A STUDY ON FIRM-LEVEL OUTPUT GROWTH, TOTAL FACTOR PRODUCTIVITY, AND FINANCIAL PERFORMANCE: FOCUSED ON SELECTED US ICT FIRMS

By

KANG, Seok-Moo

THESIS

Submitted to
KDI School of Public Policy and Management
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MASTER OF DEVELOPMENT POLICY

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Committee in charge:

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ABSTRACT

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By

Seok-Moo Kang

Productivity is believed to be a key driver for a firm's growth, especially for information and communication technology firms. This study calculated the total factor productivity growth of the major US ICT companies, and analyzed the relationship between the firms' total factor productivity and output growth. This study also investigated the factors affecting the firm's total factor productivity growth.

The analysis shows that the selected firms' output growth is positively affected by the firms' capital input growth the most, followed by the firm's total factor productivity growth. The firms' total factor productivity growth is negatively affected by the cost factors. However, the factors affecting the individual firm's total factor productivity growth are different across the firms. For example, in the case of Oracle, the firm's total factor productivity is very positively affected by the technology innovation factor.

Dedicated to In Shin Ha

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1. Introduction

Today we are living in the ICT (Information & Communication Technology) age. We generally believe that ICT has been playing a crucial role in productivity growth, and vice versa. Therefore, there have been many studies on ICT and productivity. For example, the ICT industry itself is believed to be more productive than the other industries. Many articles showed the productivity growth of the ICT industry is higher than the other industries. Secondly, there are many researches on different contributions of the ICT capital and non-ICT capital to productivity growth. The results were mixed. In some countries, the ICT capital was more important to productivity growth, but not in some other countries. However, there are relatively a small number of studies on firm-level productivity, especially the firm-level productivity of ICT firms. Is the output growth of ICT firms driven by the productivity? Or, as opposed to our general beliefs, does the capital or the labor contribute more to the output growth than the productivity? The productivity of ICT firms is mainly coming from cutting-edge technologies, or smart and savvy engineers? This research tried to analyze the source and the role of productivity in ICT firms, especially focused on some selected US ICT firms.

1.1 Objective of the study

The main objective of this study is categorized into three: to find what the main source of the output growth of the selected US ICT firms is, to analyze what affects the total factor productivity growth of those firms, and to find what the total factor productivity growth affects in terms of the firms' financial performances.

1.2 Research questions

So far, total factor productivity is mostly used for analyzing country-level or industry-level output growth. There are some studies on firm-level total factor productivity, but many of them are simply calculating firm-level total factor productivity, or focused on one side of the productivity such as the factors affecting the productivity. In contrast, this study focused on the both sides of firm-level productivity; how the productivity affects output growth, and how the productivity is formed. Thus this study asks:

I. What drives major US ICT firms' output growth?
   A. Is it capital-driven, labor-driven, or total factor productivity driven?
II. What is the source of firm-level total factor productivity growth?
   A. Are there the economies of scale in firm-level total factor productivity growth?
   B. Do costs affect firm-level TFP growth? (cost-saving channel)
   C. Does the quality of human capital affect firm-level TFP growth? (labor quality channel)
   D. Does R&D affect firm-level TFP growth? (technology innovation channel)
   E. How different are the TFP growth drivers among the companies?
III. How does TFP growth affect a firm's financial performance?
   A. Does TFP growth affect revenue, profit, and/or profit growth?

2. Theoretical Context

2.1 Conceptual Framework (Literature review)

There are many researches on total factor productivity. In many studies, the total factor productivity is calculated at country-level, industry-level, or company-type such as large enterprises and small enterprises. This is useful for comparing country to country or industry to industry. However, studies on the total factor productivity of firm-level or famous companies such as Google are not so many. One reason for that might be lack of data. For example, Google was listed in 2004 and therefore the data for Google's total factor productivity is only about 10 years.

The early studies were mainly focusing calculating the total factor productivity growth itself. Sung (1997) calculated the total factor productivity of Korea Telecom, but did not provide the factors affecting the firm's total factor productivity. Yang (2005) calculated and compared the total factor productivity growth between large enterprises and small and medium enterprises in Korea from 1991 to 2002. The paper did not suggest the influential factors for the total factor productivity growth either.

In recent researches, some scholars began to try to find the factors affecting total factor productivity growth. Kim (2012) analyzed the total factor productivity growth of Korean firms by size. The paper showed that the total factor productivity growth of the large enterprises was 0.5%p higher than that of the small and medium sized companies from 1984 to 2009. The paper also showed R&D intensity is positively affecting the total factor productivity of small companies, but not statistically affecting the total factor productivity of medium sized company. Oh and Lee (2011) analyzed the total factor productivity growth in the Korean telecommunications market. The paper calculated the industry's total factor productivity growth and used previous year's output, marketing expenses, regulations, and competition as independent variables for total factor productivity growth. The paper suggested that economies of scale are the most important factor for the total factor productivity growth of the Korean telecommunications industry, followed by regulations.

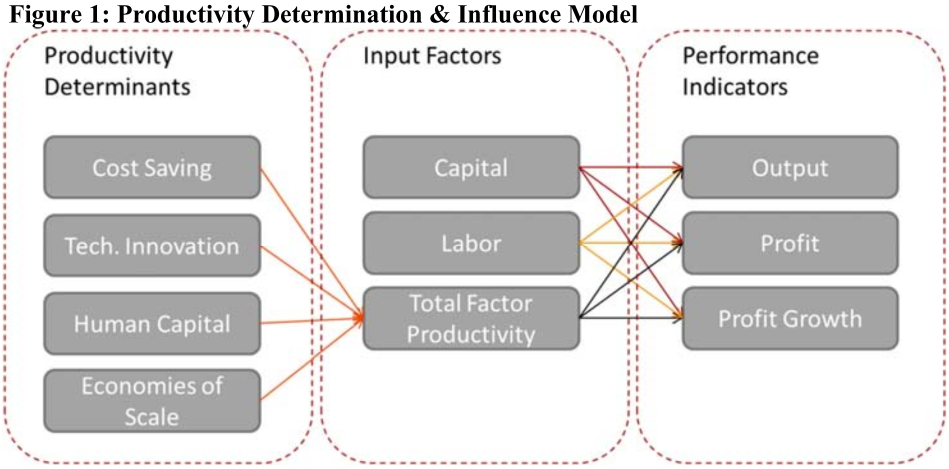
2.2 Theoretical background

Basically, productivity is a function of inputs and outputs. If a company produces more with the same input, the productivity grows. Likewise, if a company produces the same with the less input, the productivity also grows. Therefore, in terms of the input side, cost savings might be negatively influential to total factor productivity. One working paper from National Bank of Belgium (van Ark, 2014) stated that total factor productivity has also been referred to as "real" cost reductions.

