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Aggregate Total Factor Productivity and Resource Reallocation Effect of ICT Sectors in Korea: A Comparison with the USA, Japan and EU7

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The paper estimates total factor productivity and resource reallocation effect in ICT sectors from the cross-country data of the USA, Japan, EU7 and Korea. The source of economic growth has shifted from the non-ICT sector to the ICT sector after the ICT boom in the USA, Japan, EU7, and Korea. We find the contribution of ICT-producing sector to value-added growth and TFP growth has slowed down, but that of the ICT-using sector has grown since the middle of 1990s. In addition the reallocation effects of capital are outweighed in ICT-using service sectors such as trade and finance, and the reallocation effects of labor tend to be higher in non-ICT sectors, ICT-producing service, and ICT-producing manufacturing sectors, among others.

JEL Classification: O47, O57
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I. Introduction

It is well known that the ICT sector has significantly contributed to the economic growth and total factor productivity growth of ICT-adapting economies since the ICT boom started from the middle of 1990s. Even if 'IT fusion technology' has been mentioned as a new growth sector we cannot find alternative sectors to replace it so far. In addition there exist some limitations of the ICT sector on considering the contribution to economic growth due to its relatively low share of value-added in many ICT-adapting economies.[1] To understand productivity in a national economy

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[1] For example, the value-added share of ICT sector in GDP was 2.85 percent during 1990-1995, and 3.61 percent during 1996-2000, and 4.29 percent during 2001-2005, and 3.92 percent during 2006-2010 in Korea (BOK, ecos.bok.or.kr).

we have to analyze not only productivity at the industry level but also innovative activities at the firm level. Then one of the interesting issues is how to aggregate industrial data in order to estimate productivity at an economy-wide level or at the level of subsectors, such as ICT-producing, ICT-using, and non-ICT sectors etc.

Regarding the aggregation of the industrial productivities, there have been voluminous studies by Jorgenson, Gollop and Fraumeni (1987), Stiroh (2002), Jorgenson, Ho and Stiroh (2005), Jorgenson, Ho, Samuels and Stiroh (2007), Oliner, Sichel and Stiroh (2007), Fukao, Miyagawa, Pyo and Rhee (2012). Stiroh (2002) and Oliner, Sichel and Stiroh (2007) have defined the aggregate labor productivity in SNA and have analyzed the reallocation of material, the reallocation of hours through the decomposition of labor productivity. Jorgenson, Gollop and Fraumeni (1987), Jorgenson, Ho and Stiroh (2005) and Jorgenson, Ho, Samuels and Stiroh (2007) have defined the aggregate total factor productivity and have covered the resource reallocation effect through the decomposition of total factor productivity growth. In addition, Fukao, Miyagawa, Pyo and Rhee (2012) has investigated the resource reallocation in Korea and Japan through the decomposition of TFP growth. Jorgenson, Ho, Samuels and Stiroh (2007) has discussed in detail the theoretical and empirical results of total factor productivity growth and resource reallocation.

Jorgenson, Ho, Samuels and Stiroh (2007) has proposed three alternative methods 'aggregate production function method', 'production possibility frontier method' and 'direct aggregation across industries approach' to construct economy-wide estimates of output growth and the sources of growth in the United States during 1960-2005. They differ in adopting the assumption that the prices of output and the prices of capital and labor are the same across industries or not. First, the assumption of the method based on the aggregate production function is that the prices of output and the prices of input are the same across industries. This assumption is quite restrictive because output and input across industries could have been aggregated through a bottom-up process. Second, the production possibility frontier approach[2] assumes that the value-added function is no longer the same across industries. Therefore, the prices of value-added are different, but the prices of capital and labor of each type are same for all industries.[3] Third, the direct aggregation across industries has relaxed all the assumptions about the prices of

[2] The production possibility frontier describes efficient combinations of outputs and inputs for the economy as a whole. Aggregate output Y consists of outputs of investment goods and consumption goods. These outputs are produced from aggregate input X, consisting of capital services and labor services (Jorgenson, Ho and Stiroh (2005, p. 36)).

[3] The relatively small values of the capital and labor reallocation terms imply that the assumptions of input mobility and equal input prices across all industries are not grossly violated. This is reasonable in a well-functioning and relatively efficient economy like the US and shows that the production possibility frontier is an appropriate aggregation methodology(Jorgenson et al. (2007, p. 248)).

output and input, so these prices are not identical across industries any more.[4] On the one hand it will be possible to raise GDP through the mobility of factors from low price industries to high price industries if rates of return and wage rates as factor prices of capital and labor are different across industries and the factor prices are equal with its marginal productivity (Fukao, Miyagawa and Miho (2007, p. 8)). Thus, the market efficiency and potential growth will be improved if resource reallocation has a well-functioning mechanism in an economy.

This study examines whether resource reallocation is well-functioned between countries or not by constructing economy-wide estimates of output growth and the source of economic growth for three alternative aggregations assumed differently on the prices of output and factor inputs. Furthermore we measure TFP between ICT sectors and compare the sources of economic growth among USA, Japan, EU7 under the growth accounting framework.

The rest of this paper is organized as follows: Section II describes the data and methodology used to estimate resource reallocation effects; Section III investigates the concentration of ICT investment and the share of ICT investment across industries; Section IV estimates the TFP and resource reallocation effects in terms of not only in economy-wide but in 5 subsectors following the three methods of aggregation; and Section V provides a brief conclusion of the findings.

II. Data and Methodology

2.1. Data

For analysis of TFP and resource reallocation we need the detailed industrial data covered with capital and labor input of each type. As for Korea, we have used Korea Industrial Productivity (KIP) DB (2011)[5] covering with 72 industries of economy-wide during 1970-2009, and as for USA, Japan and EU7[6] we have employed EU KLEMS DB (2008)[7] covering with 30 industries of economy-wide

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[4] EUKLEMS Database has maintained the same approach as the direct aggregation across industries for aggregating output and input between industries(Timmer, Moergastel, Stuivenwold and Ypma (2007, p. 46)).

[5] KIP (Korea Industrial Productivity) DB (2011) is available at www.kpc.or.kr. We have built KIP DB under the EU KLEMS guideline since 2007 and have updated it annually, at the same time we have provided the same data for EU KLEMS, and the Korean database has been uploaded on the website of EU KLEMS DB with other countries.

[6] EU7 are Austria, Denmark, Finland, Germany, Italy, the Netherlands, and UK which is available for the detailed industrial data of capital and labor with each type in EU KLEMS DB (2008).

[7] Even though the version of EU KLEMS DB (2009, www.euklems.net) has opened, it is EU KLEMS DB (2008) that we can approach the detailed data of capital and labor of each type by countries.

during 1970-2005. In this paper we have kept the time series of 1980-2005 due to the availability for international comparison of TFP practically, but in Korea it is available during 1980-2009.

2.2. Methodology

Jorgenson, Ho, Samuels and Stiroh (2007, pp. 231-238) has presented three alternative methods for the aggregation of industrial output, capital, and labor data, as discussed below.

2.2.1. Aggregate Production Function

At first in the approach of aggregate production function, the four key assumptions are proposed. First each industry must have a gross output production function that is separable[8] in value-added, where value-added is a function of industry capital, labor, and technology. Second the value-added function is the same across all industries, up to a scalar multiple. Third in the functions the aggregate heterogeneous types of capital and labor must be identical in all industries. Fourth each type of capital receives the same prices in all industries.

Following by Jorgenson, Ho, Samuels and Stiroh (2007, p. 234) total factor productivity growth (v_T^{PF}) from the aggregate production function was defined as:

$$v_T^{PF} \equiv \Delta \ln V^{PF} - \overline{v}_K \Delta \ln K - \overline{v}_L \Delta \ln L \quad (1)$$

$$v_K = \frac{P_K K}{P_K K + P_L L} \text{ (share of capital income)} \quad \text{and}$$

$$v_L = \frac{P_L L}{P_K K + P_L L} \text{ (share of labor income)}$$

$$\overline{v}_K = 0.5^*(v_{K,t} + v_{K,t-1}) \quad \text{and} \quad \overline{v}_L = 0.5^*(v_{L,t} + v_{L,t-1})$$

V^{PF} = value-added from aggregate production function,

K = capital service, L = labor service.

2.2.2. Production Possibility Frontier

A second approach is the production possibility frontier. The major assumptions are that the prices of value-added are different across industries, and the prices of input are the same across industries. The key difference between the aggregate production function and the production possibility frontier is the relaxation of restriction that industries have identical value-added functions. If the value-added

[8] Pyo and Ha (2007, pp. 74-78) has presented that the separability assumption has not been accepted, and have concluded that gross output is a more appropriate concept than the real value-added for productivity measurement.

functions differ, the price of value-added is no longer the same across industries, so it is inappropriate simply to sum industry value-added.

