0.0387
between	0.6499	0.6556	0.6707	0.3278
overall	0.6658	0.6844	0.6763	0.2841
N	567	567	567	567

Note: 1) R&D expenditure per capita squared/100
2) Standard errors in parentheses
3) *** $p<0.01$, ** $p<0.05$, * $p<0.1$

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[8] The Hausman test results show that the fixed-effect model is more appropriate than the random-effect model.

For other variables, the total investment ratio drives up both real GDP per capita and real value added per capita in all industries. The enrollment rate of tertiary school increases real GDP per capita and real value added for manufacturing and services, suggesting that highly educated labor is a driving force of economic growth. The growth effect of tertiary enrollment is also positive, but not significant in agriculture. This may be ascribed to the fact that, in most countries, agriculture lags behind manufacturing and services, relying mostly on the less educated labor force and, therefore, does not benefit much from the nation’s pool of highly educated people. In comparison, contrary to previous studies that found a positive relationship between primary enrollment rate and economic growth, the primary enrollment rate does not exert any effect on economic growth. This finding is likely to reflect the fact that, while the labor force with some basic education would suffice for economic growth in earlier years, highly educated high-skilled manpower was needed to take advantage of knowledge capital and to boost economic growth in recent years. The devastating effect of global financial crisis appears to be most prominent in manufacturing industries.

Table 4 The effect of patent applications on economic growth

	GDP	Industrial value added		
		Manufacturing	Services	Agriculture
Investment_ratio	0.505 ***	0.348 ***	0.627 ***	0.092
	(0.078)	(0.076)	(0.082)	(0.066)
Enrollment_primary	0.016	0.021 *	0.020	0.014
	(0.012)	(0.012)	(0.013)	(0.010)
Enrollment_tertiary	0.162 ***	0.097 ***	0.210 ***	0.057 *
	(0.035)	(0.034)	(0.037)	(0.030)
Patent stock	0.109 ***	0.103 ***	0.110 ***	0.015
	(0.020)	(0.021)	(0.023)	(0.018)
*Patent stock_squared*1)	-0.025 ***	-0.021 ***	-0.025 ***	-0.005
	(0.006)	(0.006)	(0.006)	(0.005)
FinancialCrisis	-0.007	-0.028 ***	0.017 *	-0.006
	(0.009)	(0.009)	(0.009)	(0.007)
Constant	8.232 ***	6.125 ***	7.485 ***	5.751 ***
	(0.026)	(0.025)	(0.027)	(0.022)
Hausman Test(Chi2)	124.54 ***	149.70 ***	132.16 ***	64.86 ***
R-Squared				
within	0.1171	0.1417	0.1518	0.0387
between	0.6499	0.6556	0.6707	0.3278
overall	0.6658	0.6844	0.6763	0.2841
N	1,287	1,287	1,287	1,287

Note: 1) Patent applications per capita squared/100
2) Standard errors in parentheses
3) *** $p<0.01$, ** $p<0.05$, * $p<0.1$

Table 4 presents the fixed-effect panel analysis results for the growth equation when knowledge capital is measured by the stock of patents filed. Except for the agricultural sector, the estimation results are qualitatively identical to the estimation results of the growth equation with R&D stock as knowledge capital (see Table 3).

As in the case of R&D stock, the patent stock significantly contributes to real GDP per capita, also with the decreasing marginal effect, again confirming the inverted-U relationship between knowledge capital as social infrastructure and economic growth. In addition, the patent stock enhances real value added per capita for manufacturing and services, implying the inter-industry spillover effects of knowledge capital between these two industrial sectors. By contrast, the patent accumulation does not have a significant effect on industrial value added in agriculture. This may be because patents tend to be more industry-specific than R&D investment; patents filed in manufacturing industries tend to be technically distant from agricultural technology, resulting in a low likelihood of inter-industry spillover effects.

The ratio of total investment to GDP enhances economic growth in terms of both real GDP and real value added in manufacturing and services, but not in agriculture. The tertiary enrollment rate raises both real GDP and industrial value added in all industries, including agriculture. The primary enrollment rate does not have any significant effect on economic growth, as in the case of knowledge capital being measured by R&D stock; however, unlike in the case of R&D stock, a positive and significant effect on value added in manufacturing is observed.