Other factors affecting total factor productivity could be technology, human capital, and economies of scale. Jung (2011) developed the model decomposing the total factor productivity into technology change, technical efficiency change, and scale effect. The paper argued that Korean ICT companies' total factor productivity growth is primarily from technology change while technical efficiency change and scale effect are getting worse. Heshimati and Kumbhakar (2011) adopted technology index to calculate and analyze the total factor productivity growth of Chinese provinces. The technology index consists of ICT investment, foreign direct investment, percentage of highly educated labor, and reform variables. Many researches (e.g., Chow, 2011; Miller & Upadhyay, 2002) also incorporated human capital in total factor productivity growth and usually used some sort of human capital indices such as HDI (Human Development Index) mainly based on education level and others.

There could be many other possible factors for determining total factor productivity growth in macroeconomics, but this study used technology innovation, quality of labor, cost savings, and economies of scale for total factor productivity growth determination. This paper also used output, profit, and profit growth as dependent variables to find how the total factor productivity growth affects a firm's financial performance. The model used in this study is described as follows:

Figure 1: Productivity Determination & Influence Model



3. Hypotheses

3.1 Output growth driver of the selected US ICT firms

The US ICT giants such as Google and Apple have been enjoying robust growth for recent years. When we think about those highly innovative ICT firms such as Google and Apple, we probably imagine some extremely smart engineers are working for long hours and producing some extraordinary innovative products. Those could be the source of their productivity and their exceptional productivity could make their strong growth possible. This is a common perception toward the US ICT giants. So this paper will test that perception.

H1: The output growth of the selected US ICT firms is positively related with total factor productivity growth.

3.2 Factors affecting total factor productivity of selected US ICT firms

Even if the solid growth of the selected US ICT firms is led by total factor productivity, it does not mean that the total factor productivity of the selected firms is coming from technology simply because those firms are based on the cutting-edge technology. We have to test what the real engine for the total factor productivity growth is regardless of whether the output growth is driven by the total factor productivity or not. Of course, the technology innovation and the quality of human capital would positively affect the firm's total factor productivity. The costs would negatively affect the firm's total factor productivity. However, the costs include R&D expenses. R&D activities are one of core competitiveness of high-tech companies such as Google and Apple, and R&D is believed to be essential for not only productivity but also survival in the high-tech industry. Do R&D expenses negatively affect the total factor productivity growth? Here we need to separate the input and the output of R&D. The R&D expense is the input of R&D activities. If R&D activities are successful, the output of R&D would be accumulated as a technology asset. If not successful, the R&D expense is a waste of money and would contribute nothing to the total factor productivity growth. In this paper, the cost factor includes R&D expense, but it only reflects the input side of R&D activities. The influence of economies of scale is unclear, so this study initially assumes there are economies of scale in the selected US ICT firms' total factor productivity growth.

H2a: The quality of human capital positively affects the firm's total factor productivity growth.

H2b: The technology innovation positively affects the firm's total factor productivity growth.

H2c: The cost (including R&D) negatively affects the firm's total factor productivity growth.

H2d: There are economies of scale in total factor productivity growth.

H2e: The factors affecting the firm's total factor productivity growth are different across the selected firms.

3.3 Total factor productivity and financial performance

From testing the above hypotheses, we will find what affects the firms' output growth. Besides that, what else does total factor productivity growth affect in terms of a firm's financial performance? This study will test how a firm's total factor productivity growth affects the firms' output, profit, and profit growth.

H3a: Total factor productivity positively affects a firm's output (revenue.)

H3b: Total factor productivity positively affects a firm's profit.

H3c: Total factor productivity positively affects a firm's profit growth.

4. Methods and data

4.1 Measure of total factor productivity

4.1.1 Data

This paper selected five major US ICT firms for analysis. The firms are Google, Apple, Intel, Oracle, and VMware. To avoid different accounting principle issues across countries, only US companies are used. To analyze the difference from the business nature, this study chose the companies focusing on single type of business such as software or hardware, rather companies focusing on multi type of businesses. And this study picked up as big companies as possible. Google, Oracle, and VMware are mainly software companies, while Apple and Intel are mainly hardware companies. Apple is well-known for its software products such as iOS, but the most of Apple's revenues are from hardware products sales such as iPhone. Most of data is extracted from the firms' annual reports from 2002 to 2015, subject to availability. The nominal wages of the companies are usually not in the annual reports; therefore the nominal wages are inferred from Payscale.com. This study took the average salaries of each company from Payscale.com. As a result, the number of observations is 52. The sample was not selected randomly and may not represent the whole US ICT companies. Table 1 shows the descriptive statistics of the sample. This study used SPSS for analyzing the data.

Table 1: Descriptive Statistics (million USD, ratio per previous year)

	N	Minimum	Maximum	Mean	Std. Deviation
NW	52	.04	.13	.0718	.01921
NWG	52	-.62	.63	.0381	.20615
REV	52	6.94	12.12	9.9770	1.23253
RND	52	5.42	9.35	7.7867	1.03128
RNDR	52	.02	.48	.1414	.09690
RNDRG	52	-.66	.75	.0098	.18972
PROFIT	52	5.39	10.92	8.6276	1.40034
PROFITG	52	-.08	.25	.0333	.05414
RNDG	52	-.02	.98	.2268	.21308
PDT	52	.00	8.70	5.1381	2.97296
PDTG	52	-.33	2.07	.2137	.51118
RNDxRNDG	52	-.18	6.26	1.6658	1.38486
RNDRxRNDRG	52	-.14	.36	.0061	.05569
NWxNWG	52	-.04	.08	.0031	.01749
PDTxPDTG	52	-2.08	18.03	1.3794	3.72191
PDTGpRNDG	52	-24.28	24.85	-.3323	6.83209
Valid N (listwise)	52				

Note: NW = Nominal wage, NWG = Nominal wage growth, REV = Revenue, RND = R&D investment, RNDG = R&D investment growth, RNDR = R&D ratio (per revenue), RNDRG = RND ratio growth, PROFITG = Profit growth, PDT = Patent and developed technologies.

Figure 2 ~ 5 show the revenues and the operating profits of each company. Intel was already a big company in 2003, but others were not so big in the early 2000s. The figures show the solid growth of the selected US ICT giants for recent years.