Then total factor productivity growth (v_T) from the production possibility frontier following by Jorgenson, Ho, Samuels and Stiroh (2007, p. 236) was defined as:

$$v_T \equiv \Delta \ln V - \bar{v}_K \Delta \ln K - \bar{v}_L \Delta \ln L, \quad \Delta \ln V = \sum_j \bar{w}_j \Delta \ln V_j \tag{2}$$

V_j = industry value-added, $w_j = \dfrac{P_{V,j} V_j}{\sum_j P_{V,j} V_j}$,

share of industry value-added in the aggregate

$\bar{w}_j = 0.5*(w_{j,t} + w_{j,t-1})$, $P_{V,j}$ = price of industry value-added

If we decompose capital input into ICT capital[9] and non-ICT capital and labor input into quantity of labor and quality of labor, then we can rewrite equation (2) as:

$$\begin{aligned} v_T \equiv\ & \Delta \ln V - \bar{v}_{K,ICT} \Delta \ln K_{ICT} - \bar{v}_{K,NICT} \Delta \ln K_{NICT} \\ & -(\bar{v}_L \Delta \ln L - \Delta \ln H) - \Delta \ln H. \end{aligned} \tag{3}$$

The quality of labor is defined as the subtraction quantity of labor (total hours, $\ln H$) from labor services, as presented by Jorgenson, Gollop, and Fraumeni (1987, p. 264).

2.2.3. Direct Aggregation Across Industries

A third approach is the direct aggregation across industries. This approach imposes no cross-industry restrictions on either value-added or prices of inputs, which eliminates the assumptions of identical value-added functions, mobility of inputs across industries, and equal factor prices for all industries.

Jorgenson, Ho, Samuels and Stiroh (2007, pp. 237-238) has shown aggregate value-added growth from the direct aggregation across industries as:

$$\begin{aligned} \Delta \ln V \equiv\ & \sum_j \bar{w}_j \Delta \ln V_j \\ =\ & \sum_j \bar{w}_j \frac{\bar{v}_{K,j}}{\bar{v}_{V,j}} \Delta \ln K_j + \sum_j \bar{w}_j \frac{\bar{v}_{L,j}}{\bar{v}_{V,j}} \Delta \ln L_j + \sum_j \bar{w}_j \frac{1}{\bar{v}_{V,j}} v_{T,j} \end{aligned} \tag{4}$$

[9] ICT capital composes three assets such as computing equipment, communications equipment, and software etc.

$w_j = \frac{P_{V,j}V_j}{P_V V}$ (share of industry value-added in aggregate value-added)

$v_{K,j} = \frac{P_{K,j}K_j}{P_{Y,j}Y_j}$ (share of industry capital income in industry gross output)

$v_{L,j} = \frac{P_{L,j}L_j}{P_{Y,j}Y_j}$ (share of industry labor income in industry gross output)

$v_{V,j} = \frac{P_{V,j}V_j}{P_{Y,j}Y_j}$ (share of industry value-added in industry gross output)

$v_{T,j} =$ total factor productivity growth from direct aggregation across industries

Then $P_{V,j}V_j$ is value-added by industries and $P_V V$ is aggregate value-added. $P_{K,j}K_j$ is the capital income by industries, and $P_{L,j}K_j$ is the labor income by industries. $P_{Y,j}Y_j$ is the gross output by industries.

Combining equation (2) and equation (4)[10] we can find as;

$$v_T = \sum_j \frac{\overline{w}_j}{\overline{v}_{V,j}} v_{T,j} + \left(\sum_j \overline{w}_j \frac{\overline{v}_{K,j}}{\overline{v}_{V,j}} \Delta \ln K_j - \overline{v}_K \Delta \ln K \right)$$

$$+ \left(\sum_j \overline{w}_j \frac{\overline{v}_{L,j}}{\overline{v}_{V,j}} \Delta \ln L_j - \overline{v}_L \Delta \ln L \right)$$

$$= \sum_j \frac{\overline{w}_j}{\overline{v}_{V,j}} v_{T,j} + REALL_K \; REALL_L + \quad (5)$$

$REALL_K =$ reallocation of capital, $REALL_L =$ reallocation of labor

Equation (5) shows how aggregate TFP growth from the production possibility frontier relates to the sources of growth at the industry level. The first term means weighted average of industry TFP growth. And the weight, $\frac{\overline{w}_j}{\overline{v}_{V,j}} = \frac{P_{Y,j}Y_j}{P_V V}$, is

[10] Equation (4) was derived from the decomposition of industry-level gross output growth written as follows:
$\Delta \ln Y_j = \overline{v}_{K,j}\Delta \ln K_j + \overline{v}_{L,j}\Delta \ln L_j + \overline{v}_{X,j}\Delta \ln X_j + v_{T,j}$, $\Delta \ln Y_j = \overline{v}_{V,j}\Delta \ln V_j + \overline{v}_{X,j}\Delta \ln X_j$, $Y_j =$ industry gross output, $v_{K,j}$, $v_{L,j} =$ the share of industry capital or labor income in industry gross output, $v_{X,j} =$ the share of industry intermediate in industry gross output, $X_j =$ industry intermediate inputs, $V_j =$ industry value-added, and $v_{V,j} =$ share of value-added in industry gross output (Jorgenson et al. (2007, p. 237)).

interpreted as the Domar weight (Domar (1961, pp. 717–721)). The second and the third term reflect the reallocation of capital and labor respectively. These reallocation effects are generated from the difference between the growth of aggregate TFP and the sum of the Domar-weighted industry TFP growth. If these terms are positive, TFP growth from the production possibility frontier exceeds Domar-weighted TFP growth. This happens when capital and labor inputs command different prices in different industries and the industries with higher prices have faster input growth rates. In this case aggregate capital or labor inputs grow more slowly than weighted averages of their industry counterparts.

2.2.4. Reallocation of Value-added and Aggregation by ICT Sectors

As discussed above, the price of value-added is same in all industries in the aggregate production function, while the production possibility frontier does not require this assumption. This leads to different growth rates for aggregate value-added. We define the reallocation of the value-added as the difference in the growth rates of value-added from the aggregate production function and from the production possibility frontier as:

$$REALL_{VA} = \Delta \ln V^{PF} - \Delta \ln V = \Delta \ln V^{PF} - \sum_j \bar{w}_j \Delta \ln V_j \tag{6}$$

V^{PF} = aggregate value-added from aggregate production function

V = aggregate value-added from production possibility frontier.

To quantify the contribution of ICT sector's value-added to aggregate value-added we can rewrite equation (4) as:

$$\Delta \ln V = \sum_{j \in P} \bar{w}_j \Delta \ln V_j + \sum_{j \in U} \bar{w}_j \Delta \ln V_j + \sum_{j \in N} \bar{w}_j \Delta \ln V_j \tag{7}$$

P = ICT-producing, U = ICT-using, and N=non-ICT.

Similarly, the contributions of the ICT sectors to the Domar-weighted TFP growth can be estimated as follows:

$$\sum_j \frac{\bar{w}_j}{\bar{v}_{V,j}} v_{T,j} = \sum_{j \in P} \frac{\bar{w}_j}{\bar{v}_{V,j}} v_{T,j} + \sum_{j \in U} \frac{\bar{w}_j}{\bar{v}_{V,j}} v_{T,j} + \sum_{j \in N} \frac{\bar{w}_j}{\bar{v}_{V,j}} v_{T,j} \tag{8}$$

P = ICT-producing, U = ICT-using, and N = non-ICT.

On the other hand the growth of capital and labor on above descriptions is not just capital stock and quantity of labor but capital service and labor service by tornqvist index. For measurement of capital service we follow EU KLEMS methodology (Timmer, Moergastel, Stuivenwold and Ypma (2007, pp. 33-37)). Capital service is defined as translog aggregation of capital stock shown as [Appendix A].

In this study we classify assets into 11 types such as (1) residential structures, (2) non-residential structures, (3) infrastructure, (4) transport equipment, (5) computing equipment, (6) communications equipment, (7) other machinery and equipment, (8) products of agriculture and forestry, (9) other products, (10) software, and (11) other intangibles. The nominal rate of return can be estimated in two different ways. The first is ex-ante approach which is based on some exogenous value for rate of return, for example interest rates on government bonds. The second approach is the ex-post approach, which estimates the internal rate of return as a residual value of capital compensation from national accounts, depreciation, and capital gains. The latter is attractive because it ensures consistency between income and production accounts. Hence EU KLEMS DB employed the ex-post approach. This nominal rate of return is the same for all assets in an industry, but is allowed to vary across industries. The data of depreciation rates of each type are employed by Pyo (2003), Pyo, Jung and Cho (2007) as Table 1.

[Table 1] Depreciation rates of each type

(%)

	1968–1977	1977–1987	1987–1997	1997–2009
Residential structures	5.5	1.2	3.3	3.3
Non-residential structures	-6.7	-1.3	3.0	3.0
Infrastructure	9.7	8.4	1.0	1.0
Transport equipment	49.3	28.7	16.9	16.9
Computing equipment	11.5	11.5	11.5	11.5
Communications equipment	11.5	11.5	11.5	11.5
Other machinery and equipment	1.1	11.4	9.2	9.2
Products of agriculture and forestry	-	-	-	-
Other products	-	-	-	-
Software	24.7	24.7	24.7	24.7
Other intangibles	-	-	-	-

Sources: Pyo (2003) and Pyo, Jung, and Cho (2007)

Following EU KLEMS methodology (Timmer, Moergastel, Stuivenwold, and Ypma (2007, p. 24)), labor service is a translog quantity index of each type, where weights are given by the average shares of each type in the value of labor compensation shown as [Appendix A].

Regarding to industrial classification of ICT there are some of studies such as Stiroh (2002), van Ark, Inklaar and McGuckin (2003), Inklaar, O'Mahony and Timmer (2005), Pilat, Lee and van Ark (2002). We follow the classification of Inklaar et al. (2005) on account that Inklaar et al. (2005) has tried to analyze the productivity of the ICT sectors between USA and Europe, and we employ EU

KLMES DB for ICT productivity analysis. Thus we have sorted the industrial classification of EUKLEMS Database (2008) and KIP Database (2011) into ICT-producing, ICT-using, and non-ICT according to Inklaar et al. (2005), as presented in Table 12.

