ICT-specific technological change and productivity growth in Korea: comparison of 1996-2003 and 2004-2015[1]

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Abstract

This paper analyses the change in the impacts of technological change in the information and communications technology (ICT) on economic growth in Korea. The dynamic general equilibrium (DGE) model shows that ICT investment specific technological change account for 37.1% to labor productivity growth in 1995-2003, and 23.6% in 2004-2015. Along with stagnant ICT investment intensity observed in the data, this decline in the contribution of ICT investment specific technology corresponds with slowdown of ICT specific technological growth. I also find that ICT investment specific technological shocks were significant in cyclical output fluctuations in 1995-2003, but neutral technological shocks and non-ICT investment specific shocks became more dominant in 2004-2015.

JEL classifications; E22; E32

Keywords: Investment specific technological change; ICT; Growth accounting

1. Introduction

The information and communications technology (ICT hereafter) has been considered as a source of sustained productivity growth not only in Korea but also in major economies. Particularly ICT holds a significant portion in Korean economy, as ICT industry produces 10.1% of GDP and exports

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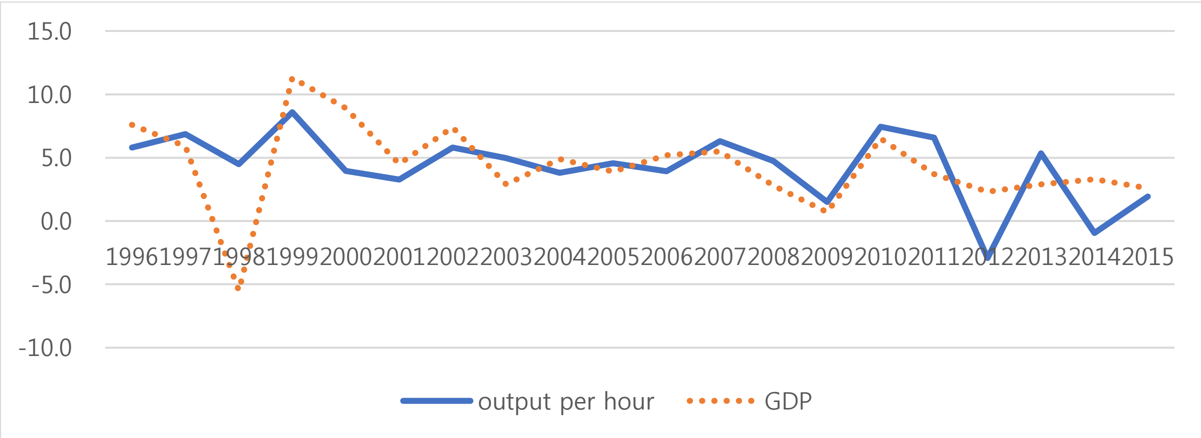
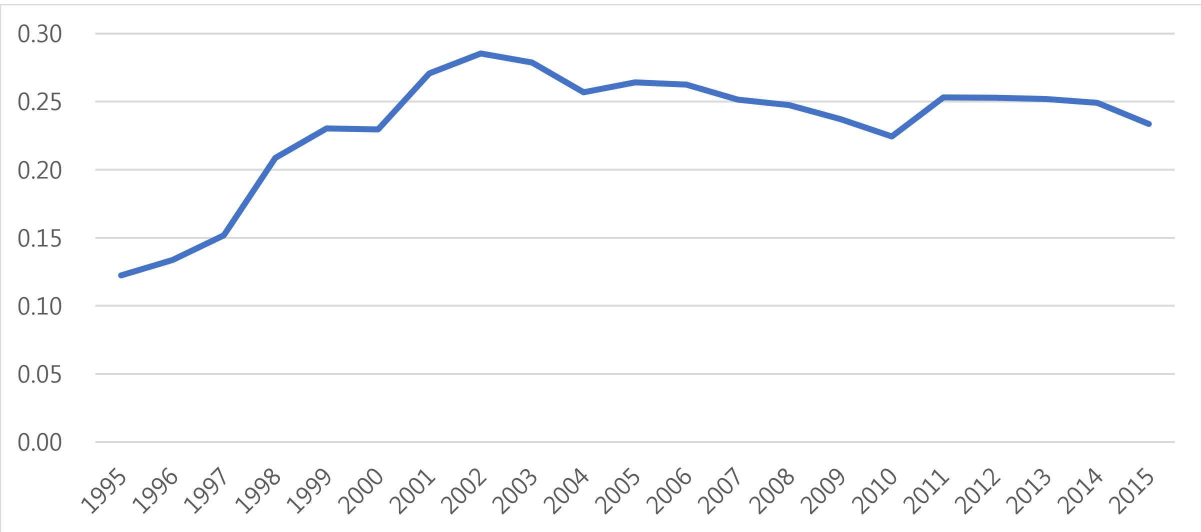
32.6% of Korean aggregate exports in 2015, per Bank of Korea. ICT intensity defined as the ratio of ICT investment to non-ICT investment also rapidly rose during the ICT industry boom from late 1990s to early 2000s, and this trend implies increasing usage of ICT in Korean economy during the period. Afterwards ICT intensity stopped increasing and reached to plateau. This change coincides with transition from high output and productivity growth rates to low output and productivity growth rates of Korean economy. Considering the economic impacts of ICT to productivity, such expansion of ICT investment is a crucial link between technology and productivity. This paper attempts to quantify such transition with investment-specific technological change.