Figure 2: Revenue and Operating Profit (Apple)

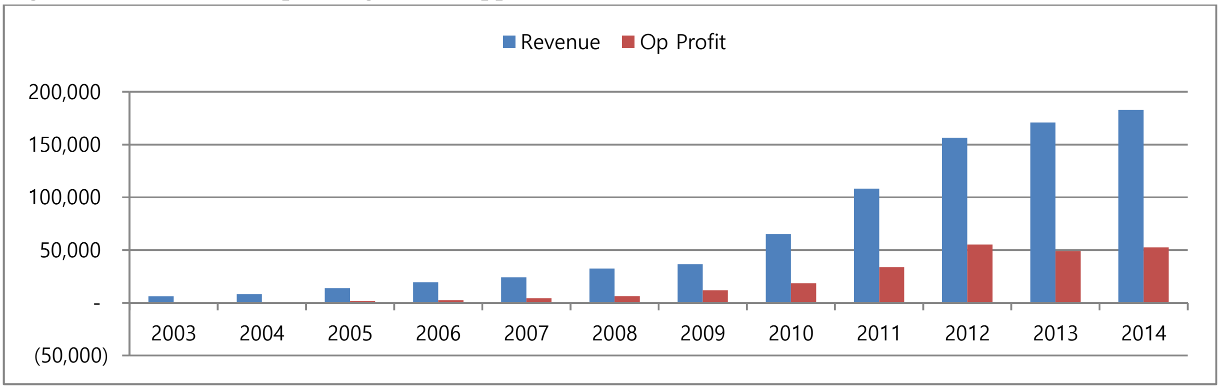


Figure 3: Revenue and Operating Profit (Google)

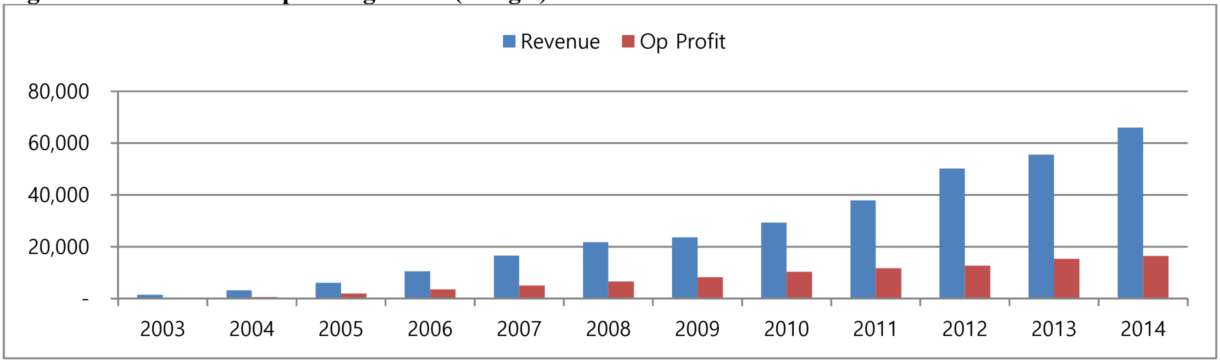


Figure 4: Revenue and Operating Profit (Intel)

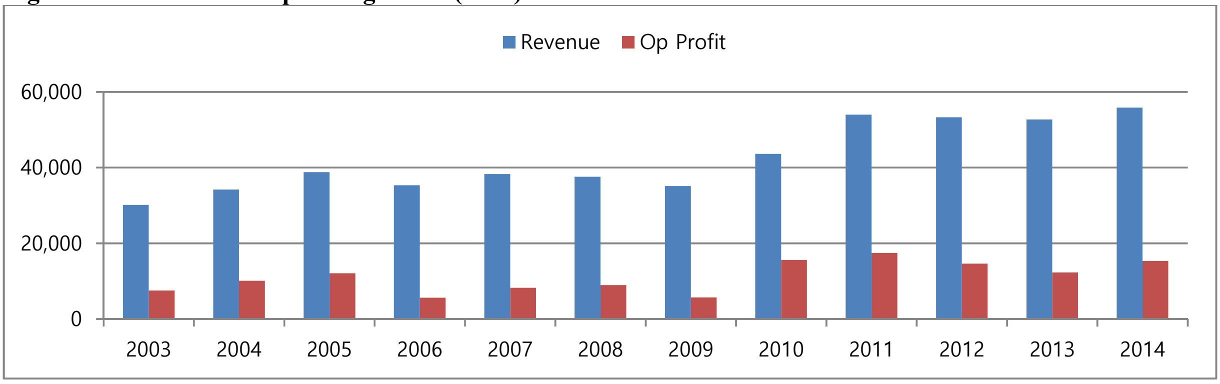
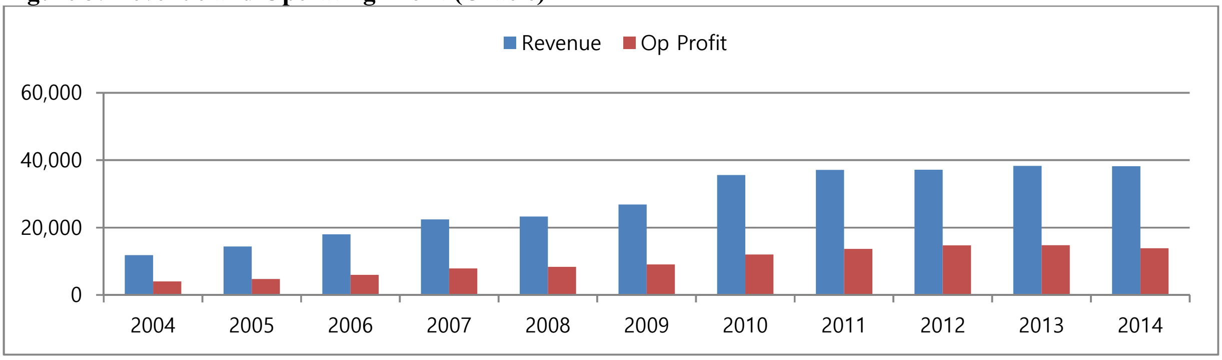


Figure 5: Revenue and Operating Profit (Oracle)



4.1.2 Measure of total factor productivity

Index methods are widely used for calculating total factor productivity, such as Laspeyres index, Paashe index, Fisher index, Tornqvist index, and Malmquist index. This paper used Tornqvist index to calculate firm-level total factor productivity. The detail equation using Tornqvist index is as follows:

$$\ln TFP\ Index_{st} = \ln \frac{Output\ \ Index_{st}}{Input\ \ Index_{st}}$$

$$= \ln\ Output\ Index_{st} - \ln\ Input\ Index_{st}$$

$$= \frac{1}{2}\sum_{i=1}^{M}\left(r_{is} + r_{it}\right)\left(\ln\ q_{it} - \ln\ q_{is}\right) - \frac{1}{2}\sum_{j=1}^{K}\left(s_{js} + s_{jt}\right)\left(\ln\ x_{jt} - \ln\ x_{js}\right)$$

In the equation, r is the relative share of the outputs, q means the output, s represents the relative share among the input factors, and x means each input factors. This paper used revenue as output. Usually, the input factors are capital and labor. However, this is for national economy, not for firm-level. Therefore, this study added intermediate goods in the input factors. In the model, the capital is the sum of property and equipment and intangible assets, minus the change in inventory. This paper took the total amount of the labor cost as the labor input, which is the product of the total number of employees and the average nominal wage. Therefore, the quantity and the quality are considered in sum, not separately in the model. Finally, intermediate goods are calculated as total costs minus capital cost and labor cost, i.e. revenue – operating profit – depreciation & amortization – labor cost.

