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Hyunbae CHUN
Sogang University

MIYAGAWA Tsutomu
RIETI

Hak Kil PYO
Seoul National University

TONOGI Konomi
Kanagawa University

Research Institute of Economy, Trade & Industry, IAA

The Research Institute of Economy, Trade and Industry
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Do Intangibles Contribute to Productivity Growth in East Asian Countries? Evidence from Japan and Korea*

Hyunbae CHUN (Sogang University)
MIYAGAWA Tsutomu (Gakushuin University and RIETI)
Hak Kil PYO (Seoul National University)
TONOGI Konomi (Kanagawa University)

Abstract

Using the Japan Industrial Productivity (JIP) and the Korea Industrial Productivity (KIP) databases and other primary statistics in Japan and Korea, we estimate intangible investment in Japan and Korea at the industry-level. Comparing our estimates from two-country data, we find that the growth in intangible investment in Korea has exceeded that in Japan in the past 30 years. Intangible investment/gross value added (GVA) ratios in the machinery industries in Japan are higher than in Korea, because Japanese machinery industries are research and development (R&D) intensive. On the other hand, ratios in some service industries in Korea are higher than in Japan, because Korean service industries are information and communications technology (ICT)-intensive. When we conduct growth accounting analysis with intangibles, we find that the contribution of intangible investment to economic growth after 1995 in Japan decreased significantly. In addition, the contribution of intangibles to productivity growth in Japan after 1995 is lower than not only Korea but also the European Union (EU) countries and the United States. The lack of synergy effects between ICT and intangibles in Japan may be the cause of low productivity growth in the 2000s.

Keywords: ICT, Intangible investment, Growth accounting, Complementarity
JEL classification numbers: E01, E22, O31, O47, O53

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1. Introduction

The ICT revolution in the 1990s and the productivity growth it caused in the US have inspired new interest amongst economists in exploring sources of growth. Table 1 shows the standard growth accounting in Korea and Japan. In the manufacturing sector in both countries, TFP growth accelerated after 1995, while the contribution of capital to economic growth declined. This has led economists to look for new sources of economic growth. Hall (2000, 2001), Bresnahan, Brynjolfsson, and Hitt (2002), and Basu et al. (2003) emphasized intangible assets -- that are complementary to ICT assets -- and play a crucial role in productivity improvement. However, they had to indirectly estimate the role of intangible assets due to the challenges in measuring intangibles.[1]

(Place Table 1 around here)

Corrado, Hulten, and Sichel (2009) (hereafter referred to as CHS) overcame this challenge and measured intangible investment at the aggregate level in the US for the first time. Based on their estimation, they found that the ratio of intangible investment to GDP exceeded the ratio of tangible investment to GDP in the early 2000s. After their success in measuring intangible assets, many economists followed their method and estimated intangible investment in their own countries.[2]

One of the major contributions of CHS's work was to show the contribution of intangibles (which have been hidden in the contributions of capital assets and TFP) to economic growth. CHS argued that one third of the productivity growth in the late 1990s and the early 2000s is attributable to the growth in intangible assets and the OECD (2013) emphasized that the effects of intangibles on productivity growth are greater than those of tangibles.

The framework constructed by CHS has been developed further, mainly in two directions. One is to measure intangible investment by industry. Aggregated data does not provide enough detailed information to conduct a productivity analysis. As Jorgenson, Ho, and Stiroh (2005), Inklaar, O'Mahony and Timmer (2005), and Fukao et al. (2011) suggested, there is a significant productivity gap between ICT industries and non-ICT industries. In addition, even in ICT-intensive service industries, there is a productivity gap between the US and Japan. To understand the above gaps, we require intangible investment data at the industry level. Moreover, the aggregate series also constrains our analysis. The measured time series intangible investment data are available for at most 30 years. This size of data is not sufficient for several econometric analyses.

As a result, economists started measuring intangible investment at the industry level in a few countries. Chun et al. (2012) estimated intangible investment by industry in Japan and Korea using the Japan Industrial Productivity (JIP) database and the Korea Industrial Productivity (KIP) database, and following the framework developed by CHS (2009). In their paper, they found that although the ratio of intangible investment to GDP in Japan is higher than in Korea, the gap in the ratios between two countries has

[1] Miyagawa and Kim (2008) also considered the role of intangible assets on productivity improvement through the indirect measurement in intangible assets by using firm-level data.
[2] Burnes and McClure (2009) for Australia, Corrado et al. (2013) for the EU countries, Fukao et al. (2009) for Japan, and Pyo, Chun, and Rhee (2010) for Korea.

contracted in many industries. Using the same data in Korea, Chun and Nadiri (2013) conducted growth accounting including intangibles. They divided 27 industries into intangible-intensive industries and non-intangible-intensive industries and found that the productivity growth in the former industries was higher than in the latter. They also showed that intangibles are key drivers in productivity growth in the intangible-intensive industries. Miyagawa and Hisa (2013) examined the effects of intangible investment on productivity growth by using data on intangibles in Japan. They found positive and significant effects of intangible investment on productivity in ICT intensive industries. Their results imply there are complementarities between ICT technology and intangibles.

In Europe, Niebel et al. (2013) estimated intangible investment by 11 sectors in 10 EU countries by using in INTAN-Invest database. They found that the contributions of intangibles to productivity growth are highest in the manufacturing and financial sectors. Following the CHS approach, Crass et al. (2015) also estimated intangible investment by six sectors in Germany. They also supported the view that the manufacturing and financial and business service sectors are intangible-intensive sectors. In these sectors, innovative capital contributes to labor productivity growth. Comparing this with intangible investment in the UK developed by Gil and Haskel (2008), they found that the UK invests more in software, firm-specific human capital, and organizational structure than Germany, while Germany invests more in R&D and advertising than the U.K.

The second direction this framework was developed towards is to reformulate CHS's components of intangibles. When CHS started to measure intangibles, only software investment was included as capital formation in the SNA based on the 93 SNA manual. However, the 08 SNA manual recommends including R&D investment as capital formation and it has been accounted for as capital formation in many advanced countries. Therefore, Corrado et al. (2014) measure intangible investment in the EU countries, reclassifying tangibles and intangibles: non-ICT tangibles, ICT, R&D, and non-R&D intangibles. Based on these new classifications, they examine complementarities between capital assets, in particular ICT assets and R&D, and ICT assets and non-R&D intangibles.

Following the two developments of CHS's study, we examine intangible investment by industry in Japan and Korea, and contributions of intangibles to productivity growth. Although Japan and Korea are the most advanced countries in East Asia, the growth paths in the recent past of the two are different. The Japanese economy has suffered from the long-term stagnation of the economy since the collapse of the bubble economy in 1990. On the other hand, the Korean economy has recorded higher economic growth than other advanced economies -- even though it experienced a serious downturn due to the financial crisis in 1997. Therefore, we expect that we will find the different effects of intangibles to economic growth in the two countries. [3]

In the next section, we introduce new asset classifications developed by Corrado et al. (2014) and explain how to measure these assets in Japan and Korea. In the third section, we show some features of intangible investment at the industry level in Japan with some comparisons with estimates in Korea. As our industry classification is more sophisticated than those in previous literature, we are able to provide useful information

[3] Using the framework developed by McGrattan and Prescott (2005, 2010), Miyagawa and Takizawa (2011) showed that the contribution of intangibles to economic growth in Korea is lareger than that in Japan.

for the composition of capital assets by industry. In the fourth section, using growth accounting with intangibles, we examine the contributions of intangible assets to productivity improvement. In the fifth section, we examine the correlations between ICT assets and intangibles. In the last section, we summarize our results.

2. Classification and measurement of Capital Assets

Economists have also developed classifications of intangibles. In Korea, Pyo (2002) defined intangibles as computer software, mineral exploration, cultural products such as entertainment, literature, original fine arts and unproduced intangible assets such as patents and licensing of mobile communication etc. van Ark (2004) argued that human capital, knowledge-based capital, organizational capital, marketing of new products, and social capital, in addition to ICT capital, should be taken into account in the knowledge economy.

The category of intangibles developed by CHS that we use to measure intangibles is broader than Pyo (2002) and narrower than van Ark (2004). Intangible assets in CHS consist of computerized information, innovative property, and economic competencies. However, as Corrado et al. (2014) integrate tangibles and intangibles and reclassify it into four types of assets: non-ICT tangibles, ICT, R&D, and non-R&D intangibles, we will explain how we measure these assets by industry. Our measurement depends mainly on the JIP database for Japan and the KIP database for Korea and we adjust industry classifications in both countries to 27 industry classifications because both industry classifications are slightly different between Japan and Korea. [4]

2-1. Measurement of ICT investment and non-ICT tangibles investment

As Fukao et al. (2011) showed, ICT assets consist of computing equipment, communication equipment, and software. We obtain the data for the first two assets from the JIP database and the KIP database. The last asset corresponds to computerized information defined in CHS Computerized information consists of custom and packaged software, and own account software. In Chun et al. (2012), the data in custom and packaged software in Japan were obtained from the Japanese SNA. However, since 2012, the Japanese government has published own account software investment as well as custom and packaged software investment. Therefore, for the aggregate software investment, not only Korea but also Japan follows the SNA data. To measure software investment by industry, we allocate the total software investment into each industry by using the *Fixed Capital Formation Matrix* (FCFM) in each country. Non-ICT tangibles are all tangibles except computing equipments and communication equipment. We also obtain this data by industry from the JIP database and the KIP database.