Figure 1. GDP and output per hour growth rates



Source: Output per hour growth rate from OECD productivity statistics(https://stats.oecd.org), GDP growth rate from Bank of Korea(http://ecos.bok.or.kr)

Figure 2. ICT investment/non-ICT investment ratio



Source: Bank of Korea(http://ecos.bok.or.kr)

This paper is based on the dynamic general equilibrium model with investment-specific technological change as Greenwood et al. (1997), Bakhshi and Larsen (2005) and Martinez et al. (2010). In the model, productivity consists of neutral technology and investment-specific technology. I distinguish two types of capital: ICT capital and non-ICT capital, where investment-specific technology for each type of capital progresses independently. The effects of expanding usage of ICT are quantified by distinguishing investment specific technologies, and this aspect separates this paper from Greenwood et al. (1997) where only productivity of equipment improves or Bahkshi and Larsent (2005) where there is no technological progress in non-ICT capital.

Based on calibration of period 1996-2003, I find that ICT investment-specific technological change had significant impacts on productivity growth. The model suggests that ICT investment-specific technological change contributed 37.1% to the productivity growth, while non-ICT investment specific technological change and neutral technological change contributed 2.6% and 60.9% to growth respectively. This study also investigates 2004-2015, when Korean economy experienced stagnation of productivity and ICT investment. ICT investment-specific technological change's contribution dropped to 23.6%, and non-ICT investment-specific technological change's contribution even declined to minus 2.2%. Instead the neutral technological change drove the productivity growth during the period. With another calibration of period 2004-2015, the model suggests slow ICT investment-specific technological change was a significant part of such transition.

Furthermore, this paper analyzes fluctuations along the balanced growth path by adding exogenous shocks to the model. This analysis shows that ICT investment specific technological shocks can have significant effects on business cycles as well. I find that ICT investment specific technology shock was a main driving factor of output variation in 1995-2003, but neutral technology shock and non-ICT investment specific technology shock were driving the output variation in 2004-2015.

The remainder of the paper consists of literature review, the model, the numerical analysis, and conclusion. After literature review of studies related to the investment-specific technological change in section 2, the model with ICT and non-ICT capital is introduced, and the stationary, steady-state balanced growth path is derived in section 3. In Section 4, I calibrate the model to Korean economy, describe characteristics of the balanced growth path, and derive composition of productivity growth. In the same section, I add cyclical fluctuations to show contribution of each type of investment specific technological change. I conclude the paper in the final section.

2. Literature review

There are two major frameworks to understand the roles of technological change on economic growth and productivity. The first approach is the standard growth accounting to measure contribution of each factor including ICT capital or R&D capital to output and productivity growth. Among the growth accounting framework with ICT, Oulton (2002) measures the contribution of ICT to GDP growth and capital deepening of the United Kingdom. He finds that ICT contributes about 20 per cent of GDP growth in 1989-1998, and 55 to 90 per cent of the growth of capital per hour worked. Jorgenson and Stiroh (2000), Oliner and Sichel (2000), and O'Mahony and Vecchi (2005) are other examples that follow the growth accounting approach. And Oulton (2012) measures the importance of ICT use effect and ICT output effect by extending the standard one-sector model to the two-sector model, and finds that ICT use effect dominates the long-run output growth. Meanwhile Cummins and Violante (2002) measure investment specific technological change by constructing price indexes for equipment and software, and find contribution of technological progress in equipment and software to growth was significant.

The second framework is based on the dynamic general equilibrium model to quantify the contribution of technological progress to economic growth. This approach can be used to measure the contribution of total factor productivity and investment specific technological change to economic growth. Greenwood et al. (1997) provide the basic dynamic general equilibrium model to decompose productivity growth into neutral and investment-specific technology along the balanced growth path, and find significant roles of investment-specific technological progress. Hobijn (2000), Bahkshi and Larsen (2005), and Martinez et al. (2010) follow this framework. On the other hand, Greenwood et al. (2000) and Fisher (2006) develop the framework to measure quantitative implications of investment-specific technological change in the business cycle. Park and Han (2008) quantify contribution of investment-specific technological change along the balanced growth path of Korean economy by applying DSGE approach of Hobijn (2000).

3. The model

The model economy consists of households, firms and government as the standard dynamic general equilibrium model. The model follows Greenwood et al. (1997), Martinez et al. (2010), and particularly Bahkshi and Larsen (2005), which distinguishes ICT capital from non-ICT capital. Unlike Bahkshi and Larsen (2005), I allow both ICT and non-ICT investment-specific technological changes in the model in addition to neutral technological change.

Capital accumulation equations for both types of capital reflect growth of both investment-specific technologies. Denoting Z and K as ICT capital and non-ICT capital respectively, capital stocks change via the following dynamics:

$$\boldsymbol{Z_{t+1} = (1 - \delta_z)Z_t + Q_t^z I_t^z} \quad \textbf{(1)}$$

$$K_{t+1} = (1 - \delta_k)K_t + Q_t^k I_t^k \quad (2)$$

where Q^z and Q^k represent technological level of ICT investment specific technology and non-ICT investment specific technology. Also I^z and I^k denote investment of each type of capital in terms of final good, δ_z and δ_k are depreciation rates, and t denotes period.

Higher Q^i implies investing less units of final good to producing type *i=z, k* investment goods. As Bahkshi and Larsen (2005), perfect competition and constant returns to scale for production of both capital assets are assumed. These assumptions are useful to simplify the calibration process, because now higher Q^i implies lower price of the capital good. Then we can use relative prices of ICT and non-ICT capital goods to calibrate Q^z and Q^k.

