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RELATIONSHIP BETWEEN TELECOMMUNICATIONS INVESTMENT AND TOTAL FACTOR PRODUCTIVITY

Abstract:

This study examines diverse production functions and total factor productivity (TFP) levels of 29 OECD countries by using regional data for the 2003-2013 period and related determinants. First, the relationship between TFP and capital and that between TFP and labor are negative (-). Second, communications equipment investment by type has a negative effect on TFP in which communications capital is considered by type, providing support for the productivity paradox. Third, imports have a negative (-) relationship with TFP, whereas the degree of openness has a positive (+) relationship. Finally, the Asian region has a positive effect on TFP, whereas the American region has the greatest negative effect.

Keywords:

TFP, Telecommunications Equipment Investment, Determinants, Random Coefficient Model

JEL Classification: D22, A10, D29

Ⅰ. Introduction

With a diverse range of smart devices such as smartphones and tablet PCs actively applied to a variety of classes as a result of advances in ICT, smart devices have served as an important growth engine at the country level. The global smartphone supply rate (per capita) in 2014 was 24.5%, an increase of 19.3%p in comparison to that in 2012 (5.2%), when smartphones were launched. Given the PC supply rate of 20.0%, these figures indicate a high dissemination rate, and ICT products can be considered to play an important role as a new growth engine.[1]

For such products to be used, the communications environment plays a crucial role. Communications environments can be broadly divided into wired and wireless ones based on the form or technology. The development of the wired communications environment entails a shift from telephone wires (copper) to optical cables, whereas the wireless communications environment has evolved toward fast access anytime, anywhere through broad bandwidths. The development of these communications environments, that is, communications technologies, depends mainly on the use of traffic. That is, traffic occurs when people use communications products through diverse devices and becomes a criterion for evaluating how many vehicles can pass the road and how fast they pass it. Traffic use has increased sharply in recent years because of the supply of smartphones. In response, diverse technologies have been developed, and the introduction of faster, more stable connections is expected to increase service diversity.

In addition, because of the development and introduction of smart work systems that enable people to work anytime, anywhere based on smart devices, diverse communications environments, and monitoring systems for diverse production processes, ripple effects of communications products on the productivity of all industries in a country are expected to gradually strengthen. In particular, the development of communications technology enhances not only the continuity of work but also its efficiency by reducing the cost of production or management in diverse areas, and therefore firms can maximize or enhance profits through cost reductions. For instance, in a management context, service or device problems can be immediately identified and addressed through real-time management based on diverse monitoring tools and communications equipment.[2)]

Therefore, before forecasting the impact of the communications industry in future, the question of how the growth potential of the communications field has thus far affected the productivity of individual countries should be addressed. More specifically, the questions of how working environments have been made more efficient by the development and supply of communications technologies and what type of value added has been created by these technologies in other industries for economic growth should be quantitatively addressed. The answers to these questions are expected to serve as basic data for determining future communications technology policies and market environments.

This study analyzes the role of communications equipment investment in regional

1) Prospective 2015 mobile trend(KT Economic and Business Research Institute, 2015)
2) The IoT(Internet of Things) can be representatively referred to. The IoT is evolving into a form that fuses communication technology with diverse industries and applications to create new added value or services.

economic growth. For this, the study proposes a model that enables the estimation of total factor productivity (TFP) by employing the economic growth theory of the neo-classical school and the Solow residual method. The model is designed to analyze TFP determinants in the OECD region by reflecting real-world factors such as interregional trade, market openness, and the level of purchasing power, including variables for estimating TFP as its determinants. That is, communications equipment investment is included as a factor TFP determinant with a significant effect on regional economic growth to better grasp how this investment affect TFP. This study's variables may be entail the potential issue of autocorrelation, and the unit root needs to be solved through an empirical analysis using panel data with time series characteristics. therefore, panel cointegration tests and empirical analyses are conducted using a probability coefficient model.

2. Literature Review

Advances in ICT have served as a core growth engine in the economy of many countries, and therefore many studies have examined the effects of ICT applications on productivity. Studies in Korea have generally employed growth accounting as an analysis method (Bank of Korea, 2000; Kang, 2002; Oh & Baek, 2005; Kim & Kim, 2009). The Bank of Korea (2000) reported that the TFP of the ICT industry increased sharply between 1994 and 1997 in comparison to before 1994, showing a rate of increase of 14.3% over the period. Kang (2002) estimated the capital stock from 1990 to 1998 and analyzed the accumulation of information capital and the effects of information capital on the growth and productivity of the Korean economy and estimated the contribution of informationization to the economic growth of the country at about 1.19%. Oh and Baek (2005) used the growth accounting method to analyze the IT-oriented manufacturing industry and the non-IT manufacturing industry separately and suggested no appearance of characteristics of the new economic system of the U.S. based on the gradually decreasing rate of increase in TFP. Kim and Kim (2009) derived TFP levels of the manufacturing sector and the service sector from 1991 to 2006 separately for areas making frequent and infrequent use of ICT and found that the areas making frequent use of ICT are more likely to show increase rates and less likely to show reduced rates.