2-2. Measurement of R&D investment

Innovative property defined in CHS consists of science and engineering R&D, mineral exploitation, copyright and license costs, and other product development, design, and research expenses. Corrado et al. (2014) defined the first two components of innovative property as R&D investment, which has been already counted in SNA in advanced

[4] In the JIP and KIP databases, we measure capital stock which firms own and do not count capital stock which firms rent. In the measurement of intangible investment by industry, we take the same approach as the capital account in the JIP and KIP databases.

countries. In Japan, we estimate science and engineering R&D costs by using the *Survey of Research and Development* published by the Statistical Bureau of the Ministry of Internal Affairs and Communications. In Korea, we estimate science and engineering R&D costs by using the *Survey of Research and Development* published by Ministry of Education, Science, and Technology. In both countries we focus only on R&D expenditures by the private sector. We obtain the data for investment in mineral exploitation from the SNA in Japan and Korea.

2-3. Measurement of non-R&D intangibles

Intangibles except software and R&D are considered to be non-R&D intangibles in Corrado et al. (2014). Non-R&D intangibles consist of copyright and license costs, other product development, design, and research expenses, brand equity, firm specific human capital, and organizational structure.

Copyright and license costs are constructed from the IO table in each country. They consist of the intermediate inputs from the publishing industry and the video picture, sound information, character information production and distribution industry. In the new estimates by Corrado et al. (2013), expenditures in entertainment and artistic originals are measured instead of copyright and license costs. However, we use only intermediate inputs from the video picture, sound information, character information production and distribution industry.

As for the estimation of product development in financial services, the estimation method by CHS was very controversial because they assumed that 20 percent of intermediate inputs produced by financial services can be assumed to be expenditures in intangible assets. Recently, Corrado et al. (2013) suggested that the cost of new product development in financial services was almost 8 percent of the compensation of high skilled workers in the financial industry, to harmonize their estimate with estimates in EU countries by COINVEST and INNODRIVE projects. Thus, following Corrado et al. (2013)'s suggestions, we also assume that 8 percent of the compensation of college graduates in the financial and the insurance industries can be regarded as expenditures in intangible assets in these industries.

Brand equity, firm specific human capital, and organizational structureis categorized as economic competencies in CHS. To measure brand equity, we obtain the output data of the advertising industry and allocate it into 27 industries by using the IO table in the JIP and KIP databases.

In estimating firm specific human capital, we focus on off-the-job-training costs. In Japan, we estimate the ratio of off-the-job training costs to total labor costs from the *General Survey on Working Conditions* by industry published by the Ministry of Health, Labor and Welfare. We estimate off-the-job training costs by firms by industry by multiplying this ratio by total labor costs in the JIP database. For the opportunity cost of off-the-job training in terms of working hours lost, we use the results obtained by Ooki (2003). Ooki calculated the average ratio of the opportunity cost of off-the-job training to direct firm expenses for training in 1998 for the entire business sector using micro-data of the Survey on Personnel Restructuring and Vocational Education/Training Investment in the Age of Performance-based Wage Systems (Gyoseki-shugi Jidai no Jinji Seiri to Kyoiku/Kunren Toshi ni Kansuru Chosa) conducted by the Japan Institute for Labor Policy and Training. The value was 1.51 and we use this same value to estimate the opportunity cost.

In Korea, employer-provided training costs are obtained from the Report on Labor Cost of Enterprise Survey published by the Ministry of Labor. The survey includes training costs only for establishments with 30 or more employees. We assume that establishments with fewer than 30 employees spend 50% (relative to the total labor costs) less than those with 30 or more employees, and we estimate the employer-provided training costs for all establishments in each industry. Total training costs are defined as the sum of the direct costs and the opportunity costs of training. As the opportunity costs of training are not available, we assume that the direct costs of training are equal to the opportunity costs.

To estimate expenditures into organizational structure, CHS assumed that 20% of the remuneration of executives can be considered intangible assets for an organizational structure. However, in Japan, we believe 9% is a more accurate number, because only 9% of the total working time of executives is spent on organizational reform and the restructuring of organization, according to Robinson and Shimizu (2006). We calculate the ratio of the remuneration of executives to value added using *the Financial Statements Statistics of Corporations by Industry* published by the Ministry of Finance. Then, we find the expenditure for the organizational structure by industry by multiplying this ratio to value added in the JIP database.

In Korea, consulting costs are considered to be firm-specific investments in organizational resources. To obtain expenditures on consulting at the aggregate level, we use the gross output of consulting industry. The industry-level consulting costs are also estimated from the IO tables.[5]

3. Intangible Investment in Japan and Korea

Our measure of intangible investment (excluding hardware ICT investment) in Japan and Korea is shown in Figure 1.[6] In Japan, the amount of intangible investment was about 40 trillion yen in 2010. It peaked in 2007, after which it declined due to the depression caused by the Global Financial Crisis that occurred in 2008. On the other hand, intangible investment in Korea has not been affected by business cycles except the Asian Financial Crisis in 1997. Growing rapidly, it reached about 80 trillion won in 2010. While growth in ICT investment is the highest (5% per annum from 1995 to 2010) among the three components in Japan, growth in R&D investment is the highest (11% per annum from 1995 to 2010) in Korea. R&D investment in Japan has not increased in the past 15 years. We also find a gap in the growth rate in investment in non-R&D intangibles between Japan and Korea. In the past 15 years, its annual growth rate in Korea was 6.5%, while its growth rate in Japan was only 1.1%. However, the ratio of intangible investment to GDP in Japan (7.5%) is still higher than in Korea (7.4%) in the 2000s.

(Place Figure 1 around here)

[5] The measurement of each component in intangible assets are explained in Chun et al. (2012) and Chun and Nadiri (2013).

[6] The industry-level Intangible investment data in Japan is uploaded at the following website: http://www.rieti.go.jp/jp/database/JIP2013/index.html#04-6.

In Figure 2, we compare intangible investment by industry and by asset between Japan and Korea in 2010. In the manufacturing sector, the composition of the assets in Japan is similar to Korea in the sense that the share of R&D investment is the largest. However, in the service sector, software investment in Korea is greater than in Japan in some industries such as information and communication and business service industries. In the non-market sector such as education and health and social work industries, software investment in Korea is also larger than in Japan. In addition, in business service, education, and culture and entertainment services industries, investment in economic competencies in Korea is greater than in Japan.

(Place Figure 2 around here)

We also compare intangible investment in Japan and Korea with Germany and the UK in Table 2.[7] Table 1 shows the intangible investment/gross output ratio by sector in four countries. The intangible investment/output ratios in European countries are higher than those in Japan and Korea. In particular, intangible investment/output ratios in the service sector are much higher than those in other countries.[8]

(Place Table 2 around here)

We estimate capital stock in intangible assets based on the measurement of expenditures in intangible assets. The capital formation series in intangible investment is measured in nominal terms. Using the deflator by assets in the JIP and KIP databases, we construct a real capital formation series in intangible assets. Then, we generate the capital formation series by using the perpetual inventory method to find real capital stock in intangible assets. To measure capital stock in intangibles, we use the depreciation rates used in Corrado et al. (2013).

To find the composition of capital assets by industry, we have the share of each asset by industry in Figure 3. The share of non-ICT tangibles for most industries is the largest among the four types of assets in both countries, but we find some differences in the shares of other assets between Japan and Korea. In the manufacturing sector, Japanese machinery industries such as machinery equipment, electrical and electric equipment, precision instruments, and transportation equipment are more R&D-intensive than Korean machinery industries. On the other hand, most Korean service industries such as information and communication, business service, education, and culture and entertainment are more ICT-intensive than Japanese service industries.

(Place Figure 3 around here)

4. The Role of Intangible Assets on Productivity Improvement

7 The data in European countries are obtained from Crass et al. (2015).

8 The intangible investment/output ratios in the manufacturing sector in Korea seem to be very low. These low ratios in Korea are caused by low value added/gross output ratio in the manufacturing sector. When we look at the intangible investment/gross value added ratio in the manufacturing sector in Figure 2, the ratios in machinery industries are very high.

Using our estimates on intangibles, we conduct a growth accounting including intangible assets to examine their impacts on productivity growth. A feature of the new growth accounting is that we can break down the contribution of capital assets into four types of assets as shown in Figure 3. Based on the asset classification in Figure 3, the production function in industry *i* for value-added, V_{it}, can be expressed as

$$\text{(1)}\quad V_{t,i} = A_{t,i} F(L_{t,i}, K_{t,i}, C_{t,i}, R_{i,t}, Z_{t,i}),$$

where $L_{t,i}$ is labor input, $K_{t,i}$, $C_{t,i}$, $R_{t,i}$, $Z_{t,i}$ are non-tangible assets, ICT assets, R&D assets, and non-R&D intangible assets, respectively. *A* is TFP. Value-added (V_{it}) is adjusted for intangibles as $P^{V}_{t,i} V_{t,i} \equiv P^{Y}_{t,i} Y_{t,i} + P^{H}_{t,i} H_{t,i}$, *Y* is value added before considering intangible assets, *H* is intangible investment that is not included in the SNA, Then, we may express a growth accounting relation from equation (1) as,

$$\text{(2)}\quad \begin{aligned} \Delta v_{t,i} &= \frac{\partial F}{\partial L_{t,i}} \frac{L_{t,i}}{V_{t,i}} \Delta l_{t,i} + \frac{\partial F}{\partial K_{t,i}} \frac{K_{t,i}}{V_{t,i}} \Delta k_{t,i} + \frac{\partial F}{\partial C_{t,i}} \frac{C_{t,i}}{V_{t,i}} \Delta c_{t,i} \\ &+ \frac{\partial F}{\partial R_{t,i}} \frac{R_{t,i}}{V_{t,i}} \Delta r_{t,i} \frac{\partial F}{\partial Z_{t,i}} \frac{Z_{t,i}}{V_{t,i}} \Delta z_{t,i} + \Delta a_{t,i} \end{aligned}$$

where $\Delta x_i = \frac{\dot{X}_i}{X_i} = \sum_{j=1}^{N} \frac{w_{Xj} X_{j,i}}{\sum_{j=1}^{N} w_{Xj} X_{j,i}} \frac{\dot{X}_{j,i}}{X_{j,i}}$ (*X=L,K,C, R, or Z*)

$X_{j,i}$ represents an input factor that has the character *j* in industry *i* and $w_{j,i}$ represents the price of an input factor which has the character *j* in industry *i*.