III. Concentration of ICT Capital

In general, the investment of ICT capital has expanded and greatly contributed to economic growth since the ICT-boom in the mid-1990s. Thus, we have investigated the shares of the ICT capitals of Korea, the USA, Japan, and EU7 countries. Moreover, we estimate whether ICT capital has been steadily invested or not through the measurement of industrial concentration of ICT capital.

3.1. Shares of ICT Capital

Table 13 shows the shares of ICT capital in Gross Fixed Capital Formation by industries between Korea, USA, Japan, Germany and UK during 1981-2005. Even if the industrial shares are a little different between countries we can find the sectors of high share are ICT-Producing Manufacturing including Office, accounting, computing and other electrical machinery, and ICT-Producing Service including Post and telecommunications, and ICT-Using Service including Wholesale and Retail trade, Finance and Insurance, Renting and business activities. In other words ICT capital shares, in Korea, are relatively high in such as Finance and Insurance (62.4%), Wholesale and Retail trade (54.3%),[11] Education (45.8%), Renting and business activities (30.9%), Transport equipment (23.0%), Office, accounting, computing and other electrical machinery (21.7%) during 1981-2005. In USA the shares are in order of Wholesale and Retail trade (62.9%), Post and telecommunications (53.2%), Renting and business activities (47.9%), Finance and Insurance (35.9%), Office, accounting, computing and other electrical machinery (29.5%). In Japan the shares are in order of Wholesale and Retail trade (58.1%), Post and telecommunications (46.2%), Finance and Insurance (38.3%), Renting and business activities (33.0%), Office, accounting, computing and other electrical machinery (16.0%). And the order of shares in Germany, UK is similar to the prior countries. Thus the shares of ICT capital are high in such as Office, accounting, computing and other electrical machinery in manufacturing, and Wholesale and Retail trade, Post and telecommunications, Finance and Insurance, Renting and business activities etc. in service.

[11] Wholesale and retail trades include "sales and maintenance of motor vehicles."

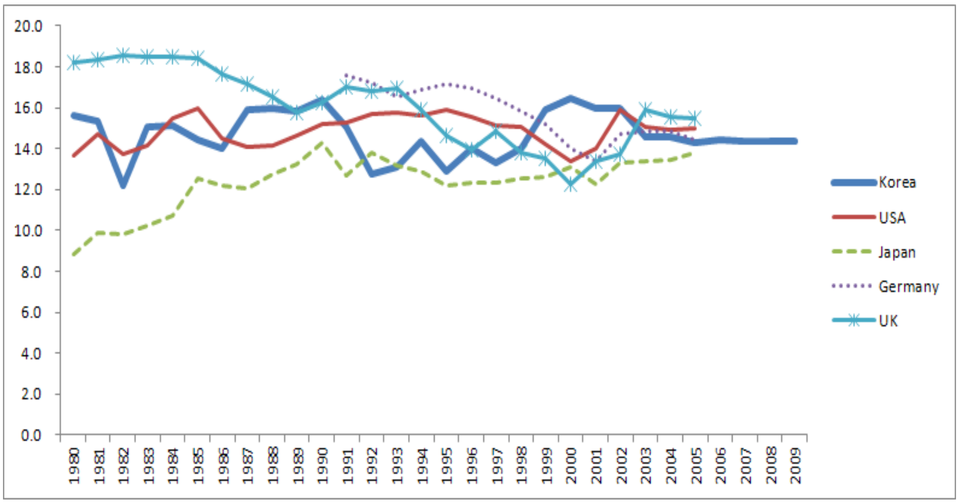
3.2. Concentrations of ICT Capital

In order to measure the concentration of industry Jacquenmin and Berry (1979) has proposed the index of entropy, and Gorzig, Gornig, Nayman and O'Mahony (2012) has analyzed the concentration of ICT capital between Germany, France and UK using by the index. Gorzig, Gornig, Nayman and O'Mahony (2012, p. 112) has presented the entropy index as:

$$E(s) = \exp\left(\sum_{i=1}^{n} s_i \ln(1/s_i)\right), \quad s_i = I_i / \sum_{i=1}^{n} I_i, \quad I_i = \text{investment by industries} \quad i$$

If all investment has done by one industry the value will be 1, and if investment is spread evenly across all industries the value is equal to be the number of industries considered. So the concentration of investment will be increased if the entropy index is more and more decreased. In Figure 1 the ICT entropy has a trend of decreasing or keeps the lower level since the middle of 1990s of ICT boom between Korea, USA, Japan, Germany, UK. In Korea the ICT entropy is relatively low level during 1992-1997 but has increased after the financial crisis of 1998, and has decreased during 2000s. In Japan we can see the investment on ICT capital has been intensively done due to the lowest level among 5 countries. And in USA, UK, and Germany the ICT entropy has a slowdown trend since the middle of 1990s, but has increased fast after 2000 of dot-com crash. On a whole we can find the ICT entropy of 5 countries has been stable since 2000. This shows the ICT entropy tends to be maintained at certain level since 2000.

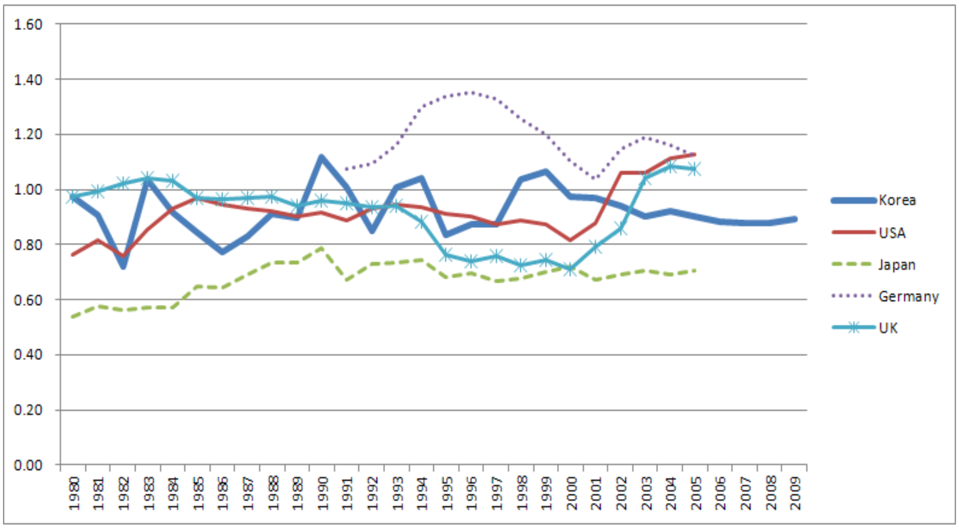
[Figure 1] Concentration of ICT capital investment (entropy of ICT capital)



Sources: EU KLEMS Database (www.euklems.net) and KIP Database (2011)

Meantime we have estimated the relative entropy by dividing the ICT entropy by the GFCF entropy to examine the concentration of ICT capital investment in the aspect of total capital investment, which includes non-ICT capital investment. If there is no difference between concentration of ICT capital and GFCF the relative entropy becomes 1. And it will be over 1 if the concentration of ICT capital investment is lower[12] than that of GFCF, and vice versa. In Figure 2 the relative entropy, in Korea, is under 1 during the middle of 1990s, but is over 1 during the financial crisis, and keeps below 1 since 2000. So we can see concentration of ICT capital investment of Korean economy is relatively high except during the financial crisis. Especially the relative entropy is under 1 in succession in Japan. Whereas in USA and UK the relative entropy have increased and became over 1 since 2002 or 2003 even if they have been kept under 1 before. In contrast the relative entropy of Germany has been over 1 during all the periods.

[Figure 2] Relative concentration of ICT capital investment (entropy of ICT capital/entropy of GFCF)



Sources: EU KLEMS Database (www.euklems.net) and KIP Database (2011)

Therefore even if the concentration of ICT capital investment has been high through ICT boom, but the trend has been changed except Japan. In other words the investment of ICT capital has been gradually eroded between countries, so the concentration of ICT capital investment has been converged at constant level during 2000s. This suggests the ICT investment should enter into some of maturing steps, so it is needed to find new growth engine industry to trigger more investments.

[12] This refers to the increase in the entropy index of ICT.

IV. Growth Accounting and Resource Reallocation Effects

4.1. Growth Accounting in Korea[13]

At first Table 2 presents the contribution to value-added growth by ICT sectors estimated by equation (7). During 1981-2009 the growth rate of value-added is on average 6.44%, and could be decomposed into as 1.70% in ICT-using, 1.17% in ICT-producing, and 3.57% in non-ICT. The contribution to value-added growth in non-ICT is estimated as 55.4% on average, and is 26.5% in ICT-using and 18.2% in ICT-producing. Thus, the contribution of non-ICT to the Korean economic growth has been dominated for the past three decades. However, the contribution of the ICT sector has exceeded that of the non-ICT sector during 1996-2000, moreover that of the ICT-producing sector has greatly increased since the ICT boom. Importantly, the contribution of the ICT-producing sector gradually decreases, and the contribution of the ICT-using sector, on the other hand, increases by degrees. Thus, the sources of Korean economic growth from the non-ICT sector to the ICT sector have changed since the ICT boom, and the contribution of the ICT-using sector has recently become greater than that of the ICT-producing sector.[14]

[Table 2] Contribution of value-added growth in the ICT sectors of Korea

	1981–1990	1991–2000	1991–1995	1996–2000	2001–2005	2006–2009	1981–2009
				Growth rates (%)			
Value-added	9.40	6.12	7.69	4.55	4.20	2.65	6.44
ICT-Using	2.64	1.49	2.26	0.71	0.92	0.91	1.70
ICT-Producing	1.05	1.44	1.11	1.77	1.25	0.71	1.17
Non-ICT	5.71	3.20	4.32	2.08	2.03	1.03	3.57
				Contributions (%)			

[13] Following the EU KLEMS methodology, capital compensation is derived as value-added minus labor compensation (Timmer, Moergastel, Stuivenwold, and Ypma (2007, p. 21)). Thus, capital compensation as residual can be estimated as negative if labor compensation, including those of the self-employed, is overestimated. This fact originated from the fact that labor compensation of self-employed individuals is not registered in the National Accounts. So there could be an imputation by assuming that the compensation per hour of self-employed is equal to the compensation per hour of employee (Timmer, Moergastel, Stuivenwold and Ypma (2007, p. 47)).