Figure 6 ~ 9 show the trend of revenues, R&D expenses, and the total factor productivity of each firm. Despite the upward trends of revenues and R&D expenses, the total factor productivity shows a considerable amount of fluctuation.

Figure 6: Revenue, R&D expense, and Total Factor Productivity Growth (Apple)

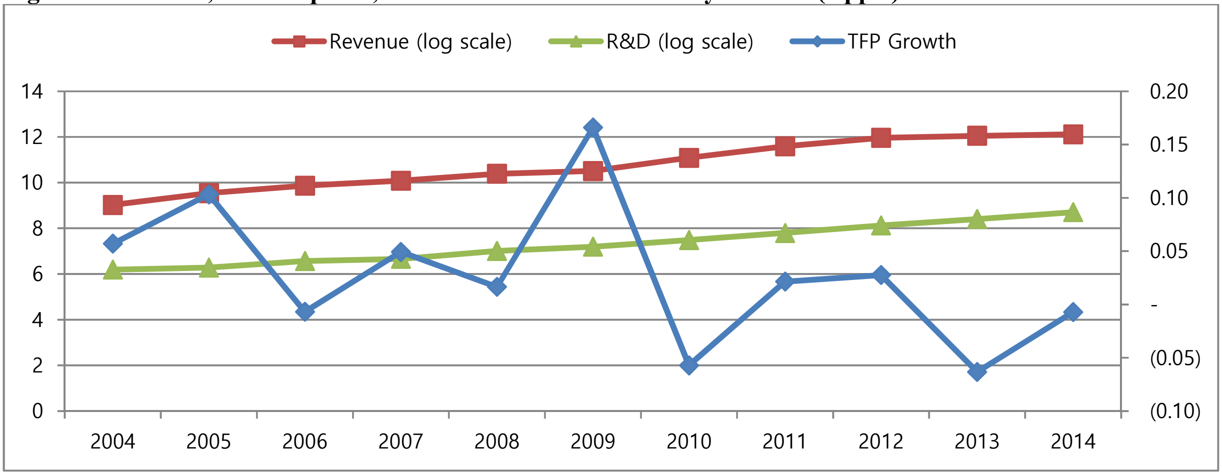


Figure 7: Revenue, R&D expense, and Total Factor Productivity Growth (Google)

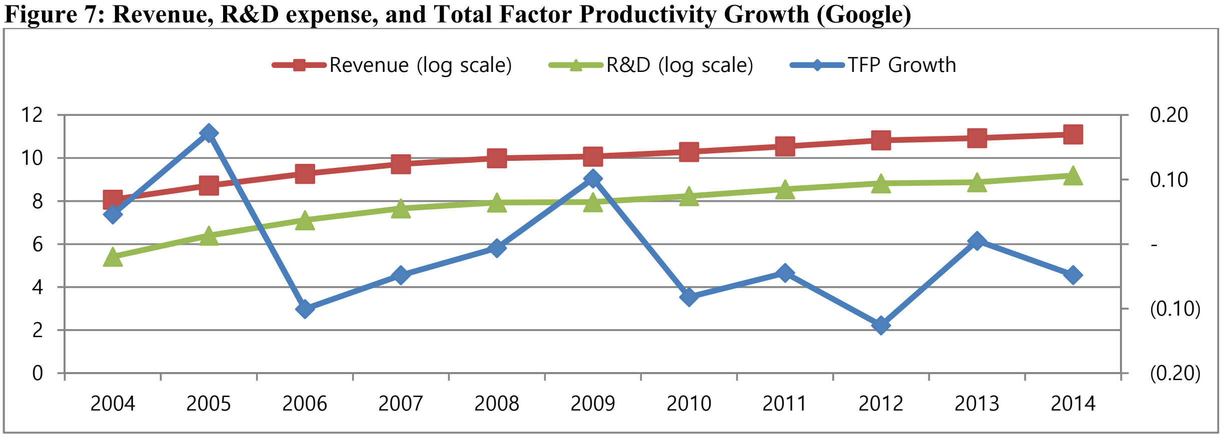


Figure 8: Revenue, R&D expense, and Total Factor Productivity Growth (Intel)

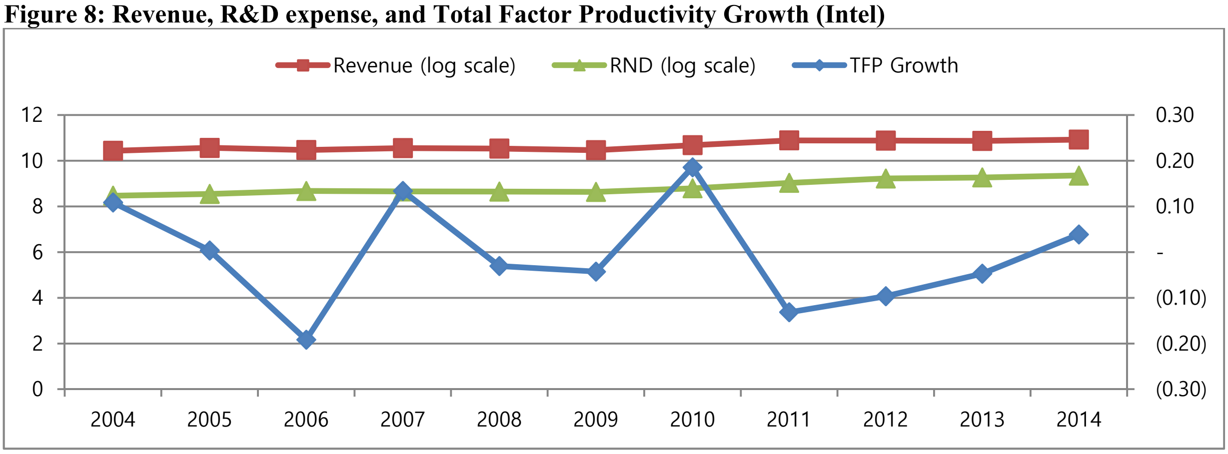


Figure 9: Revenue, R&D expense, and Total Factor Productivity Growth (Oracle)