As for the estimation strategy for growth accounting, we can estimate the production function in equation (1) using the growth rates of the value added and inputs, while interpreting coefficients on each input as a share. Alternatively, we can calculate the share of its input using the data on labor income and capital spending, and use the growth rates of value added and input to conduct the above growth accounting exercise. In our growth accounting, we take the alternative approach. To measure the share of capital income in the alternative approach and capital service, we calculate the cost of capital for asset j as follows,

$$\text{(3)}\quad CC_{t,j} = p_{t,j}(i_t + \delta_{t,j} - \pi_{t,j})/(1 - u_t),$$

where p_j is the price of investment goods for capital *j*, *i* is the nominal interest rate (calculated as the weighted sum of the bond rate and long-term prime rate)[9]. δ_j is the depreciation rate of capital *j*, π_j is the expected rate of increase in the price of investment goods. We assume perfect foresight for the expected rate of increase in the

[9] The weights used here are the ratios of debt to total assets by industry.

price of investment goods and use the growth rate of the price between this period and the next period. We can calculate the cost of capital (CC) for each type of tangible and intangible assets.[10]

Table 3 shows the results of growth accounting based on equation (2) in Japan and Korea. In Table 3, we find that the growth rate in the market economy slowed down drastically after 1995 in both countries due to the financial crises in the late 1990s. While all production factors including intangibles induced the slowdown in the growth rate after 1995 in Japan, the contribution rate of R&D assets to value added growth in Korea has kept a constant rate from 1985 to 2010.

(Place Table 3 around here)

When we compare the manufacturing and the service sectors in Japan, the growth rate of value added in the service sector has slowed more than in the manufacturing sector. While both the non-ICT tangibles and R&D assets and TFP growth are major contributors to value-added growth in the manufacturing sector, we find a low contribution of non-R&D assets and a negative contribution of TFP growth to value-added growth in the service sector after 1995.

In Korea, value added growth in both sectors has declined dramatically after 1995. However, the contribution rate of R&D assets to value added growth has kept the same pace since 1980. While TFP growth rate in the manufacturing sector accelerated after 1995, TFP growth rate in the service sector turned to be negative after 1995, as shown in the growth accounting in Japan.

Next, we compare a growth accounting with intangibles to a traditional growth accounting shown in Table 1 in both countries. The value added growth in a traditional growth accounting is different from in the growth accounting with intangibles, as spendings in intangibles are treated as investments rather than intermediate expenses, and thus are part of value-added. Due to the inclusion of intangibles into capital input, the contribution of capital input in the growth accounting with intangibles is greater than in the traditional growth accounting. In contrast, TFP growth in the growth accounting in Table 3 is smaller than that in Table 1 except for the case of the service sector after 1995 in Korea. In particular, TFP growth substantially decreased in the Japanese manufacturing during the 1985-1995 period, when intangibles were rapidly accumulated.

Lastly, we compare our growth accounting results with those for the US and Europe in Corrado et al. (2013) that also incorporates intangible assets. Corrado et al. (2013) broke down the labor productivity growth rate, which was measured using hours worked, into tangible assets, capital deepening rate of intangible assets, change in labor composition, and TFP growth rate. We follow their method in breaking down the labor productivity growth rate by using our data.

Table 4 shows the international comparison of growth accounting after taking intangible assets into account. We find that Japanese capital deepening rate of intangible assets is 0.2% and lower than the average international standard. On the other hand, the

[10] We take the effects of capital income tax on cost of capital into account only in the case of computerized information, because other intangibles are treated as intermediate inputs in the current financial statement.

capital deepening rate of intangibles in Korea is 0.6%, and is slightly higher than the average rate in European countries.

The share of capital deepening of intangible assets in the labor productivity growth rate is 9.5% in Japan and 13% in Korea, compared to 33.7% in the US and 19.9% in the EU respectively. After 1995, the accumulation of intangible assets played a key role in productivity growth in developed countries. On the other hand, the labor productivity growth in Japan after 1995 has been attributed to a compositional shift in the labor market -- an increase in higher quality labor due to a higher demand for higher education. However, there is a limit to this trend and once the number of people pursuing higher education hits the ceiling, this compositional effect would be muted. In that sense, it is necessary to accumulate intangible assets up to the level comparable to other developed countries. In the case of Korea, as tangible capital deepening and TFP growth are two main contributors to labor productivity growth. The source of labor productiovty growth in the Korean economy has changed from massive tangible capital investments in the rapid growth period of 1970s and 1980s, toward intangible investment and TFP growth after the 1990s. However, the contribution of intangibles to labor productivity growth in Korea is still relatively small compared to those in the US and European countries.

(Place Table 4 around here)

5. Correlations between ICT and R&D, and ICT and non-R&D intangibles

Bresnahan, Brynjolfsson, and Hitt (2002), and Basu et al. (2003) argued that intangibles play a complementary role on the effects of ICT assets on productivity growth. Our growth accounting in Table 3 also suggest that ICT assets and non-R&D assets moved together. However, the growth accounting exercise only captures the independent contribution of each asset. Then, we examine the correlations between ICT and R&D and ICT and non-R&D intangibles in this section. We take the five-year moving average growth of ICT assets, R&D assets, and non-R&D intangibles in Japan and Korea from 1990 to 2010, and examine correlations among these assets. Figure 4 shows the correlations between growth in ICT and R&D assets in Japan and Korea. While we find positive correlations between the two assets in Japan and Korea. However, as shown in Table 5, these positive correlations are affected by the strong positive correlations between the two assets in the1990s. The correaltions in Japan turned to be negative in the 2000s. In Korea, although the positive correlations were kept in the 2000s, they werre not significant.

(Place Figure 4 and Table 5 around here)

Figure 5 shows the correlations between ICT and non-R&D intangibles. As shown in Table 4, ICT is positively and significantly correlated with non-R&D intangibles only in the 1990s in both countries. In the 2000s, the negative correlations between ICT and non-R&D intangibles in both countries were found. Although these figures do not show any causalities among assets, low productivity growth in the 2000s in Japan may be partly caused by the lack of synergy effects among ICT assets, R&D assets, and non-R&D assets.

(Place Figure 5 around here)

We also examine the cross-sectional correlations between ICT and intangibles. Figure 6 shows cross-sectional correlations between ICT and R&D in Japan and Korea. [11] The correlation between two assets in Japan is very week (r=0.06) while we find the high positive correlation (r=0.77) in Korea. This finding imply that ICT intensive industries invest in R&D aggressively in Korea. On the other hand, ICT investment is conducted independently from R&D investment.

(Place Figure 6 around here)

Figure 7 which shows the complementarity between ICT and non-R&D intangibles is similar to Figure 6. In Korea, ICT intensive industries invest in non-R&D intangibles aggressively. On the other hand, growth in ICT assets is not associated with growth in non-R&D assets.

(Place Figure 7 around here)

6. Concluding Remarks

Based on the framework of Corrado, Hulten, and Sichel (2005, 2009) and Corrado et al. (2014), we estimated intangible investment by industry in Japan and Korea using the JIP and KIP databases. Comparing intangible investment in Japan with that in Korea, we find that Japanese growth in intangible investment slowed due to the financial crisis that occurred in 1997, and turned to be negative after the World Financial Crisis, while Korean intangible investment has grown at a high pace. While only software investment grew after 1995 in Japan, both R&D and software investments in Korea have rapidly grown. As a result, the gap in the ratio of intangible investment to GVA between Japan and Korea substantially reduced in the 2000s. When we examine intangible investment by industry, the ratio of intangible investment to GVA in Japan is higher than in Korea in many machinery industries because R&D investment to GVA ratios in these industries in Japan is higher than in Korea. However, in the service sector, the ratios in Korea are greater than those in Japan, because the Korean service sector is more ICT-intensive than the Japanese service sector.

Using intangible investment data, we construct capital stock in Japan and Korea by industry using the perpetual inventory method. Examining the composition of tangible and intangible capital, we find that machinery industries are R&D-intensive and the service industries are more ICT-intensive, although non-ICT tangibles dominate and take up the largest share in most industries in both countries.

We conducted growth accounting analysis with intangibles. Our results in growth accounting showed that the contributions of intangible assets to economic growth after

[11] In Figure 6, we examine the cross-sectional correlation in the manufacturing sector, because R&D investment is not conducted in some industries in the service sector. A numbers in Figures 6 and 7 corresponds to each industry. The corresponding table between number in Figures 6 and 7 and industry classification is shown in Appendix table.