The results are found mainly in the sectors of agriculture, forestry and fishing, hotels and restaurants, education, and other social and private services, wherein the shares of self-employed to total self-employed in economy-wide are relatively high in Korea is similar to other countries. The fact capital compensations are negative in parts of some sectors will affect the process of growth accounting in terms of income shares as weight. Namely the contribution of capital to output will be underestimated, and the contribution of labor to output will be overestimated in that case.

[14] On the source of USA economic growth Jorgenson et al. (2007, p. 245) has pointed out that the contribution of the ICT- producing sector to economic growth has been slowed down since 2000.

Value-added	100.0	100.0	100.0	100.0	100.0	100.0	100.0
ICT-Using	28.0	24.3	29.4	15.6	21.8	34.2	26.5
ICT-Producing	11.2	23.4	14.4	38.8	29.8	26.9	18.2
Non-ICT	60.8	52.3	56.2	45.7	48.4	38.9	55.4

[Table 3] Growth Accounting in Korea (Production Possibility Frontier)

(growth rates (%))

	1981–1990	1991–2000	1991–1995	1996–2000	2001–2005	2006–2009	1981–2009
Value-added	9.40	6.12	7.69	4.55	4.20	2.65	6.44
Capital	2.86	1.83	2.03	1.62	1.34	1.27	2.02
ICT capital	0.04	0.07	0.05	0.08	0.07	0.06	0.06
Non-ICT capital	2.82	1.76	1.98	1.54	1.27	1.22	1.97
Labor	2.67	2.12	2.98	1.25	1.70	0.95	2.07
Quantity of labor	2.04	1.32	2.42	0.21	1.03	0.19	1.36
Quality of labor	0.63	0.80	0.56	1.04	0.67	0.76	0.71
TFP	3.87	2.18	2.68	1.68	1.16	0.43	2.35

Next we have compared the growth accounting by the production possibility frontier approach with the growth accounting by the direct aggregation across industries in Korea as Table 3 and Table 4. The production possibility frontier assumes the prices of output are different but the prices of input are same across industries, and the direct aggregation across industries assumes there are no restriction on the prices of output and inputs. Firstly the capital growth rates of production possibility frontier are much greater than that by the direct aggregation across industries during each period. While the labor growth rates of the direct aggregation across industries during long period (1981-2009) are estimated as somewhat higher, but they are reversed during 1996-2000. Secondly TFP growth by the production possibility frontier has been estimated as 2.35% and TFP growth by the direct aggregation across industries has been estimated as 2.53% during 1981-2009. As a whole TFP growths by the production possibility frontier are greater than the direct aggregation across industries during 1980s, the second half of 2000s. On the contrary the latter is greater a little than the former during 1990s, the first half of 2000s. Thirdly the contributions of labor to value-added growth from both approaches have surpassed that of capital during the long term period (1981-2009), but the contribution of capital is greater than that of labor during 1996-2000. Fourthly the contribution of non-ICT capital to value-added growth is overall greater than that of ICT. Moreover, the contribution of quantity of labor to value-added growth is greater than that of quality of labor in the labor side.[15]

[Table 4] Growth Accounting in Korea (Direct Aggregation Across Industries)

(growth rates (%))

	1981–1990	1991–2000	1991–1995	1996–2000	2001–2005	2006–2009	1981–2009
Value-added	9.40	6.12	7.69	4.55	4.20	2.65	6.44
Capital	2.35	1.44	1.60	1.29	0.85	1.12	1.61
ICT capital	0.07	0.08	0.07	0.10	0.04	0.07	0.07
Non-ICT capital	2.29	1.36	1.53	1.19	0.81	1.05	1.54
Labor	3.24	2.06	3.37	0.74	1.82	1.20	2.30
Quantity of labor	2.04	1.32	2.42	0.21	1.03	0.19	1.36
Quality of labor	1.20	0.74	0.95	0.53	0.78	1.01	0.94
TFP	3.81	2.62	2.73	2.52	1.54	0.33	2.53

Note: ICT capital includes computing equipment, communications equipment, software, and so on.

In summary, even if some differences in terms of the growth of capital, labor, and TFP between approaches exist, the growths are not very far apart. The differences in input growths caused by unequal assumptions can be explained using the reallocation effects of capital and labor. Now we try to investigate these resource reallocation effects.

4.2. Resource Reallocation Effects

We try to analyze the reallocation effect of capital and labor using three methods such as the aggregate production function, the production possibility frontier, and the direct aggregation across industries in terms of economy-wide. The assumptions of the first approach are the most restrictive, while the third is so relaxed. Reallocation terms quantify the impact of the restrictions and show how much their violation distorts the picture of aggregate economic growth and its sources (Jorgenson et al. (2007, p. 243)). We have examined the reallocation effect of value-added through the estimators generated from the aggregate production function and the production possibility function (equation 6), at the same time investigated the reallocation effect of capital and labor through the difference of estimators generated from the production possibility function and the direct aggregation across

[15] During 1981-2009 the contribution of ICT capital to value-added growth is 0.9%, and that of Non-ICT is 30.5% in the production possibility frontier approach and each of them is 1.0%, 24.0% in the direct aggregation across industries approach. So the contribution of Non-ICT capital to value-added growth has been more dominated. In addition the contribution of quantity of labor to value-added growth is 21.1%, and that of quality of labor is 11.1% in the production possibility frontier approach and each of them is 21.1%, 14.6% in the direct aggregation across industries approach.

industries (equation 5).

At first the reallocation effects of value-added have been estimated as negative during 1980s and 1990s, but as positive during 2000s in Table 5. The estimated reallocation effects are –1.23% during 1980s, –0.49% during 1990s, 0.31% during 2001-2005, 0.53% during 2006-2009. The reason why the reallocation effect of value-added has switched from negative to positive is that for instance in the industry like as ICT sector the growth of aggregate value-added as well as the decline of its price could appear fast simultaneously, then the growth of value-added by the production possibility function could be lower due to the drop in the share of nominal value-added as a weight than by the aggregate production function.[16] So it may affect the reallocation effect of value-added becomes positive. In the Korean economy these facts have been found during 2000s.

[Table 5] Resource Reallocation Effect in Korea (economy-wide)

(growth rates (%))

	1981–1990	1991–2000	1991–1995	1996–2000	2001–2005	2006–2009	1981–2005	1981–2009
	Aggregate Production Function vs. Production Possibility Frontier							
Growth of VA (APF)	8.17	5.63	7.04	4.22	4.51	3.18	6.42	5.97
Growth of VA (PPF)	9.40	6.12	7.69	4.55	4.20	2.65	7.05	6.44
Reallocation of value-added	-1.23	-0.49	-0.65	-0.34	0.31	0.53	-0.63	-0.47
	Production Possibility Frontier vs. Direct Aggregation Across Industries							
Aggregate TFP	3.87	2.18	2.68	1.68	1.16	0.43	2.65	2.35
Domar-weighted TFP	3.81	2.62	2.73	2.52	1.54	0.33	2.88	2.53
ICT-using	0.57	0.09	0.48	-0.31	0.18	0.22	0.30	0.29
ICT-producing	0.41	1.18	0.85	1.51	0.85	0.54	0.81	0.77
Non-ICT	2.83	1.36	1.39	1.32	0.51	-0.43	1.78	1.47
Reallocation of capital (1)	-0.50	-0.38	-0.43	-0.33	-0.49	-0.15	-0.45	-0.41
Reallocation of labor (2)	0.57	-0.06	0.38	-0.51	0.11	0.25	0.22	0.23
Total = (1) + (2)	0.06	-0.44	-0.05	-0.84	-0.38	0.09	-0.23	-0.18

Note: 1) APF (Aggregate Production Function), PPF (Production Possibility Function)
2) Aggregate TFP: TFP by the Production Possibility Function
3) Domar-weighted TFP: TFP by Direct Aggregation Across Industries