3.1. Agents

Representative agents, or workers, of the economy are assumed to live infinitely, and their utility is determined by consumption C_t and leisure $1 - h_t$. To maximize the expected present value of utility with a discount factor β, the agents determine consumption, labor supply, ICT capital investment I_t^z and non-ICT capital investment I_t^k subject to the budget constraint. Now the agents' problem can be put as follows.

$$\max E \sum_{t=0}^{\infty} \beta^t U(C_t, 1 - h_t) \quad \textbf{(3)}$$

Subject to

$$C_t + I_t^z + I_t^k = (1 - \tau_k)\left(r_t^z Z_t + r_t^k K_t\right) + (1 - \tau_l)W_t h_t + T_t \quad \textbf{(4)}$$

, where r_t^z and r_t^k are ICT capital and non-ICT capital rental rate respectively, W_t is hourly wage, τ_k and τ_l represent tax rates on capital and labor income, and lump-sum transfer T_t. The budget constraint implies that income consists of after-tax labor income, after-tax rental income from capital and lump-sum transfer, while the sum of consumption and investment cannot exceed the income. The agents own ICT and non-ICT capital, and holdings of capital by the agents follow the standard capital accumulation dynamics described above.

3.2. Firms

Firms in the model produce the final good by using labor, ICT capital and non-ICT capital. The firms access to three types of technology that progress independently: A, neutral technology; Q^z, ICT investment specific technology; and Q^k, non-ICT specific technology. The production function is assumed to be concave in each input, continuous, and be constant returns to scale. Furthermore, it is assumed that the final goods and factor markets are perfectly competitive. Firms rent capital and labor every period to maximize profits, given the production function $Y_t = A_t F(Z_t, K_t, h_t)$.

$$\max \pi = Y_t - r_t^z Z_t - r_t^k K_t - W_t h_t \qquad \textbf{(5)}$$

3.3. Government

To close out the model economy, I simply assume that the government maintain its budget balanced every period by distributing income taxes to the agents as transfer. The government's budget constraint is given as follows:

$$T_t = \tau_k r_t^k K_t + \tau_z r_t^z Z_t + \tau_l W_t h_t \qquad \textbf{(6)}$$

, where τ_k is non-ICT capital income tax rate, τ_z is ICT capital income tax rate, and τ_l is labor income tax rate.

3.4. Stationary equilibrium

Equilibrium of the model consists of time-invariant policy functions of $\{\mathrm{C}, \mathrm{K}, \mathrm{Z}, \mathrm{h}\}$ and prices $\{r^k, r^k, w\}$ that solve each agent's and firm's optimization problem given the prices, clear the markets, and satisfy the balanced budget of government, the capital accumulation dynamics and the resource constraint.

To derive the non-stochastic, steady state balanced growth path, I assume a Cobb-Douglas production function and a logarithmic utility function:

$$Y_t = A_t Z_t^{\alpha_z} K_t^{\alpha_k} h_t^{1-\alpha_z-\alpha_k}$$

$$\mathrm{U}(C_t, h_t) = \varphi ln(C_t) + (1-\varphi)\ln(h_t)$$

Under the specification of production function and utility function, a system of equations that characterize the equilibrium can be derived: first order conditions of the agent's problem and the firm's problem, an Euler equation regarding to investment of each type, the accumulation dynamics of capital, and the economy's resources.

$$\frac{h_t}{1-h_t}=\frac{\varphi}{1-\varphi}(1-\tau_l)(1-\alpha_z-\alpha_k)\frac{Y_t}{C_t} \tag{7}$$

$$\frac{\alpha_z Y_t}{Z_t}=r_t^z, \qquad \frac{\alpha_k Y_t}{K_t}=r_t^k \tag{8}$$

$$\frac{1}{C_t Q_t^k}=\beta E\frac{1}{C_{t+1}}\left\{(1-\tau_k)r_{t+1}^k+\frac{1-\delta_k}{Q_{t+1}^k}\right\}, \qquad \frac{1}{C_t Q_t^z}=\beta E\frac{1}{C_{t+1}}\left\{(1-\tau_z)r_{t+1}^z+\frac{1-\delta_z}{Q_{t+1}^z}\right\} \tag{9}$$

$$Z_{t+1}=(1-\delta_z)Z_t+Q_t^z I_t^z, \qquad K_{t+1}=(1-\delta_k)K_t+Q_t^k I_t^k \tag{10}$$

$$C_t+I_t^z+I_t^k=A_t Z_t^{\alpha_z}K_t^{\alpha_k}h_t^{1-\alpha_z-\alpha_k} \tag{11}$$

The first condition is derived from first-order condition of optimization problems of the agent and a condition that implies the agent equates the marginal utility of additional supply of labor with the marginal utility of earning from additional labor. Second condition is the firm's first-order condition. Next condition is an Euler equation that relates the marginal utility of investment and the expected return from the additional capital. Subsequent equation shows the dynamics of capital accumulation of each type, and the last equation implies the economy's resource constraint derived from the agent's budget constraint and the government's budget constraint.

On the balanced growth path, all variables grow at a constant rate while working hours per worker stays constant. Y, C, I^z and I^z grow at the gross growth rate of Γ, while K grows at Γ_k, and Z grows at Γ_z. And the Cobb-Douglas production function implies that output growth is accounted by neutral technological growth, g, Γ_k and Γ_z. In turn, investment specific technological changes in ICT and non-ICT capital affect the growth of capital stock via the capital accumulation equations. In other words, we consider growth in Q_z and Q_k, which are represented as Γ_z and Γ_k respectively. The growth rates now can be expressed as the following.

$$\Gamma=g_a\Gamma_z^{\alpha_z}\Gamma_k^{\alpha_k}$$

, where

$$\Gamma \;=g_a^{\frac{1}{1-\alpha_k-\alpha_z}}g_z^{\frac{\alpha_z}{1-\alpha_k-\alpha_z}}g_k^{\frac{\alpha_k}{1-\alpha_k-\alpha_z}}$$

$$\Gamma_z=g_a^{\frac{1}{1-\alpha_k-\alpha_z}}g_z^{\frac{1-\alpha_k}{1-\alpha_k-\alpha_z}}g_k^{\frac{\alpha_k}{1-\alpha_k-\alpha_z}}$$

$$\Gamma_k=g_a^{\frac{1}{1-\alpha_k-\alpha_z}}g_z^{\frac{\alpha_z}{1-\alpha_k-\alpha_z}}g_k^{\frac{1-\alpha_z}{1-\alpha_k-\alpha_z}}$$