1995 are lower than those before 1995 in Japan. In particular, the non-R&D intangibles have not contributed to economic growth after 1995 in Japan, because expenditures on off-the-job training has decreased rapidly due to the harsh restructuring. On the other hand, the contributions of R&D assets to economic growth are constant from 1985 to 2010 in Korea. The Korean economic growth rate decreased after 1995, but the role of R&D assets to economic growth has increased.

Comparing growth accounting with traditional accounting, we find that the contribution of capital assets to economic growth and TFP growth in the traditional growth accounting includes the contributions of accumulation in intangible assets. We also find that the contribution of intangible capital accumulation to productivity growth is weaker in Japan than in other developed countries. On the other hand, the contribution of intangibles to productivity growth in Korea is similar to those in European countries.

Finally, we examine the correlation between ICT assets and intangibles. While we find positive correlations between ICT assets and intangibles in the 1990s ICT is not positively correlated with intangibles in Japan in the 2000s. Low productivity growth in Japan in the 2000s may be due to the lack of the synergy effects of ICT assets and intangibles. This implication is confirmed by cross-sectional correlations between ICT and intangibles. However, to examine causalities among ICT assets and intangibles, more sophisticated analysis is required.

Our study suggests two important policy implications for the long-term productivity growth of the Japanese and Korean economies. First, since the contributions of intangibles to economic growth in both countries are not higher than those in other advanced countries, there is room to improve labor productivity through intangible investment. Second, our results shed light on complementarities among ICT assets and intangibles suggested by Basu et al. (2003), Corrado et al. (2013), Miyagawa and Hisa (2013), and Chun and Nadiri (2013). In the case of Japan, the lack of these complementarities may be a factor in the low productivity growth in the 2000s. Therefore, policies promoting intangible investment should be accompanied with policies promoting ICT investment.

Appendix table: Industry classification of the paper

	Industry classification
1	Agriculture, forestry and fishing
2	Mining and quarrying
3	Food, beverages and tobacco
4	Textiles and leather
5	Wood, paper, and printing
6	Petroleum, coal and chemicals
7	Non-metallic mineral products except petroleum and coal
8	Metal, Fabricated metal products
9	Machinery equipment
10	Electrical and electronic equipment
11	Precision instruments
12	Transport equipment
13	Furniture and other manufacturing industries
14	Electricity, gas and water supply
15	Construction
16	Wholesale and retail trade
17	Restaurants and hotels
18	Transport and storage
19	Financial intermediation
20	Real estate and renting
21	Information and communication
22	Business services
23	Public administration and defense
24	Education
25	Health and social work
26	Culture and entertainment services
27	Other service activities

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Table 1: Traditional Growth Accounting in Japan and Korea

	Japan		Korea	
	1985-95	1995-2010	1985-95	1995-2010
Market economy				
GDP growth	**3.13%**	**0.43%**	**9.29%**	**4.23%**
Labor input	**0.44%**	**-0.39%**	**2.13%**	**0.70%**
Capital input	**1.64%**	**0.44%**	**5.14%**	**1.84%**
TFP growth	**1.05%**	**0.38%**	**2.02%**	**1.68%**
Manufacturing				
GDP growth	**2.80%**	**1.30%**	**10.90%**	**6.40%**
Labor input	**-0.28%**	**-0.94%**	**2.12%**	**0.05%**
Capital input	**1.56%**	**0.45%**	**5.67%**	**2.27%**
TFP growth	**1.52%**	**1.80%**	**3.11%**	**4.07%**
Service				
GDP growth	**3.57%**	**0.12%**	**10.04%**	**3.36%**
Labor input	**0.86%**	**-0.18%**	**3.42%**	**1.65%**
Capital input	**1.70%**	**0.45%**	**5.56%**	**1.76%**
TFP growth	**1.00%**	**-0.16%**	**1.05%**	**-0.05%**

Table 2: Comparison of Intangible Investment/Gross Output Ratio

(%)

	2000		2004		2010	
	Japan	Korea	Germany	UK	Japan	Korea
Agriculture and mining	1.6	0.3	2.8	3.0	1.6	0.4
Manufacturing	6.0	2.4	6.1	8.3	6.4	2.8
Utility	2.8	2.5	3.1	2.9	2.6	1.5
Construction	1.8	1.2	2.1	3.6	1.6	1.4
Retail, Hotel, and Transportation	2.8	2.0	3.5	6.4	2.7	2.1
Financial and business services	6.2	5.8	7.8	8.4	8.0	5.6

Table 3: Growth Accounting with Intangibles

	Japan		Korea	
	1985-95	**1995-2010**	**1985-95**	**1995-2010**
Market economy				
GDP growth	**3.03%**	**0.62%**	**9.46%**	**4.32%**
Labor input	**0.38%**	**-0.37%**	**2.00%**	**0.60%**
Capital input	**2.09%**	**0.61%**	**5.61%**	**2.11%**
Non-ICT tangibles	**1.00%**	**0.22%**	**3.88%**	**1.33%**
ICT	**0.54%**	**0.29%**	**1.04%**	**0.36%**
R&D	**0.29%**	**0.08%**	**0.30%**	**0.29%**
Non-R&D intangibles	**0.26%**	**0.02%**	**0.38%**	**0.12%**
TFP growth	**0.56%**	**0.38%**	**1.86%**	**1.61%**
Manufacturing				
GDP growth	**2.51%**	**1.53%**	**11.14%**	**6.55%**
Labor input	**-0.29%**	**-0.77%**	**1.87%**	**-0.18%**
Capital input	**2.49%**	**0.70%**	**6.40%**	**2.84%**
Non-ICT tangibles	**0.90%**	**0.28%**	**3.61%**	**1.74%**
ICT	**0.46%**	**0.17%**	**1.60%**	**0.25%**
R&D	**0.85%**	**0.23%**	**0.74%**	**0.72%**
Non-R&D intangibles	**0.28%**	**0.02%**	**0.45%**	**0.13%**
TFP growth	**0.31%**	**1.59%**	**2.87%**	**3.88%**
Service				
GDP growth	**3.57%**	**0.25%**	**10.14%**	**3.38%**
Labor input	**0.80%**	**-0.18%**	**3.27%**	**1.54%**
Capital input	**2.02%**	**0.67%**	**5.92%**	**1.84%**
Non-ICT tangibles	**1.03%**	**0.19%**	**4.58%**	**1.19%**
ICT	**0.62%**	**0.37%**	**0.84%**	**0.47%**
R&D	**0.04%**	**0.02%**	**0.08%**	**0.06%**
Non-R&D intangibles	**0.34%**	**0.09%**	**0.42%**	**0.12%**
TFP growth	**0.74%**	**-0.23%**	**0.94%**	**-0.01%**

Table 4: International Comparison of Labor Productivity Growth (1995-2007)

(%)

	Labor productivity growth	Capital deepening	Tangible assets	Intangible assets	Labor composition	TFP growth
Japan	2.1	0.9	0.7	0.2	0.8	0.5
Korea	4.6	2.3	1.7	0.6	0.7	1.7
Austria	2.4	0.8	0.3	0.5	0.2	1.4
Belgium	1.8	0.7	0.2	0.5	0.1	0.9
Chech Republic	4.2	2.4	1.9	0.5	0.3	1.5
Denmark	1.4	1.2	0.7	0.5	0.2	-0.1
Finland	3.8	0.9	0.2	0.7	0.2	2.6
France	1.9	1.0	0.4	0.6	0.4	0.4
Germany	1.7	1.0	0.7	0.3	0.0	0.7
Ireland	3.8	1.4	0.8	0.6	0.1	2.2
Italy	0.6	0.7	0.5	0.2	0.2	-0.4
Netherlands	2.3	0.9	0.4	0.5	0.7	2.8
Slovenia	5.3	1.7	1.2	0.5	0.7	2.8
Spain	0.8	1.0	0.7	0.3	0.5	-0.6
Sweden	3.7	1.9	1.1	0.8	0.3	1.4
UK	2.9	1.5	0.8	0.7	0.4	1.1
US	2.7	1.7	0.8	0.9	0.2	0.8

* In Japan and Korea, labor productivity growth from 1995 to 2010 is decomposed and the decomposition of Labor productivity growth conducted by Corrad et, al. (2013).

Table 5: Correlations between ICT and Intangibles

	ICT and R&D		ICT and Non-R&D	
	Japan	Korea	Japan	Korea
1990-2010	0.837	0.930	0.886	0.809
	(0.065)	(0.030)	(0.047)	(0.075)
1990-1999	0.986	0.995	0.964	0.830
	(0.009)	(0.003)	(0.022)	(0.098)
2000-2010	-0.499	0.225	-0.223	-0.710
	(0.226)	(0.286)	(0.287)	(0.150)

*Standard deviations are shown in parenthesis.