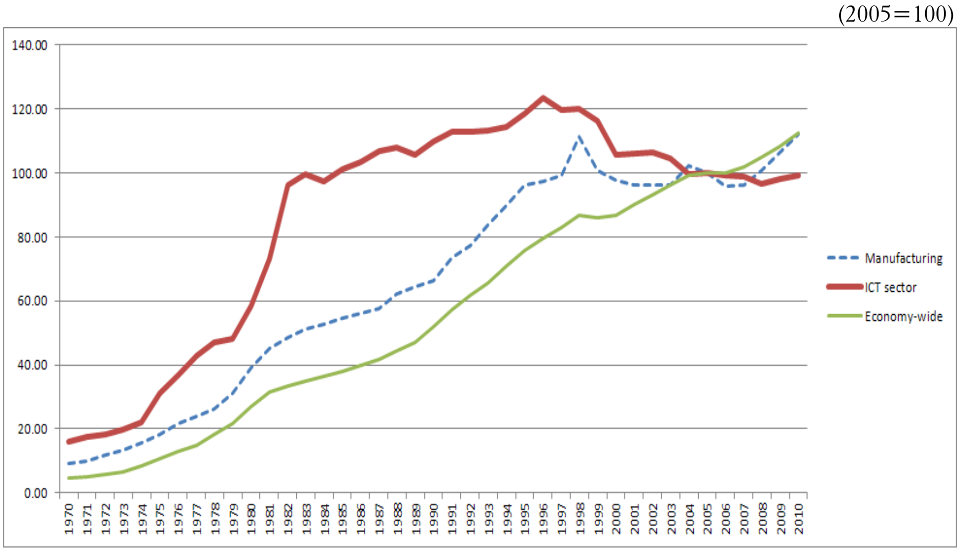
Actually in the Korean economy the GDP deflator of the ICT sector has peaked before and after 1995 (Figure 3). In other words the growths of GDP deflator have a

[16] In the production possibility frontier the prices of value-added are different across all industries, and value-added is aggregated by tornqvist index with the average share of value-added by industry. And in the aggregate production function the prices of value-added are the same across industries. So the growth of value-added by the former could be lower than by the latter due to the drop in the average share of value-added as a weight, especially in ICT sector the decline of value added deflator is fast.

decreasing pattern since the ICT boom in the middle of 1990s such as –2.2% during 1996-2000, –1.1% during 2001-2005, and –0.1% during 2006-2010 in Table 6. However the value-added growth of the ICT sector has grown fast, and the gaps of growth rates between the manufacturing and ICT sectors are expanded during the 1990s. So ICT sector has a feature that the growth of value-added has been so fast, and GDP deflator has been dropped simultaneously. Furthermore during ICT boom of 1996-2000 the positive reallocation effects of value-added have been also found in other countries such as USA (5.95%), Denmark (5.19%), Finland (8.12%), Netherlands (6.44%), UK (6.01%) as Table 7. In these countries the gap of reallocation effects of value-added between the first half and the second half of 1990s has been large.

[Figure 3] Trend of GDP deflators by industry

(2005=100)



Source: Bank of Korea, ECOS (www.ecos.bok.or.kr)

[Table 6] GDP Deflator and Growth of Value-Added By Industry

(%)

Period	GDP deflator			Growth of value-added		
	Manufacturing	ICT sector	Economy-wide	Manufacturing	ICT sector	Economy-wide
1971–1980	15.6	14.3	19.7	16.2	18.6	9.1
1981–1990	5.5	7.0	6.9	12.3	14.6	9.7
1991–1995	7.8	1.5	7.9	8.2	17.4	7.9
1996–2000	0.6	-2.2	2.7	9.2	16.7	5.4
2001–2005	0.5	-1.1	2.9	6.5	9.9	4.5
2006–2010	2.4	-0.1	2.4	6.3	3.7	3.8
1971–2010	6.7	5.1	8.6	10.9	14.3	7.4

Source: Bank of Korea, ECOS (www.ecos.bok.or.kr)

[Table 7] Reallocation of Value-Added in USA, Japan, EU7 and Korea (economy-wide)

(growth rates(%))

	1981–1990	1991–2000	1991–1995	1996–2000	2001–2005	1981–2005
USA	6.62	5.30	4.66	5.95	5.00	5.77
Japan	4.85	1.40	1.86	0.93	0.46	2.59
Austria	5.20	4.39	5.04	3.74	3.36	4.51
Denmark	6.51	4.48	3.76	5.19	3.86	5.16
Finland	9.06	4.48	0.84	8.12	4.31	6.28
Germany	-	2.98	3.92	2.23	2.23	2.71
Italy	11.94	5.13	5.63	4.63	4.13	7.66
Netherlands	3.52	5.24	4.04	6.44	4.10	4.32
UK	8.18	5.43	4.86	6.01	5.68	6.58
Korea	-1.23	-0.49	-0.65	-0.34	0.31	-0.63

Note: In Germany the growth rates are available during 1992-2005.

Secondly equation (5) shows the growth of aggregate TFP by the production possibility frontier can be decomposed into the Domar weighted TFP by the direct aggregation across industries and the reallocation of capital and the reallocation of labor. In Table 5 total reallocation effects (reallocation effect of capital and labor) are 0.06% during 1981-1990, and –0.05% during 1991-1995, and –0.84% during 1996-2000, and –0.38% during 2001-2005, and 0.09% during 2006-2009. The values are small during the periods of 1981-1990, 1991-1995, 2006-2009. Thus the result that the production possibility frontier is reasonable method as Jorgenson et al (2007, p. 248) presented has been found during not all periods but some periods in the Korean economy.

In detail during 1981-1990 the reallocation of capital is estimated as negative even if the reallocation of labor is positive. So we can say labor inputs have increased in the industries the prices of labor have been high, but we can't find such a positive effect in capital reallocation. During 1991-2000 the reallocation effects of capital and labor are all negative, especially the negative reallocation effect of labor (–0.51%) has been the most high during 1996-2000 confronting the strong restruction process of labor due to the financial crisis of 1997-1998. The reallocation effects of capital have not improved because the effects have been negative continuously since 2000 as well, but the reallocation effects of labor have been improved since the financial crisis. Thus we can find the efficiency of reallocation of capital is insufficient in the aspect of resource mobility. Consequently, the reallocation effects of capital and labor in the USA, Japan and EU7 have been estimated as in Table 14. In the USA, all the reallocation effects of capital and labor are negative in each period, so the contribution of reallocation to aggregate TFP growth is negative.[17] In the Netherlands and UK, the reallocation effects of labor

[17] The result of negative reallocation of capital and labor is similar to that of Jorgenson et al. (2007). Only the absolute values of Jorgenson et al. (2007) are not equal to this study using EU KLEMS

are negative in each period. In Japan experiencing the "lost decade" in the 1990s, the reallocation of capital is negative (–0.01%), and the reallocation of labor is positive (0.02%). During 1981-2005 the countries the contribution of reallocation of capital has been greater than that of labor are Japan (0.02%), Denmark (0.04%), Germany (0.12%), and UK (0.12%). In addition, the countries the contribution of reallocation of labor has been reversely higher than that of capital are Finland (0.05%), Italy (0.08%). Therefore during the whole period the countries the contribution of total reallocation effect to aggregate TFP growth is positive are Japan (0.02%), Denmark (0.04%), Finland (0.02%), Germany (0.08%), Italy (0.09%). On the contrary the countries the total effect is negative are the USA (–0.34%), Austria (–0.09%), the Netherlands (–0.06%), and UK (–0.09%).

Thirdly we have estimated the decomposition of the Domar-weighted TFP from equation (8) into the ICT-using, ICT-producing, and non-ICT sectors (Table 5). The growth of the TFP of non-ICT was 2.83% during the 1980s and 1.39% from 1991 to 1995, and thus, it has dominated TFP growth. Since the second half 1990s, however, the contribution of ICT-producing to Domar-weighted TFP has been much greater.

Similar to the contribution of value-added, the contribution of the ICT-using sector to Domar-weighted TFP has gradually increased, and the contribution of the ICT-producing sector has decreased slowly, but the contribution of the non-ICT sector has slowed down greatly. In other words, the TFP growth of the ICT-using sector was 0.57% during the 1980s, 0.48% during 1991-1995, –0.31% during 1996-2000, 0.18% during 2001-2005, 0.22% during 2006-2009, so it has increased since the middle of 1990s. While the TFP growth of the ICT-producing sector was 0.41% during the 1980s, 0.85% during 1991-1995, 1.51% during 1996-2000, 0.85% during 2001-2005 and 0.54% during 2006-2009, so the growths have slowed down since the middle of 1990s. Thus the source of Korean economic growth in terms of TFP growth can be found in the ICT-producing sector so far, but we can find it may have slowly shifted to the ICT-using sector. Meantime this tendency of TFP growth from the ICT-producing sector to the ICT-using sector has also been discovered in the USA, Japan, the Netherlands, and UK, among others (Table 15). Therefore it has been detected the source of economic growth in terms of TFP growth have been shifted from the ICT-producing sector to the ICT-using sector not only in Korea

Database.

	1960–2005	1960–1995	1995–2000	2000–2005
Aggregate TFP	0.48	0.35	0.52	1.30
Domar-weighted TFP	0.57	0.43	0.70	1.38
Reallocation of capital(1)	-0.06	-0.07	-0.14	0.06
Reallocation of labor(2)	-0.02	-0.01	-0.04	-0.14

Source: Jorgenson et al. (2007, p. 244)

but also in other countries.