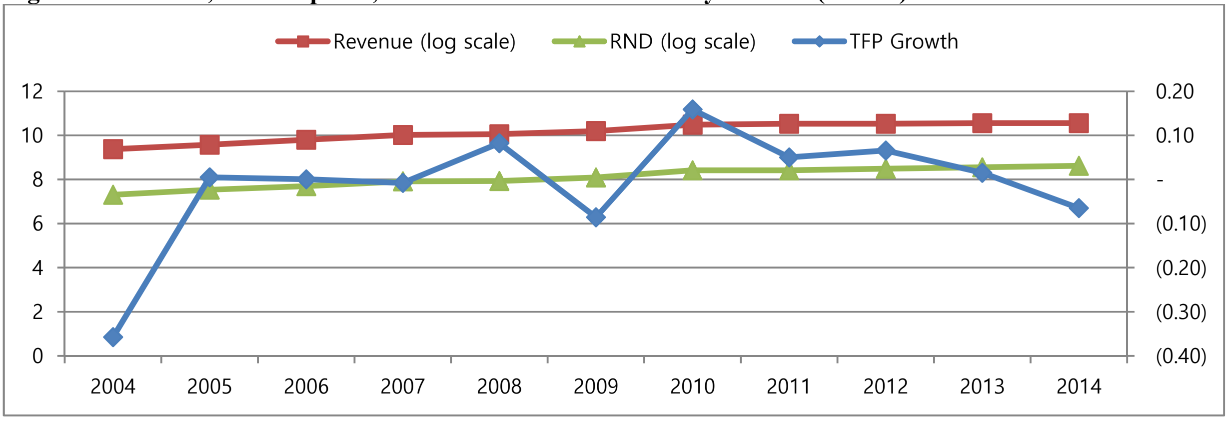


Table 2: Descriptive Statistics (Contribution to Output Growth)

	N	Minimum	Maximum	Mean	Std. Deviation
TFPG	52	-.34	.19	-.0047	.09809
K	52	-.07	.37	.0690	.08437
L	52	-.03	.10	.0263	.02912
Q	52	-.60	.92	.2170	.24654
Valid N (listwise)	52				

Table 2 shows the summary statistics of the total contribution to the output growth of each input factor. On average, capital growth contributes 6.9% of the selected US ICT firms' output growth. Labor growth accounts for 2.6% of the total output growth. Interestingly, the total factor productivity growth contributes even -0.47% of the total output growth. However, this does not mean the total factor productivity growth is not significant in explaining the yearly firm-level output growth.

4.2 Results

4.2.1 Output growth driver of the selected US ICT firms

To find the output growth driver of the selected US ICT firms, this study simply used capital growth, labor growth, and total factor productivity growth as an independent variable.

From this test, we will find how the input factors (capital, labor, and total factor productivity) affect the ICT firms' output growth. The estimated regression model is:

$$\ln Q = \alpha + \beta \ln TFPG + \gamma \ln K + \delta \ln L$$

where Q is output growth, TFPG is total factor productivity growth, K is capital input growth, and L is labor input growth.

Table 3: Regression Result for Output Growth

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.462[a]	.213	.197	.22089
2	.626[b]	.392	.367	.19607

a. Predictors: (Constant), K

b. Predictors: (Constant), K, TFPG

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.660	1	.660	13.533	.001[b]
	Residual	2.440	50	.049		
	Total	3.100	51			
2	Regression	1.216	2	.608	15.815	.000[c]
	Residual	1.884	49	.038		
	Total	3.100	51			

a. Dependent Variable: Q

b. Predictors: (Constant), K

c. Predictors: (Constant), K, TFPG

Coefficients[a]

Model		Unstandardized Coefficients B	Unstandardized Coefficients Std. Error	Standardized Coefficients Beta	t	Sig.
1	(Constant)	.124	.040		3.121	.003
	K	1.349	.367	.462	3.679	.001
2	(Constant)	.064	.039		1.646	.106
	K	2.315	.413	.792	5.606	.000
	TFPG	1.350	.355	.537	3.802	.000

a. Dependent Variable: Q

Table 3 shows that the regression model is valid ($F = 15.815$, $p = 0$) and capital input growth and total factor productivity growth explain 36.7% of the difference in the firms' output growth ($R^2_{adj} = 0.367$.) Capital input growth is the most important factor in explaining the output growth with standardized $\beta = 0.792$, followed by total factor productivity growth with standardized $\beta = 0.537$. If a firm's capital input growth increases by 1%, the firm's output growth would increase by 2.315%. In addition, if a firm's total factor productivity growth increases by 1%, the firm's output growth would increase by 1.35%. This result does not exactly match the initial expectation, because even in ICT firms, capital input growth is the most influential factor for their output growth. However, total factor productivity growth still remains statistically important for the selected ICT firms' output growth.

4.2.2 Factors affecting total factor productivity of selected US ICT firms

As a second step, this paper developed a regression model for firm-level total factor productivity growth. As mentioned earlier, the model adopted four input factors such as scale effect, cost saving, quality of labor, and technology innovation. The estimated regression model is:

$$\begin{aligned}\ln TPFG = {} & \alpha + \beta_1 \ln REV_{t-1} + \beta_2 \ln RND + \beta_3 \ln RNDG + \beta_4 \ln RND * RNDG + \beta_5 \ln RNDR \\ & + \beta_6 \ln RNDRG + \beta_7 \ln RNDR * RNDRG + \beta_8 \ln NW + \beta_9 \ln NWG \\ & + \beta_{10} \ln NW * NWG + \beta_{11} \ln LABOR + \beta_{12} \ln LABORG + \beta_{13} \ln LABOR * LABORG \\ & + \beta_{14} \ln PDT + \beta_{15} \ln PDTG + \beta_{16} \ln PDT * PDTG + \beta_{17} \ln PDTGpRNDG\end{aligned}$$

where REV is previous year's revenue for testing a scale effect, RND and RNDG are R&D expense and its growth, RNDR and RNDRG are R&D ratio per revenue and its growth, NW and NWG are nominal wage and its growth, LABOR and LABORG are labor cost and its growth, and PDT and PDTG are patent and developed technology in the balance sheets and its growth.