Figure 1-1: Intangible Investment by Industry and Component in Japan

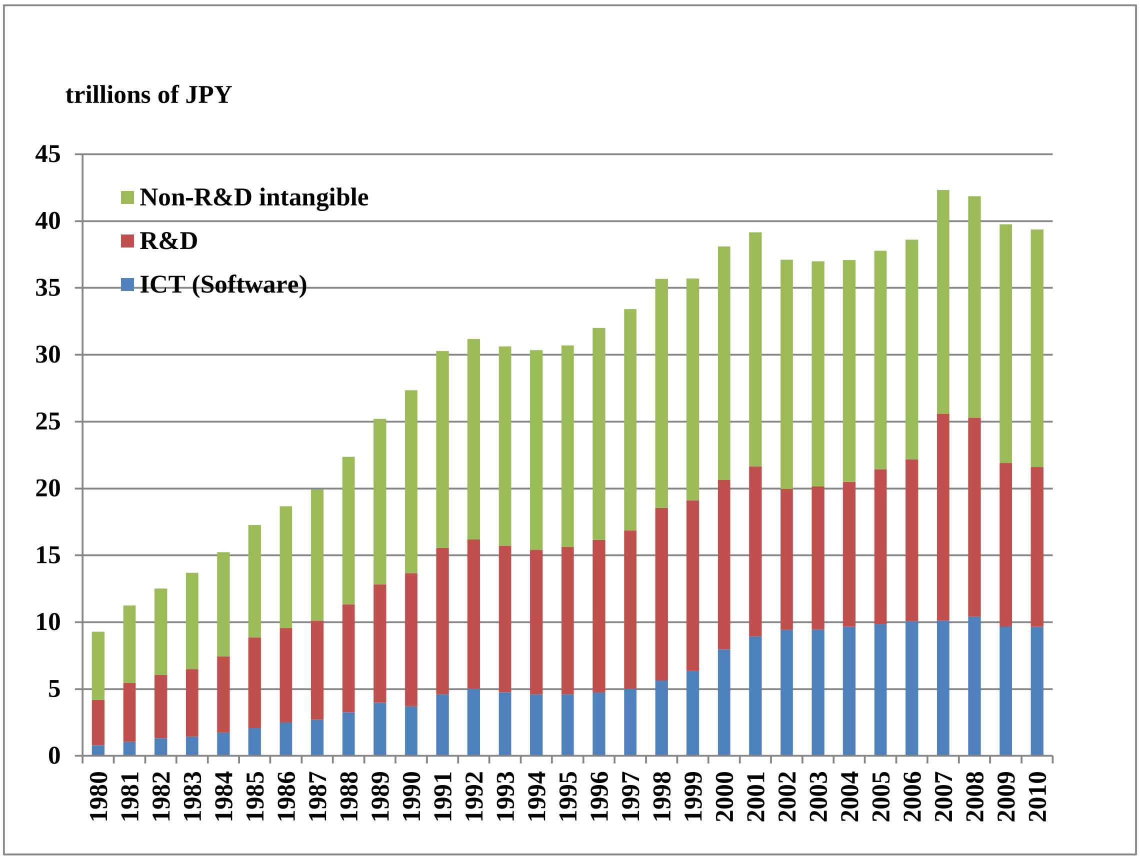


Figure 1-2: Intangible Investment by Industry and Component in Korea

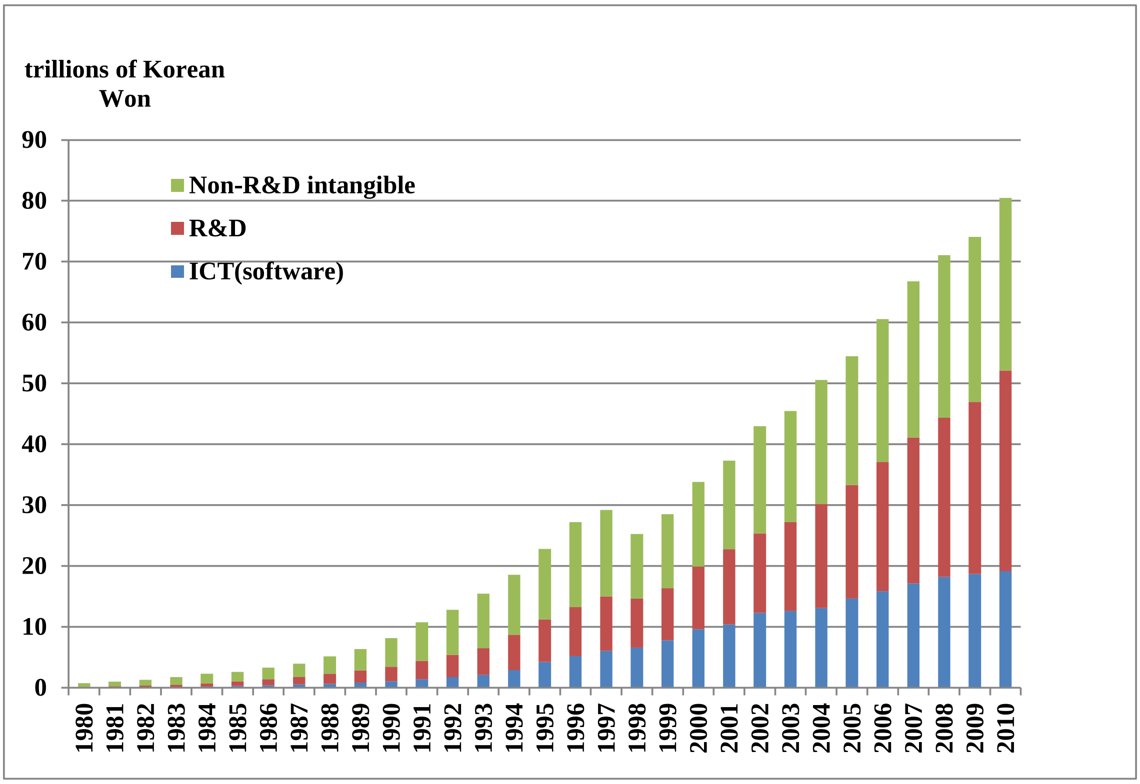


Figure 2-1: Ratio of intangible invesment to GVA by industry in 2010 (Japan)

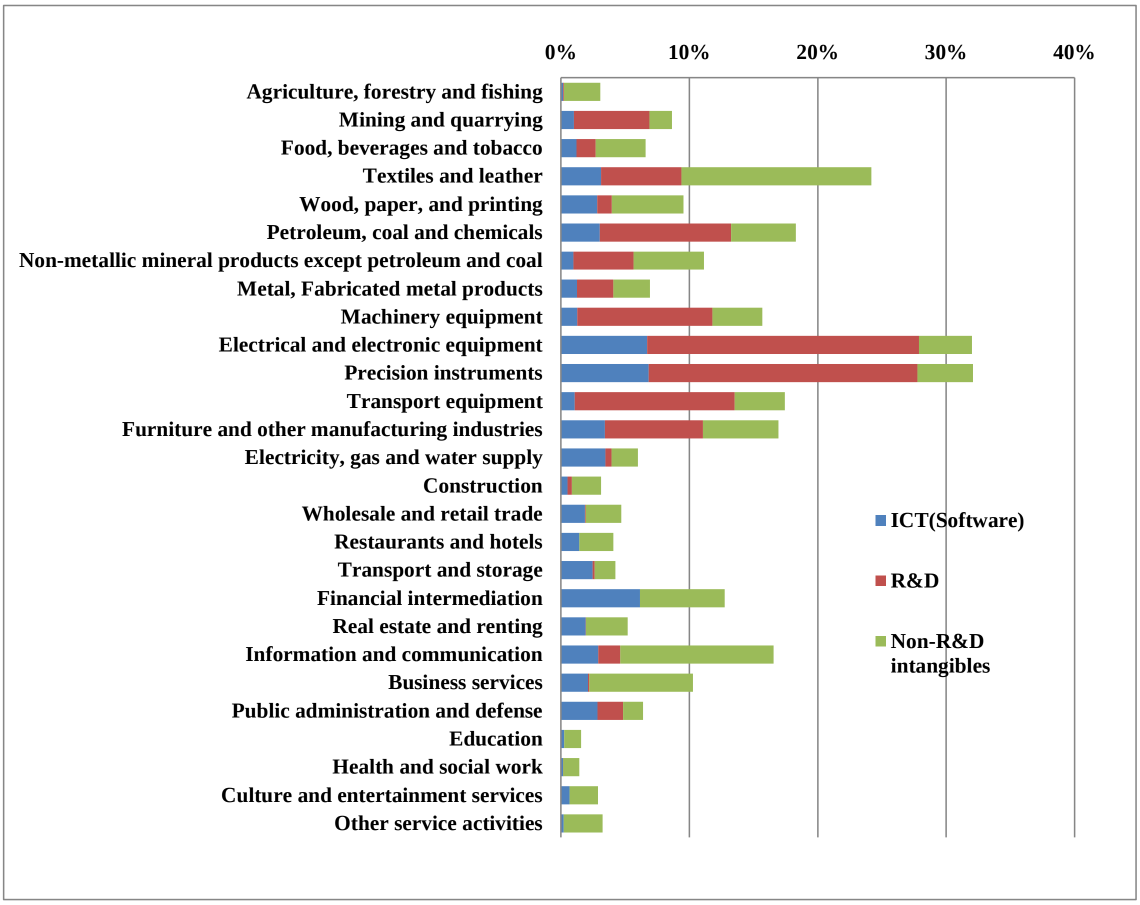


Figure 2-2: Ratio of intangible invesment to GVA by industry in 2010 (Korea)