(1) Reallocation Effects of Capital by the ICT Sector

Until now we have analyzed resource reallocation in economy-wide as the aggregated economy. Furthermore we have examined it in each subsector such as ICT-using manufacturing, ICT-using service, ICT-producing manufacturing, ICT-producing service, and non-ICT sectors.[18] Following Fukao, Miyagawa, Pyo and Rhee (2012, p. 284) equation (5) of the reallocation of capital can be decomposed as;

$$\sum_j \bar{w}_j \frac{\bar{v}_{K,j}}{\bar{v}_{V,j}} \Delta \ln K_j - \bar{v}_K \Delta \ln K$$
$$= \sum_j \left(\bar{w}_j \frac{\bar{v}_{K,j}}{\bar{v}_{V,j}} - \bar{w}_{K,j} \bar{v}_K \right) \Delta \ln K_j + \bar{v}_K \left(\sum_j \bar{w}_{K,j} \Delta \ln K_j - \Delta \ln K \right). \quad (9)$$

Then $w_{K,j} = \frac{\sum_k p_{K,k} K_{k,j}}{\sum_j \sum_k p_{K,k} K_{k,j}}$ means capital income by industries, and has been assumed the prices of capital by each type are equal in all industries according to the assumption of production possibility frontier approach ($P_{K,k} = P_{K,k,i}$). The second term, $\bar{v}_K \left(\sum_i \bar{w}_{K,j} \Delta \ln K_j - \Delta \ln K \right)$, of equation (9) means the reallocation effect of changes in the capital composition within each industry following by Fukao et al. (2007, p. 11). We try to focus mainly on the inter-industry reallocation effects from the first term of equation (9) like as Fukao et al. (2007, p. 12). Among the first parenthesis of equation (9), $\bar{w}_j \frac{\bar{v}_{K,j}}{\bar{v}_{V,j}}$ means the average share of industry capital income to aggregated value-added when the prices of capital are different by industries (direct aggregation across industries approach), and $\bar{w}_{K,j} \bar{v}_K$ means the average share of industry capital income to aggregated value-added when the prices of capital are same by industries (production possibility frontier approach).[19]

In other words the first parenthesis of (9) means the difference of industry share of capital income to the aggregated value-added when the prices of capital of each

[18] The classification of the five ICT sectors is based on Table 12.

[19] Theoretically there may be not any problems that the $w_{K,j} v_K$ means the industry capital share to GDP. But in practice the sum of capital income of each type is not equal to the capital income in GDP composition. So we try to measure the first parenthesis of (9) as the difference of industry share of capital income to aggregated value-added ($\frac{\sum_j p_{K,k,j} K_{k,j} - \sum_j p_{K,k} K_{k,j}}{V}$) whether the prices of capital by each type are assumed as same or not. Similarly in labor input side we also measure it as $\frac{\sum_j p_{L,l,j} L_{l,j} - \sum_j p_{L,l} L_{l,j}}{V}$.

type are assumed as same or different in all industries. If we multiply this parenthesis by the growth of capital ($\Delta \ln K_j$) it stands for the change of capital growth according to the dissimilar assumption of prices of capital in industry, that is the reallocation effect of capital. Then if the parenthesis is positive and the growth of capital is positive the reallocation effect of capital will be positive. Similarly if the parenthesis is negative and the growth of capital is negative the reallocation effect of capital will be positive. However the reallocation effect of capital will be negative in the others, and it means the reallocation of capital does not work efficiently across industries.

The reallocation of labor is also analogous to the above considerations. For the reallocation of labor we apply as:

$$\sum_j \overline{w}_j \frac{\overline{v}_{L,j}}{\overline{v}_{V,j}} \Delta \ln L_j - \overline{v}_L \Delta \ln L$$
$$= \sum_j \left(\overline{w}_j \frac{\overline{v}_{L,j}}{\overline{v}_{V,j}} - \overline{w}_{L,j} \overline{v}_L \right) \Delta \ln L_j + \overline{v}_L \left(\sum_j \overline{w}_{L,j} \Delta \ln L_j - \Delta \ln L \right) \tag{10}$$

[Table 8] Reallocation effects of the capitals of ICT sectors in Korea

(average by periods(%))

	1981–1990	1991–2000	1991–1995	1996–2000	2001–2005	2006–2009	1981–2005	1981–2009
ICT-Using-Manufacturing	-0.168	-0.079	-0.089	-0.069	-0.045	-0.033	-0.108	-0.098
ICT-Using-Service	0.464	0.297	0.334	0.260	0.174	0.131	0.339	0.311
ICT-Producing-Manufacturing	-0.176	0.004	-0.063	0.070	0.090	0.092	-0.051	-0.031
ICT-Producing-Service	-0.024	-0.012	-0.005	-0.018	-0.069	0.120	-0.028	-0.008
Non-ICT	-0.868	-0.784	-0.795	-0.773	-0.590	-0.448	-0.779	-0.733

We have estimated the reallocation effect of capital in Korea (Table 8). First, the sector the reallocation effect of capital is relatively large during 1981-2009 is the ICT-using service (0.311%). Within the ICT-using service, the asset prices of wholesale and retail and finance intermediation are relatively higher than the industry average, and thus, the share of capital income is high. The growth of capital is also high in such industries. Thus, the facts contribute positively to the reallocation effect of capital. In the ICT-producing service, including post and telecommunications, the reallocation effect of capital (0.120%) was especially large from 2006 to 2009. Second, in the ICT-producing manufacturing sector, including office, accounting, computing, and other electrical machinery, the reallocation effect of capital was estimated to be high because of the rising asset prices and rapid growth of capital since the ICT boom in the mid-1990s. Third, in the ICT-using manufacturing sector, including pulp, paper, publishing, printing, and machinery, and in the non-ICT sector, all the reallocation effects of capital were estimated to be negative. These results originate from the fact that the growth of capital is relatively high even when the asset prices are lower than the industry average, and thus, the shares of capital income are low. It means that the inefficiency of reallocation of capital could exist in these sectors. For instance, the industries typically include pulp, paper, publishing, printing, and machinery in ICT-using manufacturing, and public administration and defense, education, and real estate activities in the non-ICT sector.[20]

Next we have estimated the reallocation of capital in the USA, Japan, and EU7 (Table 9). The reallocation effects of capital were relatively high in ICT-using service in Austria, Denmark, Germany, Japan, the Netherlands, UK, and the USA from 1981 to 2005.[21] In the ICT-using service, the differences between the share of capital income and the aggregated value-added tended to be positive on average, except in Italy, and the growth of capital was relatively high. In ICT-producing manufacturing, the reallocation effects of capital from 1996 to 2000 were high because of the increase in asset prices and the fast growth of capital in Austria, Denmark, Finland, Italy, Japan, UK, and the USA.[22] Third, in the non-ICT sector, all the reallocation effects of capital were estimated to be negative because the asset prices were lower than the industry average and the growth of capital in most countries.

[Table 9] Reallocation effects of the capital of ICT sectors in the USA, Japan, EU7, and Korea (1981 to 2005)

(%)

	AUS	DNK	FIN	GER	ITA	JPN	NLD	UK	USA	KOR
ICT-Using-Manufacturing	0.001	0.002	0.013	0.004	0.001	0.006	0.007	0.006	0.006	-0.108
ICT-Using-Service	0.128	0.076	-0.009	0.230	-0.073	0.073	0.082	0.149	0.167	0.339
ICT-Producing-Manufacturing	0.003	0.011	0.087	0.000	0.009	0.022	-0.023	0.013	-0.003	-0.051
ICT-Producing-Service	-0.004	0.008	0.021	0.002	0.004	-0.002	0.004	-0.037	-0.011	-0.028
Non-ICT	-0.093	-0.045	-0.158	-0.130	-0.049	-0.024	-0.118	-0.171	-0.051	-0.779

Note: Authors' calculation using EU KLEMS DB (www.euklems.net)

[20] During 1981-2009 the difference of the share of capital income is, on average, –0.15%, and the growth of capital is 11.52% in Pulp and Paper. These are –0.05%, 10.27% in Publishing, and –0.03%, 10.64% in Printing, and –0.63%, 11.51% in Machinery. Moreover these are –3.10%, 14.04% in Public administration and defense, –1.53%, 15.74% in Education, and –1.54%, 8.91% in Real estate activities.

[21] In these countries the reallocation effect of capital are relatively high in ICT-Using Service such as Wholesale, Finance and Insurance.

[22] During 1996-2000 the growths of capital service are, on average, 2.82% (Austria), 13.92% (Denmark), 11.77% (Finland), 5.87% (Italy), 4.08% (Japan), 6.50% (UK), 8.65% (USA). There are some of differences of the growth of capital service between in the first half of 1990s and in the second half of 1990s in each country.

In summary, the reallocation effects of capital in the five ICT sectors of Korea, the USA, Japan, and EU7 are high overall in the ICT-using service and in the ICT-producing manufacturing from 1996 to 2000. These effects were consistently estimated to be negative in the non-ICT sector, and thus, the reallocation of capital may be inefficient.

(2) Reallocation Effects of Labor by ICT Sectors

From 1981 to 2009, the sectors in Korea wherein the reallocation of labor was estimated to be relatively high include the non-ICT sector (0.540%), which focuses on public administration and defense, education, and health and social work, and the ICT-using service sector (0.040%), which focuses on financial intermediation and others (Table 10). In these sectors, the share of labor income was positive because of the high price of labor, and the growth of labor input was relatively high.[23] Moreover, in the ICT-producing service, which includes post and telecommunications, the reallocation effects of labor effect from 1996 to 2000 were higher compared with those of the first half of the 1990s because of the high price of labor and the growth of labor input.