This study divided the cost factors into R&D related costs and labor costs. The R&D related costs are also divided into R&D expense and R&D expense ratio per revenue. Doing so, if the cost factors are affecting the firms' total factor productivity growth, we would find specifically which cost is more influential. Nominal wage is used as a proxy for quality of labor. Higher nominal wages usually mean better talents. Of course, labor costs reflect individual nominal wages, but the total labor cost which is the product of the total number of employees and nominal wage indicates the quantity side of labor input, because ten employees of \$10,000 and one employee of \$100,000 are treated as the same labor input. Similarly, the total R&D expense means the quantity side of R&D activities for technology innovation, but patent and developed technology in the firms' balance sheets would explain only the successful result of R&D activities and technology innovation.

The model incorporated five interaction terms to see the impact of growth rates as well as the absolute size in measuring R&D expense, R&D ratio, labor costs, nominal wage, and patent and developed technology. Thus this model could capture the effects of each factor more precisely. Table 4 shows that the regression model is valid ($F = 6.233$, $p = 0.005$) and 20.7% of the firms' total factor productivity growth variances can be explained with this model (R^2_{adj} = 0.367.)

Table 4: Regression Result for Total Factor Productivity Growth

Model Summary

Model	R COMPANY ~= 1.00 (Selected)	R Square	Adjusted R Square	Std. Error of the Estimate
1	.319[a]	.102	.079	.09961
2	.497[b]	.247	.207	.09240

a. Predictors: (Constant), PDTxPDTG

b. Predictors: (Constant), PDTxPDTG, NWG

ANOVA[a,b]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.044	1	.044	4.430	.042[c]
	Residual	.387	39	.010		
	Total	.431	40			
2	Regression	.106	2	.053	6.233	.005[d]
	Residual	.324	38	.009		
	Total	.431	40			

a. Dependent Variable: TFPG

b. Selecting only cases for which COMPANY ~= 1.00

c. Predictors: (Constant), PDTxPDTG

d. Predictors: (Constant), PDTxPDTG, NWG

Coefficients[a,b]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	.001	.017		.031	.976
	PDTxPDTG	-.008	.004	-.319	-2.105	.042
2	(Constant)	.011	.016		.687	.496
	PDTxPDTG	-.011	.004	-.421	-2.890	.006
	NWG	-.178	.066	-.394	-2.705	.010

a. Dependent Variable: TFPG

b. Selecting only cases for which COMPANY ~= 1.00

Interestingly, PDTxPDTG is the most important factor for the firms' total factor productivity growth, but negatively related. The second important factor is nominal wage growth and also negatively related. This result is also against my initial expectation. Initially, I assumed patent and developed technology is regarded as a technology innovation factor, not a cost factor. Also, nominal wage growth is believed to be the quality of labor. However, the result indicates that patent and developed technology and nominal wage growth are acting like a cost factor. In addition, there is no statistical evidence for scale effects

As a next step, I did the same regression analyses independently on each firm to see whether the total factor productivity growth factors are same across the firms. In the suggested regression model, nothing is statistically significant for Google and Apple. Only Oracle, Intel, and VMware produced statistically significant results under the suggested regression model. Table 5 shows that the regression model is valid (F = 18.314, p = 0.001) and 77.6% of Intel's total factor productivity growth variances can be explained with this model (R^2_{adj} = 0.776.)

Table 5: Regression Result for Total Factor Productivity Growth (Intel)

Model Summary

Model	R COMPANY = Intel (Selected)	R Square	Adjusted R Square	Std. Error of the Estimate
1	.817[a]	.668	.631	.07019
2	.906[b]	.821	.776	.05473

a. Predictors: (Constant), RNDRG

b. Predictors: (Constant), RNDRG, PDTG

ANOVA[a,b]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.089	1	.089	18.131	.002[c]
	Residual	.044	9	.005		
	Total	.134	10			
2	Regression	.110	2	.055	18.314	.001[d]
	Residual	.024	8	.003		
	Total	.134	10			

a. Dependent Variable: TFPG

b. Selecting only cases for which COMPANY = Intel

c. Predictors: (Constant), RNDRG

d. Predictors: (Constant), RNDRG, PDTG

Coefficients[a,b]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	.023	.022		1.034	.328
	RNDRG	-.908	.213	-.817	-4.258	.002
2	(Constant)	.032	.018		1.819	.106
	RNDRG	-.877	.167	-.789	-5.260	.001
	PDTG	-.075	.029	-.391	-2.608	.031

a. Dependent Variable: TFPG

b. Selecting only cases for which COMPANY = Intel

In the case of Intel, R&D ratio growth and patent and developed technology growth are the most and the second important cost factors for the total factor productivity growth, respectively.

Table 6: Regression Result for Total Factor Productivity Growth (Oracle)

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
	COMPANY = Oracle (Selected)			
1	.695[a]	.483	.425	.09790

a. Predictors: (Constant), PDT

ANOVA[a,b]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.081	1	.081	8.405	.018[c]
	Residual	.086	9	.010		
	Total	.167	10			

a. Dependent Variable: TFPG

b. Selecting only cases for which COMPANY = Oracle

c. Predictors: (Constant), PDT

Coefficients[a,b]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	-1.465	.502		-2.918	.017
	PDT	.194	.067	.695	2.899	.018

a. Dependent Variable: TFPG

b. Selecting only cases for which COMPANY = Oracle

Table 6 shows the case of Oracle. The regression model is valid ($F = 8.405$, $p = 0.018$) and 42.5% of the firm's total factor productivity growth variances can be explained with this model ($R^2_{adj} = 0.425$.) The most influential factor for the company's total factor productivity growth is patent and developed technology. Unlike the above results, in the case of Oracle, patent and developed technology is acting as a technology innovation factor and reflecting the successful results of company's R&D activities. Moreover, none of the other factors is statistically significant in explaining the company's total factor productivity growth. This is a very interesting result and could be strong empirical evidence that successful R&D activities are enormously important for the company's total factor productivity growth in some companies like Oracle.

Table 7: Regression Result for Total Factor Productivity Growth (VMware)

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
	COMPANY = Vmware (Selected)			
1	.879[a]	.773	.736	.04267

a. Predictors: (Constant), NWxNWG

ANOVA[a,b]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.037	1	.037	20.474	.004[c]
	Residual	.011	6	.002		
	Total	.048	7			

a. Dependent Variable: TFPG

b. Selecting only cases for which COMPANY = Vmware

c. Predictors: (Constant), NWxNWG

Coefficients[a,b]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	.029	.020		1.455	.196
	NWxNWG	-9.678	2.139	-.879	-4.525	.004

a. Dependent Variable: TFPG

b. Selecting only cases for which COMPANY = Vmware

Table 7 shows the case of VMware. The regression model is valid ($F = 20.474$, $p = 0.004$) and 73.6% of the firm's total factor productivity growth variances can be explained with this model ($R^2_{adj} = 0.736$.) In this company, nominal wage is not acting as quality of labor, rather acting as a cost factor. The labor cost factor is the most important factor in explaining the firm's total factor productivity growth variances. None of the other factors is statistically significant for this company's total factor productivity growth.