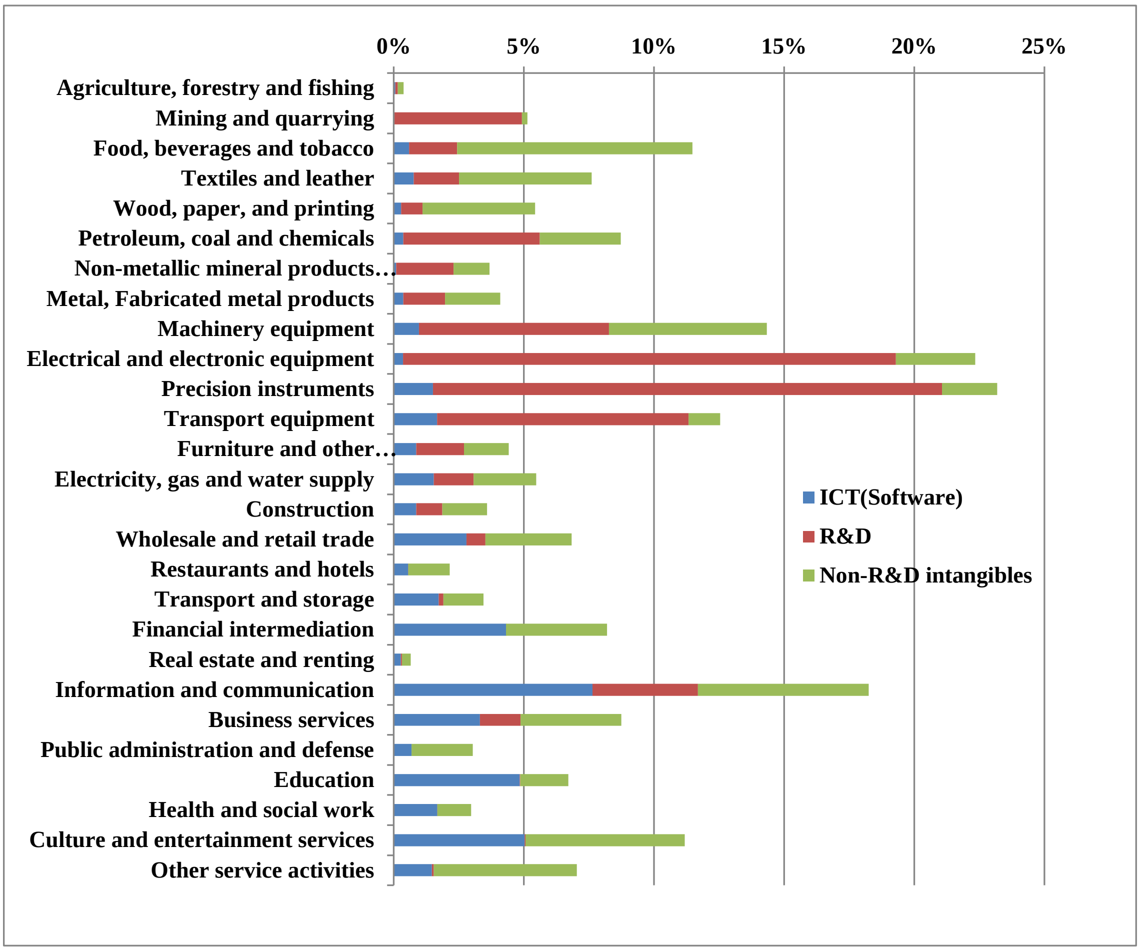


Figure 3-1: The composition of capital assets by industry in 2010 (Japan)

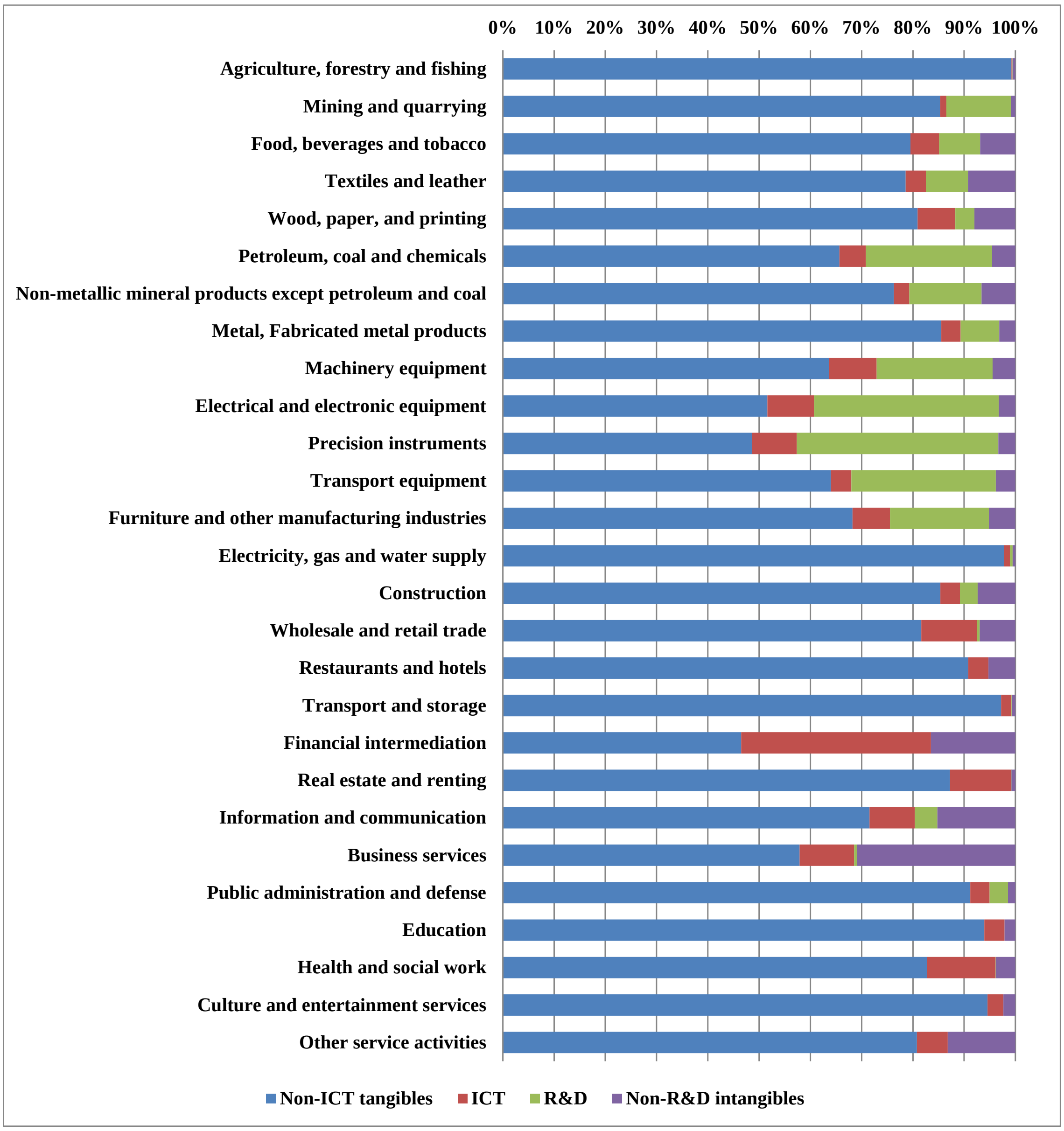


Figure 3-2: The composition of capital assets by industry in 2010 (Korea)