3.5. Balanced growth path

To derive the stationary variables, all variables except h are normalized by Γ, Γ_z, or Γ_k. Expressions of the stationary variables expressed by lower case can be given as:

$x_t = \frac{X_t}{\Gamma^t}$ where $X_t = Y_t, C_t, I_t^k, I_t^z$

$k_t = \frac{K_t}{\Gamma_z^t}$, $z_t = \frac{Z_t}{\Gamma_k^t}$

Based on this transformation to stationary variables, the equilibrium conditions can be rewritten as the following set of equations. At the equilibrium, those transformed variables are stationary, while the detrended variables are on the balanced growth path. Time subscript is dropped for convenience.

$$\frac{h}{1-h} = \frac{\varphi}{1-\varphi}(1-\tau_l)(1-\alpha_z-\alpha_k)\frac{y}{c} \quad \textbf{(12)}$$

$$\frac{1}{\beta} = \frac{1}{\Gamma g_k}\left\{(1-\tau_k)\frac{\alpha_k y}{k} + 1 - \delta_k\right\}, \qquad \frac{1}{\beta} = \frac{1}{\Gamma g_z}\left\{(1-\tau_z)\frac{\alpha_z y}{z} + 1 - \delta_z\right\} \quad \textbf{(13)}$$

$$\Gamma_z z = (1-\delta_z)z + i^z , \qquad \Gamma_k k = (1-\delta_k)k + i^k \quad \textbf{(14)}$$

$$c + i^z + i^k = y \quad \textbf{(15)}$$

4. Numerical analysis

4.1. Calibration

To assess the contribution of each type of technological change to productivity growth, the parameters of the model will be calibrated. A group of the parameters will be derived from related studies, while some will be assigned by empirical evidences.

The parameters in the model to be calibrated are summarized in Table 1. Among them, the focus is on the growth rates, g_z and g_k. In the literature, the growth rate of Q_k is calibrated by using a deflator of investment goods, and it is defined as the investment goods deflator growth rate minus the consumption deflator growth rate. While deflators for investment is available from Bank of Korea, the hedonic deflators for ICT investment goods and non-ICT investment goods are not specifically provided. Bank of Korea instead provides the producer price indices of ICT goods and non-ICT goods. Even though the levels of ICT investment goods and non-ICT investment goods prices might be different from those of ICT consumption goods and non-ICT consumption goods prices, I assume that relative prices of those two investment goods change at the same rate as the relative producer prices of ICT goods and non-ICT goods. Figure 3 implies that ICT prices in Korea has followed similarly downward trend in other countries. To calculate prices of two types of capital as Bakhshi and Larsen (2005) and Martinez et al. (2010), define $Q_i(i = z, k)$ as

$$Q_i = CPI \times \frac{Real\ investment\ of\ type\ i}{Nominal\ investment\ of\ type\ i}$$

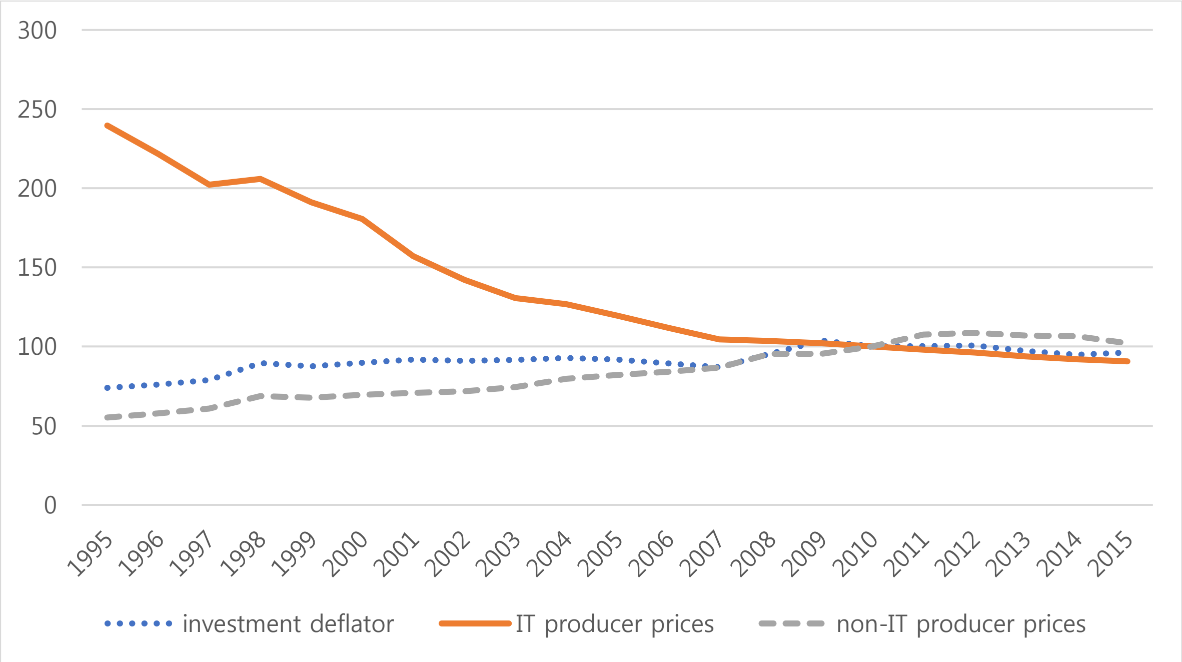
, where CPI is the consumption deflator.