As discussed above, the factors affecting a firm's total factor productivity growth are different across the selected firms. There is no statistically significant factor for the total factor productivity growth of Google and Apple. In the case of Intel, R&D ratio per revenue growth is the most important cost factor (negatively related) for the firm's total factor productivity growth, while in the case of Oracle, patent and developed technology is the most influential factor (positively related) for the firm's total factor productivity growth. In the case of VMware, the interaction of nominal wage and nominal wage growth is the most negatively related factor for the firm's total factor productivity growth.

4.2.3 Total factor productivity and financial performance

As a next step, the study developed a regression model to test how total factor productivity growth, capital growth, and labor growth affect a firm's financial performance. Originally, total factor productivity growth is derived from the relationship among output growth, capital input growth, and labor input growth. However, we don't know how total factor productivity growth, capital input growth, and labor input growth affect a firm's other financial performances such as revenue itself, profit, and profit growth. The estimated regression model is:

$$\ln FinPerformance = \alpha + \beta \ln TFPG + \gamma \ln K + \delta \ln L$$

where FinPerformance is a firm's financial performance indicator such as revenue, profit and profit growth, TFPG is the firms' total factor productivity growth, K is the firms' capital input growth, and L is the firms' labor input growth.

Table 8 shows the result of the regression analysis for revenue. The regression model is valid (F = 19.417, p = 0) and 26.5% of the firm's revenue variances can be explained with this model (R^2_{adj} = 0.265.) The regression result indicates that the firms' revenue is significantly and negatively related with the firms' labor input growth. If a firm's labor input increases by 1%, the firm's revenue would decrease by 22.387%. The firms' capital input growth and total factor productivity growth are not significantly related with the firms' revenue.

Table 8: Regression Result for Revenue

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.529[a]	.280	.265	1.05645

a. Predictors: (Constant), L

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	21.671	1	21.671	19.417	.000[b]
	Residual	55.804	50	1.116		
	Total	77.475	51			

a. Dependent Variable: REV

b. Predictors: (Constant), L

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	10.566	.198		53.290	.000
	L	-22.387	5.081	-.529	-4.406	.000

a. Dependent Variable: REV

Table 9 shows the result of the regression analysis for profit. The regression model is valid ($F = 16.574$, $p = 0$) and 23.4% of the firm's profit variances can be explained with this model ($R^2_{adj} = 0.234$.) The regression result indicates that the firms' profit is significantly and negatively related with the firms' labor input growth. If a firm's labor input increases by 1%, the firm's profit would decrease by 23.996%. The firms' capital input growth and total factor productivity growth are not significantly related with the firms' profit.

Table 9: Regression Result for Profit

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.499[a]	.249	.234	1.22565

a. Predictors: (Constant), L

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	24.898	1	24.898	16.574	.000[b]
	Residual	75.110	50	1.502		
	Total	100.008	51			

a. Dependent Variable: PROFIT

b. Predictors: (Constant), L

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	9.259	.230		40.251	.000
	L	-23.996	5.894	-.499	-4.071	.000

a. Dependent Variable: PROFIT

Table 10 shows the result of the regression analysis for profit growth. The regression model is valid ($F = 41.466$, $p = 0$) and 61.3% of the firm's profit growth variances can be explained with this model ($R^2_{adj} = 0.613$.) The regression result indicates that the firms' profit growth is significantly and positively related with the firms' total factor productivity growth the most, followed by the firms' capital input growth. If a firm's total factor productivity growth increases by 1%, the firm's profit growth would increase by 0.533%. Similarly, if a firm's capital input growth increases by 1%, the firm's profit growth would increase by 0.523%. The firms' labor input growth is not significantly related with the firms' profit growth.

Table 10: Regression Result for Profit Growth

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.464[a]	.215	.200	.04844
2	.793[b]	.629	.613	.03366

a. Predictors: (Constant), TFPG

b. Predictors: (Constant), TFPG, K

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.032	1	.032	13.726	.001[b]
	Residual	.117	50	.002		
	Total	.150	51			
2	Regression	.094	2	.047	41.466	.000[c]
	Residual	.056	49	.001		
	Total	.150	51			

a. Dependent Variable: PROFITG

b. Predictors: (Constant), TFPG

c. Predictors: (Constant), TFPG, K

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	.034	.007		5.127	.000
	TFPG	.256	.069	.464	3.705	.001
2	(Constant)	.000	.007		-.049	.961
	TFPG	.533	.061	.966	8.746	.000
	K	.523	.071	.816	7.384	.000

a. Dependent Variable: PROFITG

To sum up, a firm's revenue and profit are significantly and negatively related with the firm's labor input growth. But a firm's profit growth is significantly and positively related with the firm's total factor productivity and capital input growth. If a firm want to maximize revenue and profit and profit growth at the same time, the firm should reduce the firm's labor input growth and increase capital input growth and total factor productivity growth.

5. Conclusion

5.1 Discussion and limitation of the study

Table 11 shows the summary of the hypotheses test results. From the result, we found that the output growth of the selected US ICT firms is positively related with the firms' total factor productivity growth. However, the firms' total factor productivity growth is not the most important factor, but the second important factor. The selected firms' output growth is mainly contributed by the firms' capital input growth. One possible reason is that the firms' capital accumulation is still going on and has not reached to a saturation point. The firms' labor input growth is not significantly related with the firms' output growth.

As for the firms' total factor productivity growth, the interaction of patent and developed technology and its growth is the most important factor and negatively related with the firms' total factor productivity growth. The firms' nominal wage growth is the second important factor and negatively related with the firms' total factor productivity growth. Unlike the initial assumptions, patent and developed technology is not acting as a technology innovation factor, rather acting as a cost factor negatively affecting a firm's total factor productivity growth. Also, the firms' nominal wage growth is not acting as quality of labor, rather acting a cost factor. However, when looking at individual firms, the factors affecting a firm's total factor productivity growth are different. This study did not found any statistically significant factors affecting the total factor productivity growth of Google and Apple. In the case of Intel, R&D ratio per revenue growth is the most important and negatively related with Intel's total factor productivity growth. Intel is a semi-conductor design company, which requires huge and long-term R&D investments.