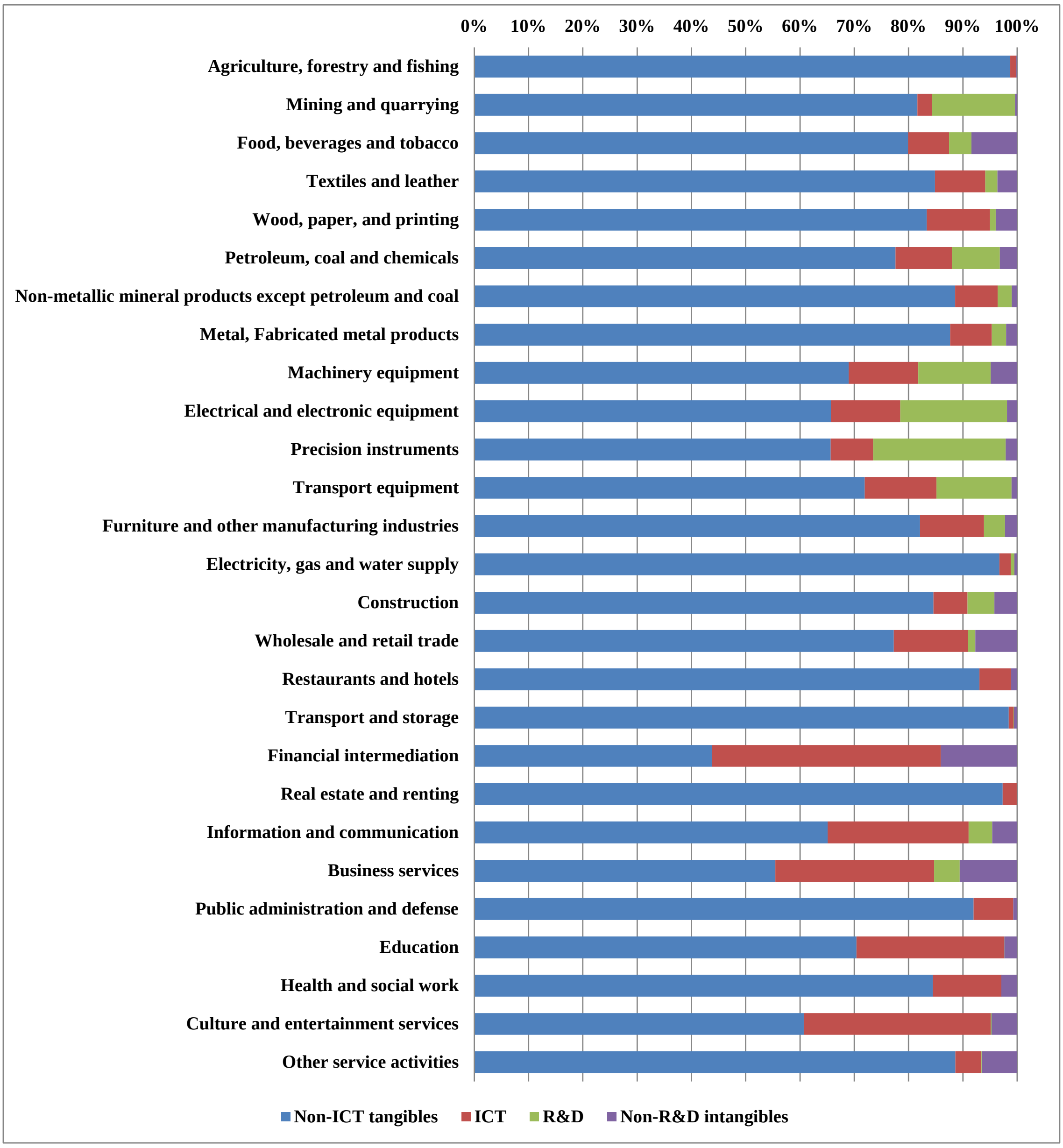


Figure 4-1: The Correlation between ICT and R&D in Japan

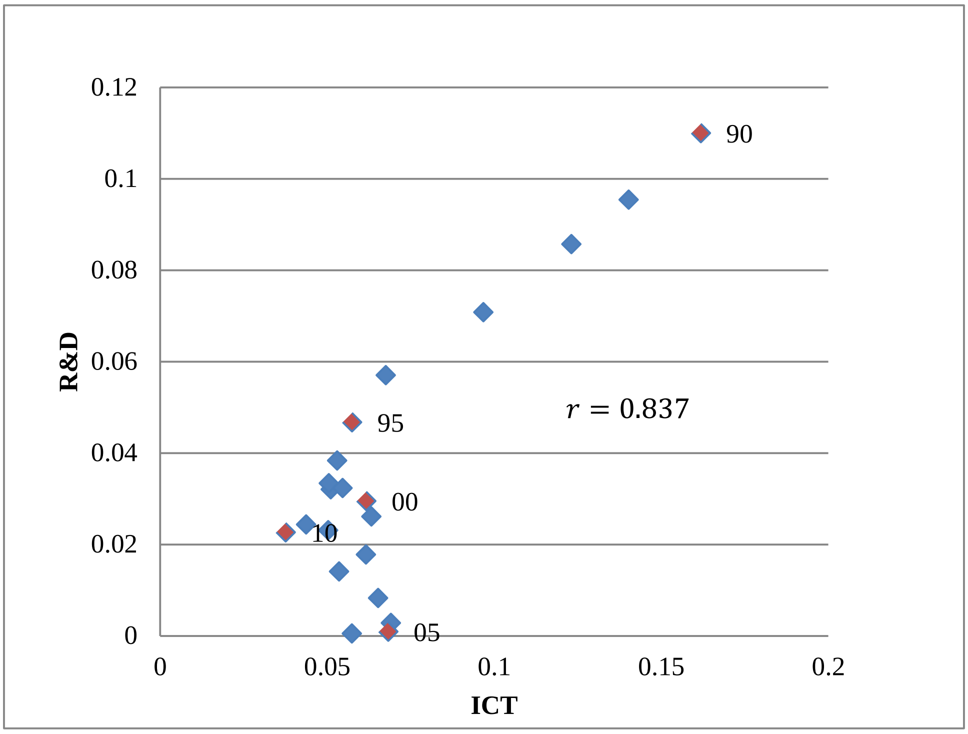


Figure 4-2: The Correlation between ICT and R&D in Korea

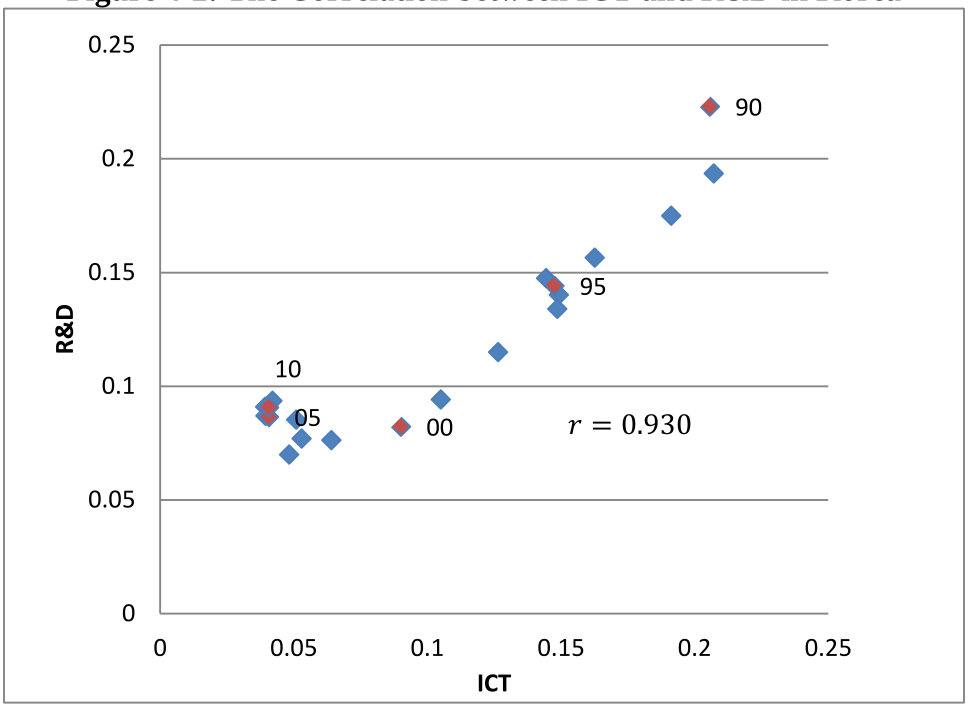


Figure 5-1: The Correlation between ICT and non-R&D in Japan

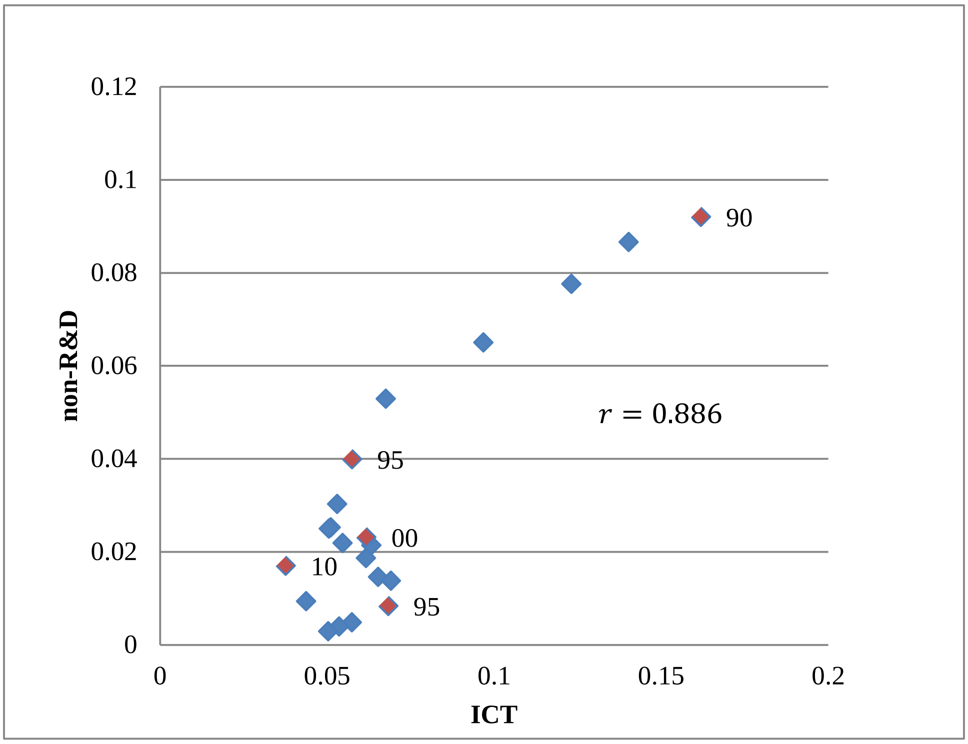


Figure 5-2: The Correlation between ICT and non-R&D in Korea

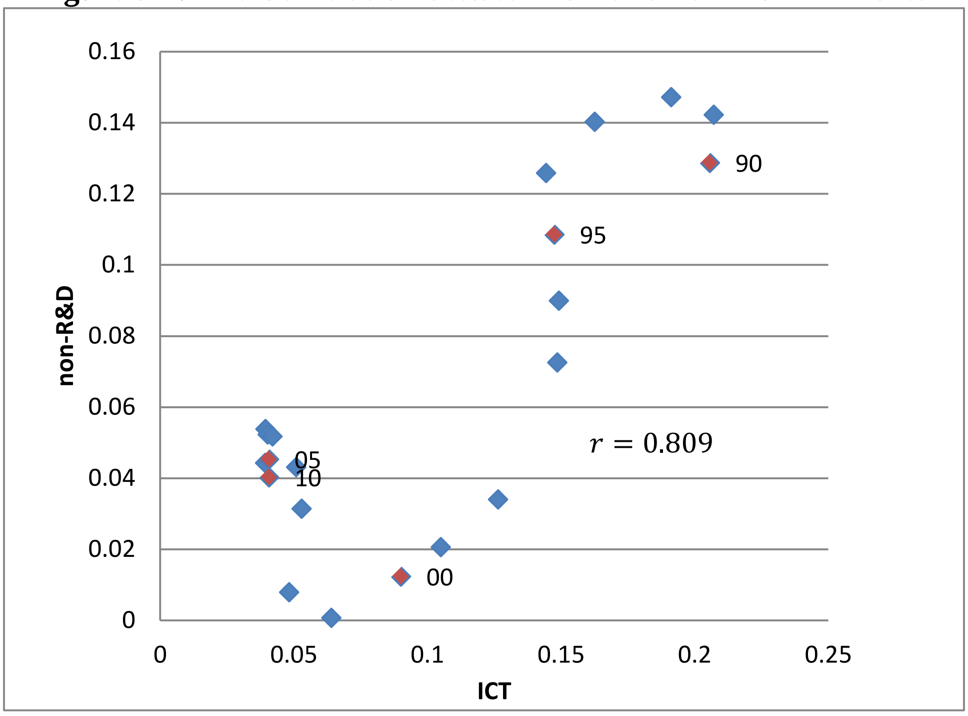
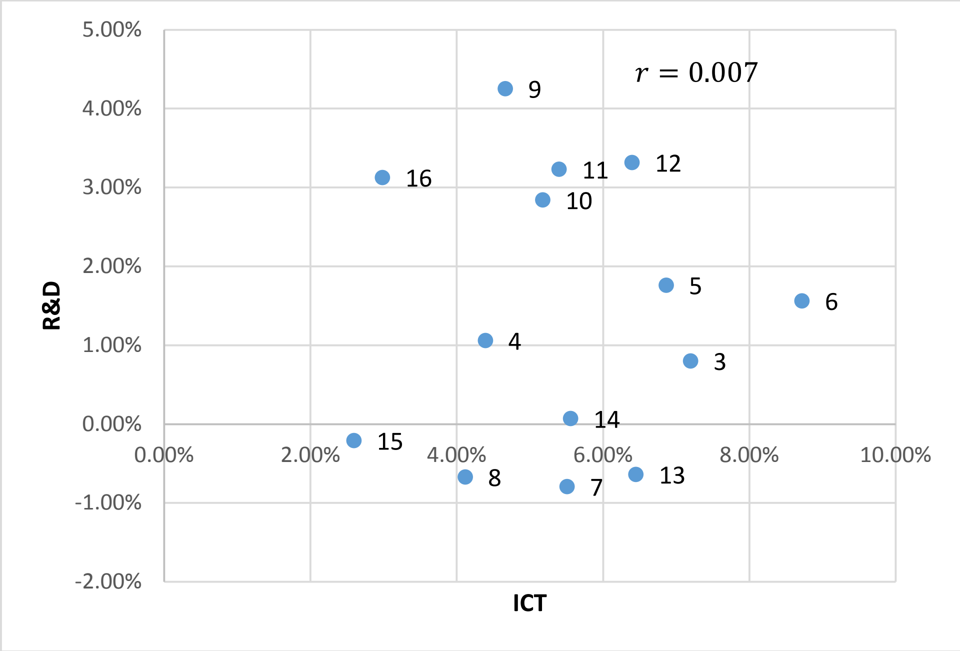
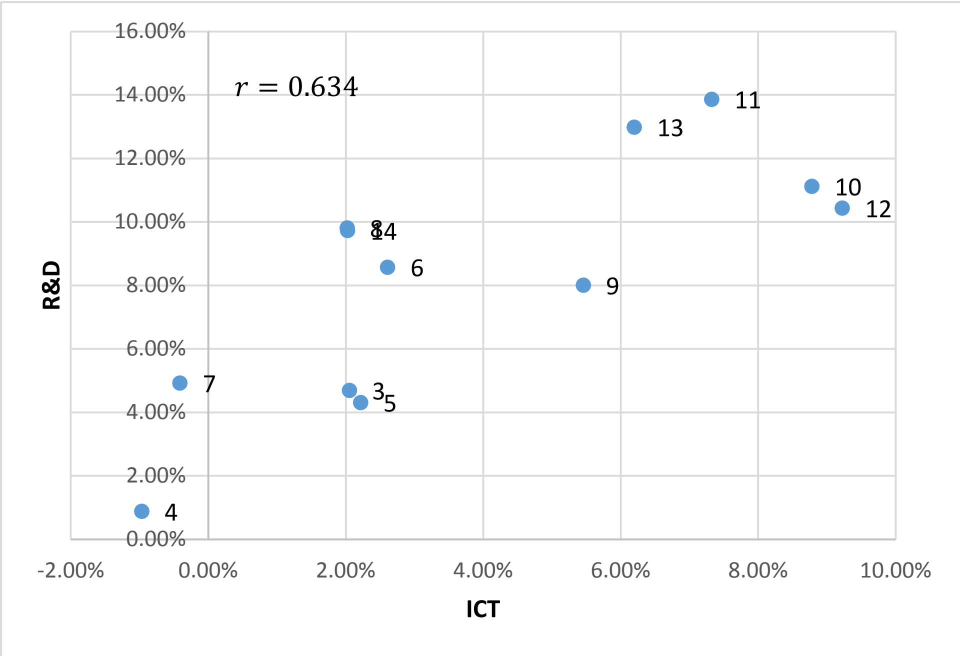


Figure 6-1: The Cross-sectional correlations between ICT and R&D in Japan