As nominal ICT investment and nominal non-ICT investment are not provided by Bank of Korea economic statistics online system, I use the producer prices of ICT and non-ICT goods to calculate nominal values as alternatives. Figure 4 implies that this assumption is reasonable, as the investment deflator data appears to be very close to the calculated investment deflator derived from the weighted average of ICT investment and non-ICT investment. In this procedure, the consumption deflator is used as a common deflator for output, capital stocks, and investments as Greenwood et al. (1997) and Bakhshi and Larsen (2005). And the neutral technological growth rate g_A is derived as a Solow residual from output per working hour and calibration above. The output per hour is from OECD productivity database. For calibration of α_k and α_z, Conference Board Total Economy Database, Pyo et al. (2007) and Shin (2010) are used to derive a range of reasonable values. I also calibrate δ_k and δ_z from Pyo et al. (2007). I calibrate tax rates from personal income rates and corporate income tax rates from OECD tax statistics, and I assume $\tau_k = \tau_z$.

Table 1. Parameters

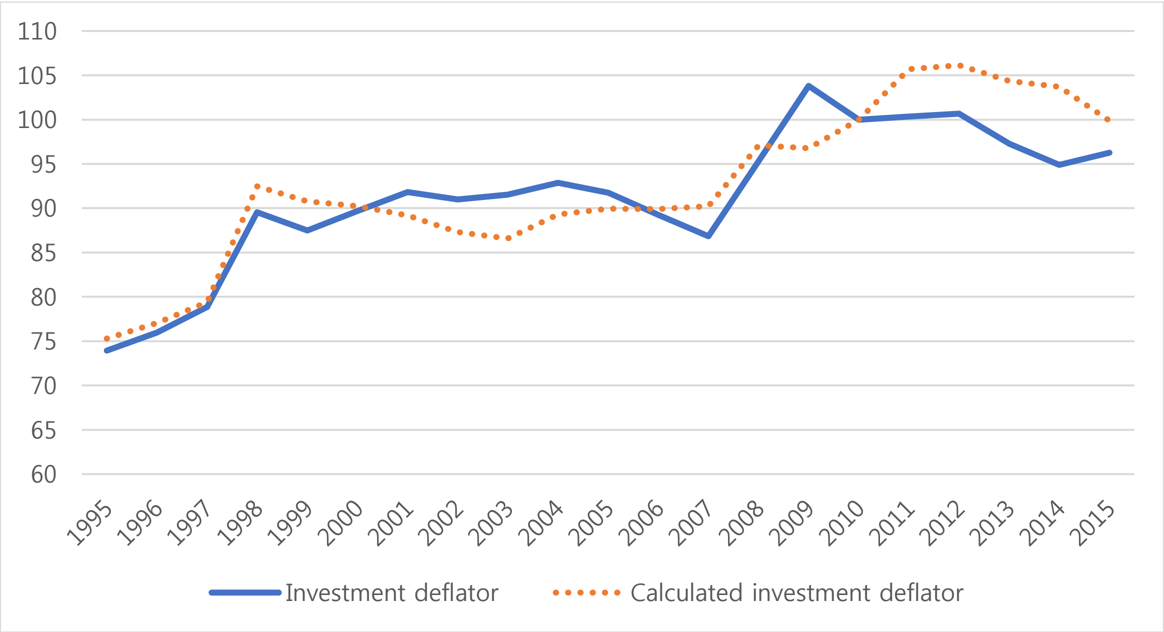
	1995~2003	2004~2015
g_A	1.033	1.028
g_k	1.009	0.996
g_z	1.130	1.055
β	0.9	0.9
θ	0.35	0.35
δ_k	0.06	0.06
δ_z	0.20	0.20
α_k	0.167	0.218
α_z	0.155	0.153
τ_k, τ_z	0.28	0.22
τ_l	0.15	0.15

Figure 3. Producer price indices and investment deflator



Source: Bank of Korea (http://ecos.bok.or.kr)

Figure 4. Investment deflator and calculated investment deflator



Source: Bank of Korea (http://ecos.bok.or.kr); calculated by author

4.2. Accounting for growth: contribution of ICT and transition

Next two tables summarize the calculated composition of productivity growth rates, based on the calibration. The observed growth rates of productivity measured as labor productivity per hour are 5.46% for 1996-2003, 3.52% for 2004-2015, and 4.3% for 1996-2015, Meanwhile, the calculated productivity growth rates based on the calibration are 5.43%, 3.54%, and 4.32% respectively.

On the other hand, ICT investment-specific technological change rate dropped from 13.0% to 5.5%, and non-ICT investment-specific technological change rate even declined from 0.85% to minus 0.35%. Because of this transition in the investment-specific technological changes, ICT investment-specific technological change rate is on average at 8.5% while non-ICT investment-specific technological change rate is at negligible 0.1% in the whole period 1996-2015.

While neutral technological growth has driven most of the productivity growth, I find that ICT investment specific technological change contributed 37.1% of the productivity growth, while non-ICT investment specific technological change did only 2.6% in 1996-2003. Afterward the productivity growth slowed down in 2004-2015 and this is caused by stagnant investment specific technological changes. This slowdown in the investment specific technological change resulted in 23.6% contribution to the productivity growth by ICT investment specific technological change and minus 0.22% contribution by non-ICT investment specific technological change in 2004-2015. This rapid non-ICT investment specific productivity slowdown is also found in Martinez et al.(2010).

Thus, rapid technological progress in ICT leads to corresponding decline in ICT goods and to increasing usage of ICT capital in Korea during 1996-2003. Furthermore, this resulted in quick rise in ICT investment intensity during 1995-2003 period. With slowdown in ICT specific technological progress, ICT investment intensity has been stable since then.