VI. Conclusions

This study analyzed the role of knowledge capital in economic growth, defining knowledge capital as core social infrastructure. As for knowledge capital, we used the R&D stock as measured by the weighted sum of annual R&D expenditure and the patent stock as measured by the weighted sum of patents annually filed in each country. For the empirical analysis, we constructed the panel dataset from 120 countries for the years of 2000 to 2014 and conducted the fixed-effect panel analysis.

The major findings and implications of this study are as follows. First, the accumulation of knowledge capital-measured both by the stock of R&D expenditure and patent applications-promotes economic growth, confirming that knowledge capital is a key social infrastructure supporting economic growth. The growth effect of knowledge capital is greater in the earlier development stage when it is a rather scarce resource, implying that the accumulation of knowledge capital is particularly critical in the developing and less-developed countries. Second, knowledge capital accumulated in a society enhances the industrial productivity-as measured by the real value added per capita-in all industries, implying a substantial degree of inter-industry spillover effects. The R&D stock promotes growth in services and agriculture, as well as in manufacturing where R&D investment is concentrated; the stock of patents filed also increases industrial value added, although such an effect is not statistically significant in agriculture. These results confirm the important role of knowledge capital as social infrastructure that benefits both those industrial sectors where it is accumulated and other industrial sectors through inter-industry technology transfer.

Due to the lack of sufficient data, this study has some limitations. The consistent macro data were difficult to gather for the years prior to 2000, especially for the developing and less-developed countries. Therefore, our dataset was the unbalanced panel data for 15 years starting from 2000, with some missing values for some variables and/or countries. Owing to this data problem, we could not try a sufficient time lag in the growth equation and a larger set of explanatory variables that could have a bearing on economic growth. We also could not conduct a comparative analysis for the countries in different development stages. When a richer set of international data becomes available, an extension of the present study that considers these issues will shed further light on the role of knowledge capital in economic growth.

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Appendix List of Countries Analyzed

Developed Countries	Developing Countries		Less-Developed Countries
Argentina	Albania	Mauritius	Benin
Australia	Armenia	Mexico	Bhutan
Belgium	Azerbaijan	Moldova	Burkina Faso
Canada	Bangladesh	Mongolia	Burundi
Chile	Belarus	Morocco	Center African, Rep.
Costa Rica	Bolivia	Namibia	Chad
Croatia	Botswana	Nicaragua	Cote d'lvoire
Denmark	Cambodia	Oman	Ethiopia
Estonia	Cameroon	Panama	Gambia, The
Finland	Columbia	Paraguay	Guinea
France	Congo, Rep.	Peru	Malawi
Germany	Dominican, Rep.	Philippines	Mauritania
Greece	Ecuador	Romania	Mozambique
Hungary	Egypt	Russia	Nepal
Iceland	El Salvador	Saudi Arabia	Niger
Ireland	Fiji	Serbia	Nigeria
Italy	Georgia	South Africa	Pakistan
Japan	Ghana	Sri Lanka	Rwanda
Korea, Rep.	Guatemala	Swaziland	Senegal
Kuwait	Honduras	Tajikistan	Sierra Leone
Latvia	India	Thailand	Sudan
Lithuania	Indonesia	Tonga	Tanzania
Netherlands	Iran	Tunisia	Togo
New Zealand	Jamaica	Turkey	Uganda
Norway	Jordan	Ukraine	Zambia
Poland	Kazakhstan	Uruguay	
Portugal	Kenya	Uzbekistan	
Slovenia	Kyrgyz, Rep.	Venezuela	
Spain	Lesotho	Vietnam	
Sweden	Malaysia	Zimbabwe	
Switzerland			
Trinidad & Tobago			
UAE			
United Kingdom			
USA			

Note 1) The countries that do not have the data for real GDP or real value added on the industry level were excluded, and so were city-states or island nations.

2) The countries were classified into each development stage according to the Human Development Index (HDI) of UNDP.