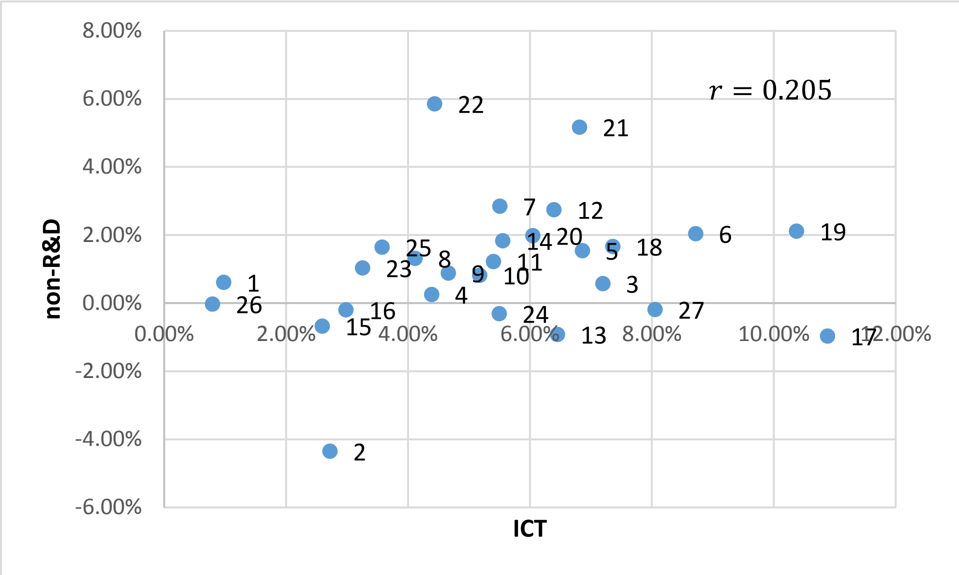
*The number corresponds to the industry shown in the Appendix table.

Figure 6-2: The Cross-sectional correlations between ICT and R&D in Korea



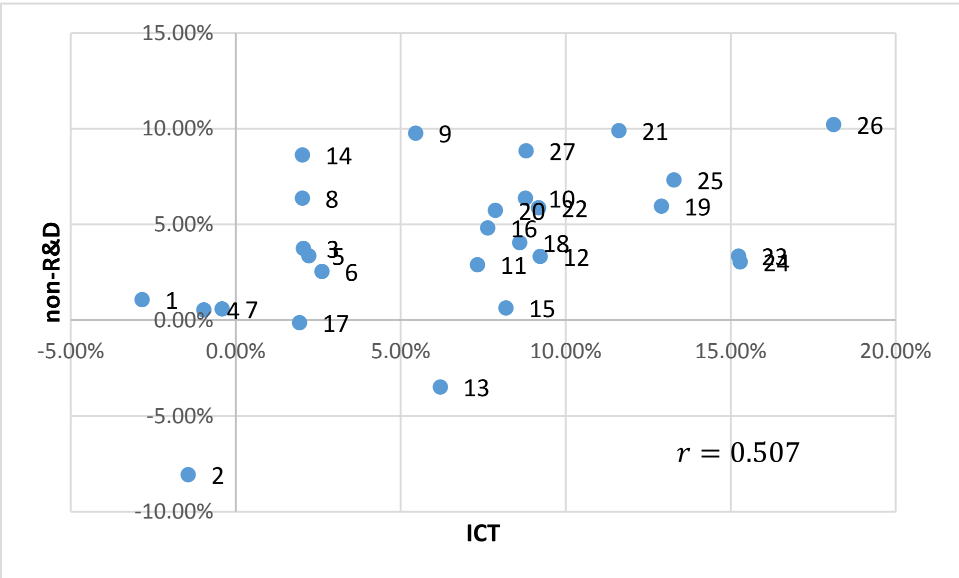
*The number corresponds to the industry shown in the Appendix table.

Figure 7-1: The Cross-sectional correlations between ICT and non-R&D in Japan



*The number corresponds to the industry shown in the Appendix table.

Figure 7-2: The Cross-sectional correlations between ICT and non-R&D in Korea



*The number corresponds to the industry shown in the Appendix table.