In Table 11, the reallocation of labor was estimated to be negligible or negative in the USA, Japan, and EU7 from 1981 to 2005, but the effects were relatively high in the non-ICT sector in Austria, Denmark, Finland, Germany, Italy, and Japan.[24] Moreover, in both the ICT-producing manufacturing and ICT-producing service from 1996 to 2000, the reallocation effects of labor were estimated to be positive in Denmark, Finland, UK, and the USA.[25] In summary, based on the estimated reallocation effects of labor in the five ICT sectors in Korea, the USA, Japan, and EU7, the effects were relatively high in the non-ICT sector focusing on public service sectors, ICT-producing service, and ICT-producing manufacturing during the ICT boom in the mid-1990s. As a whole, the reallocation effects of labor tended to be slightly lower compared with those of capital.

[23] During 1981-2009 the difference of the share of labor income is, on average, 2.59%, and the growth of labor is 4.36% in Public administration and defense. These are 1.62%, 4.53% in Education, and these are 0.70%, 6.82% in Health and social work, and these are 1.49%, 4.88% in Financial intermediation.

[24] The reallocation effects of labor of these countries are mainly high in sectors such as Transportation equipment, Transportation and warehousing, Public administration and defense, Education, Health and social work etc.

[25] The reallocation effects of labor are, on average, 0.42% in ICT-Producing Manufacturing, and 0.23% in ICT-Producing Service in Denmark during 1996-2000. These are 3.69%, 0.09% in Finland, and are 0.05%, 1.11% in Netherlands, and are 0.62%, 1.06% in UK, and are 0.55%, 2.11% in USA.

[Table 10] Reallocation effects of labor of the ICT sectors in Korea

(average by periods (%))

	1981–1990	1991–2000	1991–1995	1996–2000	2001–2005	2006–2009	1981–2005	1981–2009
ICT-Using-Manufacturing	0.015	-0.005	-0.014	0.003	-0.004	-0.010	0.003	0.001
ICT-Using-Service	-0.014	0.152	0.158	0.146	-0.036	-0.008	0.048	0.040
ICT-Producing-Manufacturing	0.029	0.003	0.028	-0.022	0.096	-0.019	0.032	0.025
ICT-Producing-Service	0.020	0.047	0.037	0.057	0.040	-0.049	0.035	0.023
Non-ICT	1.018	0.279	0.646	-0.088	0.228	0.385	0.564	0.540

[Table 11] Reallocation effects of labor of the ICT sectors in the USA, Japan, EU7, and Korea (1981 to 2005)

(%)

	AUS	DNK	FIN	GER	ITA	JPN	NLD	UK	USA	KOR
ICT-Using-Manufacturing	-0.004	-0.002	-0.010	-0.018	-0.001	0.003	0.002	-0.005	-0.003	0.003
ICT-Using-Service	-0.039	0.014	0.012	-0.032	-0.055	0.008	-0.011	-0.053	-0.034	0.048
ICT-Producing-Manufacturing	-0.005	0.000	0.012	-0.017	-0.003	0.000	-0.003	-0.003	-0.001	0.032
ICT-Producing-Service	0.000	0.000	0.002	-0.012	0.001	0.000	0.002	0.000	0.001	0.035
Non-ICT	0.086	0.046	0.203	0.033	0.118	0.141	-0.012	-0.043	-0.055	0.564

Note: Authors' calculation using EU KLEMS DB (www.euklems.net)

V. Conclusion

In this paper we have estimated the concentration of ICT capital, the growth accounting in Korea, and the reallocation of capital and labor in Korea, the USA, Japan and EU7 by using three approaches of aggregation the aggregate production function, the production possibility frontier, the direct aggregation across industries. Our major findings are as below.

First we have found the concentration of ICT capital investment has been converged at a steady level during the 2000s. It could be interpreted as the ICT investment may enter into some of maturing steps, so it is needed to find new growth engine industry to trigger more investment. Second the fact that the production possibility frontier is a reasonable method due to the total reallocation effects is small as Jorgenson et al. (2007, p. 248) presented has been partly found during some periods such as 1981-1990, 1991-1995, and 2006-2009 in the Korean economy. In addition the total reallocation effects are estimated as small in Japan, EU7. Thus unlike the advanced countries the aggregation by the production possibility frontier in the Korean economy may not be a good approximate of the direct aggregation across industries, because the Korean economy is not a system yet that capital and labor can move flexibly across industries according to the difference of input prices. Third the source of economic growth have shifted from the non-ICT sector to the ICT sector in light of the contributions of value-added growth and TFP growth of ICT sectors to aggregate economy. In particular, the contribution of ICT-using has increased gradually, but the contribution of ICT-producing has been slowed down since the middle of 1990s of ICT boom. Importantly this situation has been found not only in Korea but in the USA, Japan, the Netherlands, and UK. Fourth, the reallocation effects of capital are relatively high in ICT-using service in Korea, the USA, Japan, and EU7 and are consistently estimated as negative in the non-ICT sector. So there seems to be the inefficiency of the reallocation of capital in the non-ICT sector. In turn, the reallocation effects of labor are relatively high in the non-ICT sector focusing on public service sectors, and are high in both the ICT-producing service, and ICT-producing manufacturing during the ICT boom. As a whole, the reallocation effects of labor tend to be a little lower than the reallocation of capital.

In short it will be still valid alternatives to invest ICT capital like as computer, communication and software in order for the sustainable economic growth in Korea. However we need in future to find new growth industry to trigger more investment due to the concentration of ICT capital has converged at a steady level since 2000. Regarding to aggregation the direct aggregation across industries approach assuming the input prices are different across all industries may be more appropriate than the production possibility frontier approach assuming the input prices are the same across all industries so far in the Korean economy. Finally productivity analysis at industry level as well as firm level is the other important base besides the analysis on the aggregated economy.

[Appendix A]

1. Measurement of capital service

$$\Delta \ln K_t = \sum_k \bar{v}_{k,t} \Delta \ln A_{k,t}$$

$$\bar{v}_{k,t} = \frac{1}{2}[v_{k,t} + v_{k,t-1}], \quad v_{k,t} = (\sum_k p^K_{k,t} A_{k,t})^{-1} p^K_{k,t} A_{k,t} ,$$

K_t = capital service, $v_{k,t}$ = capital income (compensation) by each type,

$A_{k,t}$ = capital stock by each type

$p^K_{k,t}$ = price of capital service by each type

In the absence of taxation user cost of capital can be expressed as:

$$P_{k,t} = P^I_{k,t-1} i_t + \delta_k P^I_{k,t} - (P^I_{k,t} - P^I_{k,t-1}),$$

$P^I_{k,t}$ = investment deflators by each type, i_t = nominal rates of return,

δ_k = depreciation rates

So, $P_{k,t} A_{k,t} = P^I_{k,t-1} i_t A_{k,t} + [\delta_k P^I_{k,t} - (P^I_{k,t} - P^I_{k,t-1})] A_{k,t}$

Then the nominal rates of return can be rearranged as:

$$i_{j,t} = \frac{1}{\sum_k P^I_{k,j,t-1} A_{k,j,t}} \{ P^K_{j,t} K_{j,t} + \sum_k [(P^I_{k,j,t} - P^I_{k,j,t-1})] A_{k,j,t} - \sum_k P^I_{k,j,t} \delta_k A_{k,j,t} \}$$

2. Measurement of labor service

$$\Delta L_t = \sum_l \bar{v}_{L,t} \Delta \ln H_{l,t}$$

$$\bar{v}_{L,t} = \frac{1}{2}[v_{l,t} + v_{l,t-1}], \quad v_{l,t} = (\sum_l p^L_{l,t} H_{l,t})^{-1} p^L_{l,t} H_{l,t}$$

L_t = labor service, $v_{l,t}$ = labor compensation by labor types,

$H_{l,t}$ = = hours by labor types, $p^L_{l,t}$ = price per hour by labor types

[Appendix B]

[Table 12] Industrial classification of ICT

EUKLMES	KIP	Industry	ICT
AtB	1-3	(1)Agriculture, forestry and fishing	N
C	4-8	(2)Mining	N
15t16	9-10	(3)Food, beverages and tobacco	N
17t19	11-13	(4)Textiles, wearing apparel, fur and footwear	N
20	14	(5)Wood	N
21t22	15-17	(6)Pulp, paper , publishing and printing	U
23	18	(7)Coke, refined petroleum and nuclear fuel	N
24	19-20	(8)Chemicals and pharmaceuticals	N
25	21	(9)Rubber and plastics	N
26	22	(10)Other non-metallic mineral	N
27t28	23-24	(11)Basic metals and Fabricated metal	N
29	25	(12)Machinery, nec.	U
30t33	26-33	(13)Office, accounting, computing and other electrical machinery	P
34t35	34-37	(14)Transport equipment	N
36t37	38-39	(15)Manufacturing nec.	U
E	40-42	(16)Electricity, gas and water	N
F	43	(17)Construction	N
G50	44	(18)Sale, maintenance of motor vehicles	U
G51	45	(19)Wholesale trade	U
G52	46	(20)Retail trade	U
H	47	(21)Hotels and restaurants	N
60t63	48-51	(22)Transportation and warehousing	N
64	52	(23)Post and telecommunications	P
J	53-55	(24)Finance and insurance	U
70	56-57	(25)Real estate activities	N
71t74	58-62	(26)Renting and business activities	U
L	63	(27)Public administration and defense	N
M	64	(28)Education	N
N	65	(29)Health and social work	N
Q	66-72	(30)Other social and private service	N

Note: P= ICT-Producing, U= ICT-Using, N= Non-ICT.