Table 2. Productivity growth and sources of growth, Korea economy, 1995-2015

		1996-2003	2004-2015
productivity growth (gross)	data	1.055	1.035
	calibrated	1.054	1.035
Decomposition (gross)	neutral	1.033	1.028
	ICT	1.130	1.055
	non-ICT	1.009	0.997
Contribution	Neutral (%)	60.9%	78.5%
	ICT (%)	37.1%	23.6%
	non-ICT (%)	2.6%	-2.2%

5. Cyclical fluctuations and ICT

This section analyzes economic dynamics around the balanced growth path when stochastic processes are added to technology, while the previous sections are about the balanced growth path. I assume an independent stochastic process for each type of technology, and specify the stochastic process for exogenous shocks as follows:

$$A_t = \widetilde{A_t} e^{a_t}$$

$$Q_t^z = \widetilde{Q_t^z} e^{q_t^z}$$

$$Q_t^k = \widetilde{Q_t^k} e^{q_t^k}$$

The terms, $\widetilde{A_t}$, $\widetilde{Q_t^z}$ and $\widetilde{Q_t^k}$, indicate deterministic trends that grow at gross growth rates of g_A, g_Z and g_k respectively. On the other hand, the lower-case letters represent the cyclical component. They are assumed to follow AR(1), and $\{\rho_A, \rho_Z, \rho_k\}$ are estimated after detrending $\{A, Q_z, Q_k\}$.

$$a_t = \rho_A a_{t-1} + \varepsilon_t^A$$

$$q_t^z = \rho_z q_{t-1}^z + \varepsilon_t^z$$

$$q_t^k = \rho_k q_{t-1}^k + \varepsilon_t^k$$

The estimation suggests that ρ_A=0.96, ρ_z=0.93, ρ_k=0.76, and the standard deviations of the shocks are 0.12%, 3.0% and 2.9% for the whole period. Splitting the period, the standard deviations of the shocks are 1.0%, 4.7% and 3.0% (1.4%, 1.2% and 2.7%) respectively for 1995-2003 (2004-2015).

The responses of variables to each technology shock is described in Figure 5~7. In Figure 5, a neutral technology shock increases marginal product of both types of capital and output as well. The shock increases non-ICT capital investment more than ICT capital investment, and results in lower ICT investment/non-ICT investment ratio.

In Figure 6, an ICT investment-specific technology shock leads to higher rental rate of ICT capital due to increased expected marginal product of ICT capital, but the rental rate of non-ICT capital declines. At the moment, the sharp rise of the ICT capital rental rate reduces ICT investment due to the increased demand, and lowers ICT investment/non-ICT investment ratio at the same time. Subsequently the substitution of non-ICT capital to ICT capital raises ICT investment/non-ICT investment ratio, and drops non-ICT capital rental rate due to relatively higher productivity of ICT capital. As ICT capital accumulation proceeds, the complementarity between ICT capital and non-ICT capital in the production function leads to improved marginal return from non-ICT investment.

On the other hand, impulse responses to a non-ICT investment-specific technological shock are responded in Figure 7. The shock to non-ICT investment-specific technology quickly raises the marginal product of non-ICT capital and increases non-ICT capital rental rate. Combined with the drop in ICT capital rental rate, ICT investment/non-ICT investment ratio jumps up immediately. However, as workers shift their capital holdings towards more productive non-ICT capital, the ratio of ICT investment to non-ICT investment drops. Increased non-ICT capital stock leads to higher marginal product of ICT capital due to the complementarity, and the rental rate of ICT capital recovers. In sum, the dynamic responses to ICT investment-specific technology shock is quantitatively opposite to responses to non-ICT investment-specific technology shock.

Figure 2. Impulse response functions (neutral technology shock)

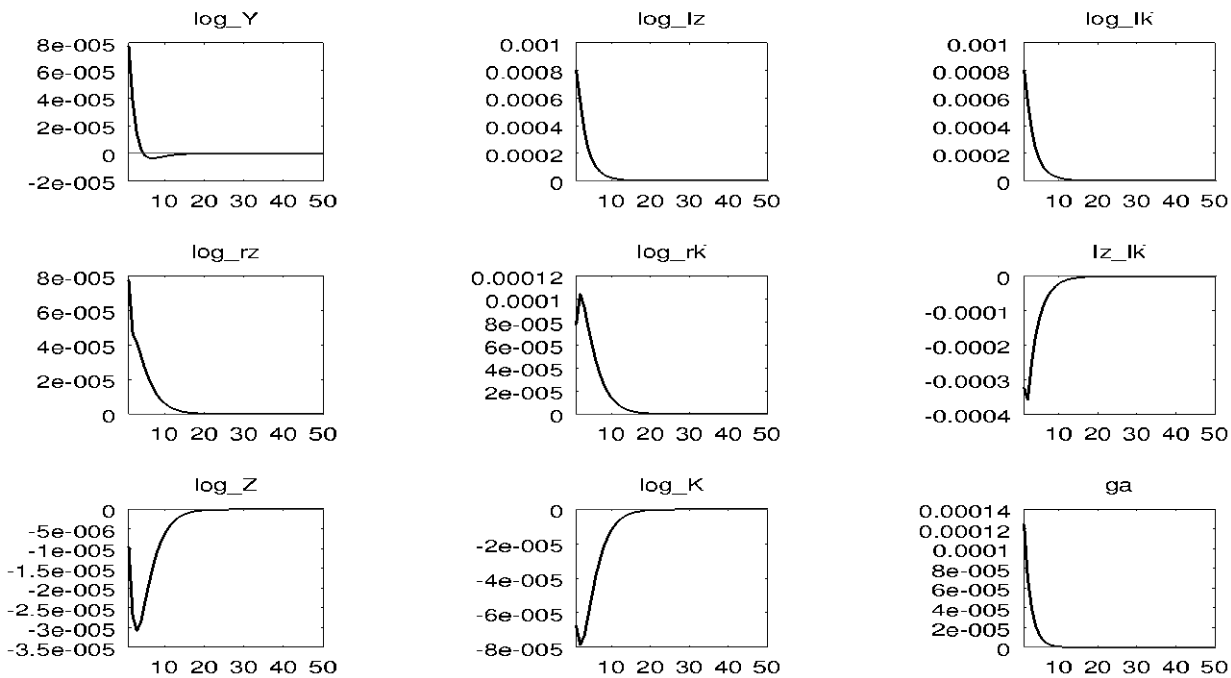


Figure 3. Impulse response functions (ICT investment-specific technology shock)