Therefore, Intel's total factor productivity growth seems to be very sensitive to the ratio of R&D expenses over its revenue. On the other hand, in the case of Oracle, patent and developed technology is the most important factor and positively related with its total factor productivity growth. In Oracle's balance sheet, patent and developed technology properly reflects the successful outcomes of its R&D activities.

This paper did not found any evidence that a firm's quality of labor affects the firm's total factor productivity growth. However, it does not mean a firm's quality of labor does not affect the firm's total factor productivity growth. This research used nominal wage as a proxy for a firm's quality of labor, but the results suggest that nominal wage often serves as a cost factor, not a quality factor. In the future, we need to find another variable to capture a firm's quality of labor properly.

Finally, the firms' revenue and profit are significantly and negatively related with the firms' labor input growth. The firms' profit growth is significantly and positively related with the firms' total factor productivity growth and capital input growth. In estimating a firm's profit growth, the firm's total factor productivity growth is the most important factor, followed by the firm's capital input growth. To sum up, the absolute numbers (revenue and profit) are mainly negatively correlated with the firms' labor input growth and the growth rates (revenue growth and profit growth) are positively correlated with the firms' total factor productivity growth and capital input growth. From this result, we can infer that the way to maximize revenue and profit as well as revenue and profit growth is to minimize the labor input growth and to maximize the capital input growth and the total factor productivity growth.

Due to the limitation of the sample size and the sampling method, this result may not represent the whole population of the US ICT firms. In addition, since we found that the factors affecting a firm's total factor productivity growth are different across the firms, it would be difficult to generalize the factors affecting ICT firms' total factor productivity growth.

Table 11: Results of Hypotheses Testing

Hypotheses	Result
H1a: The output growth of the selected US ICT firms is positively related with total factor productivity growth.	Supported
H2a: The quality of human capital positively affects the firm's total factor productivity growth.	Not Supported
H2b: The technology innovation positively affects the firm's total factor productivity growth.	Partially Supported
H2c: The cost (including R&D) negatively affects the firm's total factor productivity growth.	Partially Supported
H2d: There are economies of scale in total factor productivity growth.	Not Supported
H2e: The factors affecting the firm's total factor productivity growth are different across the selected firms	Supported
H3a: Total factor productivity positively affects a firm's output (revenue.)	Not Supported
H3b: Total factor productivity positively affects a firm's profit.	Not Supported
H3c: Total factor productivity positively affects a firm's profit growth.	Supported

5.2 Future research

As discussed above, the model in this study might not reflect all factors affecting a firm's total factor productivity growth. However, the study addressed the basic relationship between the firm-level total factor productivity growth and the elements in the selected firms' financial statements. Future researches could extend the sample size to capture the relationship discussed in this paper more accurately. Also, it would be meaningful to compare the US firms case and other countries' firms such as Korean companies. Furthermore, comparing ICT firms and other industries or comparing software companies and hardware companies in the ICT industry would be valuable.

6. References

Castany, L., López-Bazo, E., & Moreno, R. (2007). Decomposing differences in total factor productivity across firm size.

Castany, L., López-Bazo, E., & Moreno, R. (2005, August). Differences in total factor productivity across firm size. A distributional analysis. In *45th Congress of the European Regional Science Association* (pp. 23-27).

Chow, W. (2011). Human Capital and Total Factor Productivity.

Diewert, W. E., & Nakamura, A. (2002). The measurement of Aggregate Total Factor Productivity. *Capítulo del Handbook of Econometrics*, *6*.

Dobbelaere, S., & Vancauteren, M. (2014). *Market imperfections, skills and total factor productivity: Firm-level evidence on Belgium and the Netherlands* (No. 267). National Bank of Belgium.

Fosse, H. B., Jacobsen, J., & Højbjerg Jacobsen, R. (2014). *The Short-run Impact on Total Factor Productivity Growth: Of the Danish Innovation and Research Support System*. CEBR, Copenhagen Business School.

Griliches, Z. (1998). Issues in assessing the contribution of research and development to productivity growth. In *R&D and Productivity: The Econometric Evidence* (pp. 17-45). University of Chicago Press.

Heshmati, A., & Kumbhakar, S. C. (2011). Technical change and total factor productivity growth: The case of Chinese provinces. *Technological Forecasting and Social Change, 78*(4), 575-590.

Jorgenson, D. W., Ho, M. S., & Samuels, J. D. (2011). Information technology and US productivity growth: evidence from a prototype industry production account. *Journal of Productivity Analysis*, *36*(2), 159-175.

Jung, M., Lee, K., & Fukao, K. (2008). Total Factor Productivity of the Korean Firms and Catching up with the Japanese Firms.

Miller, S. M., & Upadhyay, M. P. (2002). Total Factor Productivity, Human Capital and Outward Orientation: Differences by Stage of Ddevelopment and Geographic Regions.

Oh, K., & Lee, T. H. (2011). Measurement of Total Factor Productivity Growth in the Korean Telecommunications Market. *International Telecommunications Policy Review, 18*(1).

Ondrej, M. A. C. H. E. K., & Jiri, H. (2012). Total factor productivity approach in competitive and regulated world. *Procedia-Social and Behavioral Sciences*,*57*, 223-230.

Peeters, C., & Van Pottelsberghe, B. (2004). Innovation capabilities and firm labor productivity. *Working papers CEB*, *4*.

Tamkin, P., Hillage, J., & Willison, R. (2002). Indicators of management capability: developing a framework. *London, Council for Excellence in Management and Leadership*.

van Ark, B. (2014). Total factor productivity: Lessons from the past and directions for the future (No. 271).

김석현. (2007). 외환위기 이후 한국 기업의 성장 요인 분석. *정책자료*, 1-80.

김원규. (2012). 기업규모별 총요소생산성 분석. *Issue Paper 2012-279*.

박승록. (2002). *공기업과민간기업의생산성분석* (Vol. 2). 한국경제연구원.

성낙일. (1997). 한국통신의 총요소생산성 측정 및 추정오차 원인분석.

양현봉. (2005). 중소기업과 대기업의 총요소생산성 비교분석-외환위기 전후를 중심으로. *중소기업연구*, *27*(3), 195-213.

이영수, 김정언, & 정현준. (2008). IT 제조업의 총요소생산성 추정 및 결정요인 분석. *한국산업정보학회논문지*, *13*(1), 76-86.

정선영. (2011). 정보통신산업의 총요소생산성 국제비교: 기술적 효율성을 감안한 접근방법. *한국경제학회, 경제학연구*, *59*(1), 25-53.

표학길, 정선영, & 조정삼. (2007). 한국의 총고정자본형성, 순자본스톡 및 자본계수추계: 11 개 자산-72 부문 (1970~ 2005). *한국경제의 분석*, *13*(3), 137-186.