[Table 13] Shares of ICT capital by industry (1981-2005)

(%)

	KOR		USA	JPN	GER	UK
(1) Agriculture, forestry and fishing	0.3	(0.3)	1.6	1.0	2.3	0.8
(2) Mining	0.8	(1.0)	4.5	3.0	6.9	1.6
(3) Food, beverages and tobacco	13.7	(14.8)	15.0	5.2	8.8	16.0
(4) Textiles, wearing apparel, fur and footwear	10.5	(12.0)	12.0	4.4	12.8	22.9
(5) Wood	4.7	(5.1)	9.9	4.5	6.7	19.7
(6) Pulp, paper , publishing and printing	19.1	(20.1)	21.5	6.9	17.0	24.0
(7) Coke, refined petroleum and nuclear fuel	14.8	(14.9)	14.6	4.8	7.9	9.2
(8) Chemicals and pharmaceuticals	12.3	(13.0)	22.0	9.0	10.5	14.7
(9) Rubber and plastics	18.0	(19.8)	7.2	3.2	9.5	16.2
(10) Other non-metallic mineral	7.7	(7.9)	17.0	5.1	8.5	14.8
(11) Basic metals and Fabricated metal	10.6	(10.7)	17.0	6.8	9.4	14.9
(12) Machinery, nec.	21.8	(22.7)	31.1	9.8	17.1	28.3
(13) Office, accounting, computing and other electrical machinery	21.7	(21.7)	29.5	16.0	18.3	29.8
(14) Transport equipment	23.0	(23.9)	26.3	4.9	12.5	15.7
(15) Manufacturing nec.	18.2	(19.8)	19.4	8.8	11.5	17.1
(16) Electricity, gas and water	0.3	(0.4)	10.0	4.6	7.4	11.0
(17) Construction	12.6	(13.1)	13.7	10.4	13.5	9.9
(18) Sale, maintenance of motor vehicles	18.1	(19.1)	18.7	24.4	15.8	19.7
(19) Wholesale trade	18.1	(19.2)	26.6	15.8	28.1	37.2
(20) Retail trade	18.1	(19.1)	17.6	17.9	25.3	19.8
(21) Hotels and restaurants	4.1	(4.6)	6.4	2.4	15.6	9.2
(22) Transportation and warehousing	0.2	(0.2)	24.2	3.8	7.4	8.4
(23) Post and telecommunications	13.0	(16.9)	53.2	46.2	44.3	51.0
(24) Finance and insurance	62.4	(64.1)	35.9	38.3	37.8	35.7
(25) Real estate activities	5.2	(5.9)	0.5	0.2	0.3	1.2
(26) Renting and business activities	39.0	(40.2)	47.9	33.0	23.7	35.9
(27) Public administration and defense	14.8	(16.6)	13.2	15.9	6.3	15.6
(28) Education	45.8	(46.2)	13.6	4.6	13.7	19.8
(29) Health and social work	17.4	(18.1)	13.1	5.0	11.8	11.3
(30) Other social and private service	20.3	(23.7)	12.0	9.9	6.5	12.6

Note : Germany is the average during 1991-2005. ( ) is the share in Korea during 1981-2009.
Source: Authors' calculation using EU KLEMS DB(www.euklems.net) , KIP DB(2011).

[Table 14] Resource Reallocation Effects in USA, Japan, EU7 and Korea (economy-wide)

(growth rates(%))

	81-'90	91-'00	91-'95	96-'00	01-'05	81-'05
			USA			
Reallocation of capital(1)	-0.17	-0.33	-0.23	-0.43	-0.25	-0.25
Reallocation of labor(2)	-0.06	-0.10	-0.12	-0.09	-0.13	-0.09
Total =(1)+(2)	-0.23	-0.43	-0.35	-0.52	-0.38	-0.34
			Japan			
Reallocation of capital(1)	0.04	-0.01	0.05	-0.07	0.07	0.02
Reallocation of labor(2)	0.03	0.02	-0.02	0.06	-0.09	0.00
Total =(1)+(2)	0.07	0.00	0.02	-0.02	-0.02	0.02
			Austria			
Reallocation of capital(1)	-0.02	0.03	0.04	0.02	-0.07	-0.01
Reallocation of labor(2)	-0.13	-0.03	-0.03	-0.04	-0.06	-0.08
Total =(1)+(2)	-0.16	0.00	0.01	-0.02	-0.12	-0.09
			Denmark			
Reallocation of capital(1)	0.06	0.02	0.02	0.03	0.03	0.04
Reallocation of labor(2)	0.03	-0.02	-0.01	-0.02	0.00	0.00
Total =(1)+(2)	0.09	0.01	0.01	0.01	0.03	0.04
			Finland			
Reallocation of capital(1)	0.03	-0.04	-0.09	0.00	-0.13	-0.03
Reallocation of labor(2)	0.05	0.07	0.02	0.11	0.02	0.05
Total =(1)+(2)	0.08	0.02	-0.06	0.11	-0.12	0.02
			Germany			
Reallocation of capital(1)	-	0.19	0.23	0.15	0.00	0.12
Reallocation of labor(2)	-	-0.06	-0.11	-0.03	0.01	-0.04
Total =(1)+(2)	-	0.12	0.12	0.13	0.01	0.08
			Italy			
Reallocation of capital(1)	-0.01	0.02	-0.01	0.05	0.02	0.01
Reallocation of labor(2)	0.24	0.00	0.04	-0.04	-0.06	0.08
Total =(1)+(2)	0.23	0.02	0.02	0.01	-0.04	0.09
			Netherlands			
Reallocation of capital(1)	0.03	0.02	0.03	0.01	-0.14	-0.01
Reallocation of labor(2)	-0.03	-0.06	-0.09	-0.04	-0.05	-0.05
Total =(1)+(2)	0.00	-0.05	-0.06	-0.03	-0.19	-0.06
			UK			
Reallocation of capital(1)	0.19	0.08	0.03	0.13	0.03	0.12
Reallocation of labor(2)	-0.25	-0.19	-0.23	-0.15	-0.17	-0.21
Total =(1)+(2)	-0.06	-0.11	-0.20	-0.02	-0.14	-0.09
			KOR			
Reallocation of capital(1)	-0.50	-0.38	-0.43	-0.33	-0.49	-0.45
Reallocation of labor(2)	0.57	-0.06	0.38	-0.51	0.11	0.22
Total =(1)+(2)	0.06	-0.44	-0.05	-0.84	-0.38	-0.23

Note: In Germany the figures are available during 1992-2005.

Source: Authors' calculation using EU KLEMS DB (www.euklems.net).

[Table 15] TFP growth of ICT sectors in USA, Japan, EU7 and Korea

(growth rates(%))

	81-'90	91-'00	91-'95	96-'00	01-'05	81-'05
			USA			
ICT-Using TFP	0.04	0.15	0.04	0.27	0.57	0.19
ICT-Producing TFP	0.23	0.41	0.30	0.51	0.43	0.34
Non-ICT TFP	-0.02	0.01	-0.04	0.05	0.55	0.10
			Japan			
ICT-Using TFP	0.66	0.30	0.56	0.04	0.27	0.44
ICT-Producing TFP	0.51	0.32	0.25	0.39	0.25	0.38
Non-ICT TFP	0.50	-0.66	-1.06	-0.26	-0.16	-0.10
			Austria			
ICT-Using TFP	0.42	0.23	0.23	0.23	-0.22	0.22
ICT-Producing TFP	0.17	0.12	0.17	0.08	0.15	0.15
Non-ICT TFP	0.43	0.64	0.64	0.63	0.32	0.49
			Denmark			
ICT-Using TFP	0.20	0.09	0.38	-0.20	0.32	0.18
ICT-Producing TFP	0.14	0.09	0.12	0.05	0.14	0.12
Non-ICT TFP	0.30	0.09	0.27	-0.10	-0.52	0.05
			Finland			
ICT-Using TFP	0.19	0.36	0.21	0.50	0.37	0.29
ICT-Producing TFP	0.19	0.65	0.18	1.11	0.63	0.46
Non-ICT TFP	0.15	0.45	0.55	0.35	-0.05	0.23
			Germany			
ICT-Using TFP	-	-0.25	-0.20	-0.30	-0.38	-0.30
ICT-Producing TFP	-	0.23	0.13	0.31	0.19	0.22
Non-ICT TFP	-	0.73	0.84	0.64	0.51	0.65
			Italy			
ICT-Using TFP	-0.36	0.16	0.39	-0.06	-0.39	-0.16
ICT-Producing TFP	0.11	0.08	0.07	0.09	0.13	0.10
Non-ICT TFP	0.91	0.34	0.74	-0.07	-0.61	0.38
			Netherlands			
ICT-Using TFP	0.17	0.12	-0.13	0.37	0.38	0.19
ICT-Producing TFP	0.07	0.13	0.06	0.20	0.17	0.11
Non-ICT TFP	0.42	-0.01	0.08	-0.09	-0.12	0.14
			UK			
ICT-Using TFP	0.09	0.10	0.18	0.01	0.64	0.20
ICT-Producing TFP	0.18	0.33	0.30	0.35	0.04	0.21
Non-ICT TFP	0.67	0.36	0.82	-0.10	-0.29	0.36
			KOR			
ICT-Using TFP	0.57	0.09	0.48	-0.31	0.18	0.30
ICT-Producing TFP	0.41	1.18	0.85	1.51	0.85	0.81
Non-ICT TFP	2.83	1.36	1.39	1.32	0.51	1.78

Note: In Germany the figures are available during 1992-2005.
Source: Authors' calculation using EU KLEMS DB (www.euklems.net).

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