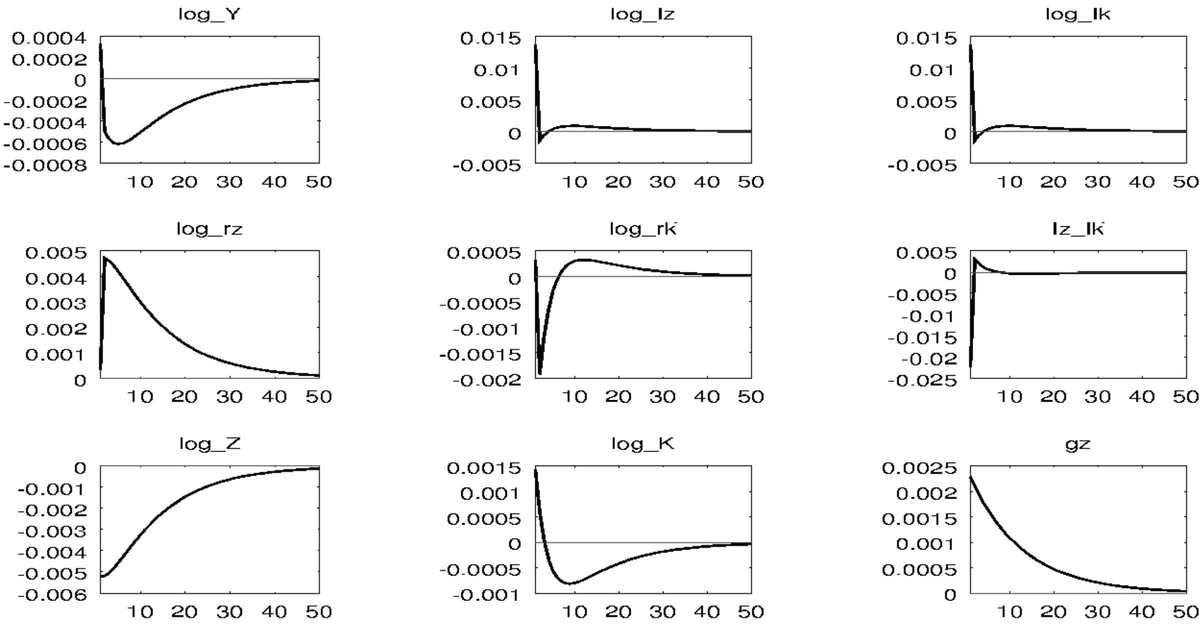
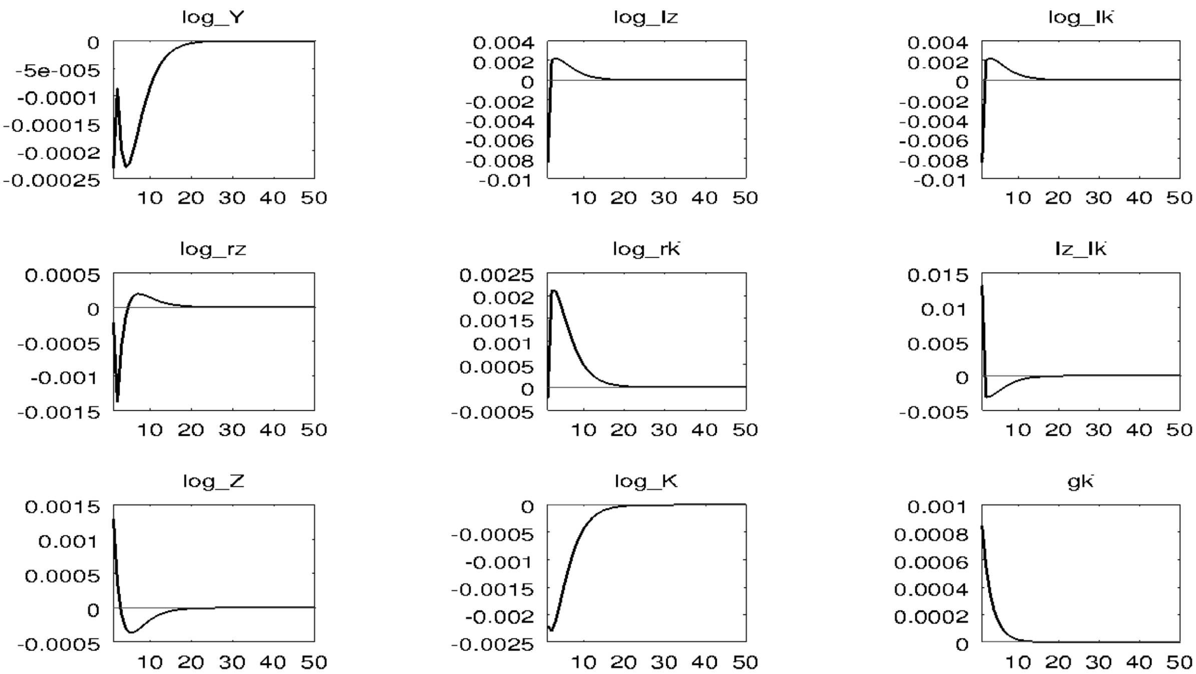


Figure 4. Impulse response functions (non-ICT investment-specific technology shock)



In addition to the response analysis, the decomposition of output variance shows significant impacts of shocks on investment specific technology. For the first period of 1995-2003, ICT investment-specific shock dominates the output variance. ICT investment specific shock accounts for 56.9% at the first period after the shock, and its portion in the output variance continues to increase. On the contrary, neutral and non-ICT investment specific shocks explain most of the output variance for the latter period of 2004-2015. Neutral technology shock's share in the output variance begins from 74% then slowly decline to 49.3% after ten periods, and non-ICT investment-specific technological shock accounts for 25.1% at the first period, then 49.5% after ten periods. I think that the change in the variance decomposition between 1995-2003 and 2004-2015 reflects stagnated technological progress of ICT.

Table 3. Decomposition of output variance

	1995-2003			2004-2015		
period	A	Qz	Qk	A	Qz	Qk
t=1	0.0462	0.5689	0.3849	0.7398	0.0093	0.2509
t=2	0.0374	0.7605	0.2022	0.8137	0.0098	0.1766
t=5	0.0225	0.7826	0.1949	0.5560	0.0098	0.4342
t=10	0.0193	0.8199	0.1608	0.4939	0.0114	0.4947

6. Conclusions

In this paper, I use a dynamic general equilibrium model to decompose the productivity growth of Korea into neutral technology, ICT investment-specific technology and non-ICT investment specific technology. This study finds that ICT investment-specific technological change contributed 20~30% of the productivity growth along the balanced growth path. Furthermore, the model implies stagnated ICT and non-ICT investment-specific technological changes had significant impacts on lowered productivity growth rate since early 2000s.

To analyze cyclical fluctuations around the balanced growth path, I add stochastic processes to the model. In particular, impulse responses show that a neutral technology shock and a non-ICT investment specific shock lower ICT investment/non-ICT investment ratio, while an ICT investment specific shock leads to higher ICT investment/non-ICT investment ratio. Furthermore, variance decompositions suggest that contribution of ICT specific technology to output fluctuation accounted for 50~80% in 1995-2003, but it significantly decreased in 2004-2015. This exercise implies that the slowdown of ICT investment specific technological change was an important factor to explain not only lower productivity growth but also smaller contribution to output fluctuations. While this paper does not analyze an exact transition from the balanced growth path in 1995-2003 to another one in 2004-2015, I think that it still can explicate how productivity of an economy is affected by ICT.

References

Armbrust, Michael, Fox, Armando, & Buxmann, Peter (2009). Drivers. *Korean Economic Review*, 28(2), 203-230.

Bakhshi, Hasan, & Larsen, Jens (2005). ICT-specific technological progress in the United Kingdom. *Journal of Macroeconomics*, 27, 648-669.

Cummins, Jason, & Violante, Giovanni (2002). Investment-Specific Technical Change in the United States (1947-2000): Measurement and Macroeconomic Consequences. *Review of Economic Dynamics*, 5(2), 243-284.

Fisher, Jonas D. (2006). The Dynamic Effects of Neutral and Investment-Specific Technology Shocks. *Journal of Political Economy*, 114(3), 413-451.

Greenwood, Jeremy, Hercowitz, Zvi, & Krusell, Per (1997). Long-Run Implications of Investment-Specific Technological Change. *The American Economic Review*, 87(3), 342-362.

Greenwood, Jeremy, Hercowitz, Zvi, & Krusell, Per (2000). The role of investment-specific technological change in the business cycle. *European Economic Review*, 44(1), 91-115.

Hobijn, Bart (2000). Identifying sources of growth. Federal Reserve Bank of New York.

Jorgenson, Dale W., & Stiroh, Kevin J. (2000). Raising the speed limit: US economic growth in the information age. *Brookings Papers on Economic Activity*, 2000(1), 125-210.

Martinez, Diego, Rodríguez, Jesús, & Torres José L. (2010). ICT-specific technological change and productivity growth in the US: 1980-2004. *Information Economics and Policy*, 22, 121-129.

Oliner, Stephen D., & Sichel, Daniel E. (2000). The Resurgence of Growth in the Late 1990s: Is Information Technology the Story?. FEDS Working Paper No.2000-20.

O'Mahony, Mary, & Vecchi, Michela (2005). Quantifying the impact of ICT capital on output growth: a heterogenous dynamic panel approach. *Economica*, 72(288), 615-633.

Oulton, Nicholas (2002). ICT and productivity growth in the United Kingdom. *Oxford Review of Economic Policy*, 18(3), 363-379.

Oulton, Nicholas (2012). Long term implications of the ICT revolution: Applying the lessons of growth theory and growth accounting. *Economic Modelling*, 29(5), 1722-1736.

Park, Seryoung, & Han, Youngok (2008). Effects of Quality Improvement of Investment on Growth: Productivity Effects of Embodied Technological Progress. *BOK Monthly Bulletin*, March, 23-50 (in

Korean).

Pyo, Hak K., Jung, Sunyoung, & Cho, Jung Sam (2007). Estimates of Gross Fixed Capital Formation, Net Capital Stock and Capital Intensity in Korea: 11 Assets by 72 Sectors (1970-2005). *Journal of Korean Economic Analysis*, 13(3), 137-191 (in Korean).

Shin, Sukha (2010). Information Communication Technology Capital and Total Factor Productivity across sectors in Korea. *KDI Journal of Economic Policy*, 32(4), 75-114 (in Korean).