Previous studies have derived TFP regression analysis methods, including Lee (2001) and Shin, Lee, and Lee (2004). Lee (2001) estimated the ICT capital stock of 26 individual industries by using interindustry relationship tables for 1985, 1990, and 1995, and based on the level of non-ICT capital per laborer as a variable, he conducted regression analyses to determine whether high labor productivity levels would appear in industries with relatively high levels of ICT capital. He identified productivity levels to be higher in industries with higher ICT capital ratios based on panel data but found significance only in service-oriented industries, making this a limitation. As in Shin et al.(2004), Lee (2004) estimated the ICT capital stock of 27 individual industries based on interindustry relationship tables and conducted panel regression analyses to determine the ICT capital stock of those industries directly affected the productivity of relevant industries and assess whether the ICT capital stock of the industry would indirectly affect other industries through interindustry ripple effects. They found direct/indirect positive effects on productivity only in the ICT production industry. In addition, previous studies have examined the relationship between TFP and ICT based on enterprise data (Shin, Kim & Song, 1998; Park, 2004). First, Shin, Kim, and Song (1998) analyzed whether the scale of enterprises' information investment would be positively related to productivity, and Park (2004) divided small and medium-sized manufacturing enterprises into those with the ratio of R&D investment to average sales not lower than 8% and those with the said ratio lower than 8% and compared the performance of these enterprise groups, and they found that the former are more likely to show superiority in manpower management, R&D costs, employment, technology acquisition, and cooperation with other institutions.

In the case of countries outside Korea, previous studies have analyzed the relationship between labor productivity and communications market investment and focused mainly on relevant markets. That is, studies have examined the relationship between labor productivity and communications market investment within the communications market. Kreamer and Dedrick (1994) analyzed the correlation between labor productivity growth and IT investment in 43 countries based on CEPII's (2003) findings and examined the relationships between capital investment and labor hours in the IT industry during the 1996-2000 period, revealing the presence of capital investment and a decrease in labor hours. Raul (2009) estimated the ICT capital stock of Spain from 1980 and 2000 to analyze the relationship between the ICT capital stock and productivity and found these two factors to show the same directivity. Chunhui (2014) conducted an empirical analysis of effects of communications investment on labor productivity based on 1998-2000 survey data on U.S. enterprises and suggested that labor productivity may increase gradually through ICT investment.

Most of the aforementioned studies used data at the country level and showed changes in TFP and the relationships between TFP and the ICT capital stock. In addition, because these studies used data from the whole IT industry, they could not present the effects of communications investment on TFP as a result of the actual economic growth of the country as a whole. Therefore, the present study extends the literature by estimating TFP based on the capital stock in the area of communications making substantial contributions to GDP to determine the production function and analyze TFT determinants. That is, communications equipment investment is considered to estimate TFP based on the Solow residual method, and determinants of estimated TFP are analyzed to examine the actual relationship between communications equipment investment and TFP. In addition, communications equipment investment is divided by type, and the question of whether there are peculiarities by continent is addressed through a panel analysis.

3. Analysis Model

3.1. Theoretical Background

3.1.1. Relationship Between Information and Communications Equipment Investment and Productivity

Advances in ICT have given rise to a diverse range of related products and services, and such products and services have accounted for an increasing portion of the economy of many countries. Recent studies examining whether ICT can directly enhance the TFP of each country have generally found positive correlations between productivity and IT investment. In general, the development of ICT is considered to facilitate decision making by increasing the communication speed between objects as well as reducing unnecessary costs through the promotion of immediate mechanical responses without human users' subjective intervention. However, there is another argument that even if IT-related investment increases, TFP (i.e., value added) does not increase.[3)]

The former argument is related mainly to ICT and can be achieved by preparing environments where communication can occur anytime, anywhere through technological development and investment that can increase the communication speed and environments. The latter argument is related mainly to IT, but IT can be efficiently operated only if it is linked to communications technologies. For instance, users of products that implement certain programs are humans, and the reliability of such products increases only if they have the means to provide information for decision making and on current situations to human users. Through this relationship between these two arguments, purchases of products or services through ICT applications can enhance the efficiency of production in other industries by facilitating decision making and removing unnecessary costs even when those products or services are not directly used in those industries.

In addition, recent years have witnessed concepts such as M2M (Machine-to-Machine) and IoT (Internet of things) being incorporated into products, and this is expected to change systems such that decisions can be made and products can be produced by products without any human interference in many industries for optimal productivity. Although this expectation is an outcome of the process of theorization in which ICT has direct positive effects on productivity and the "productivity paradox," which stands in contrast to this, also exists. The key point in the productivity paradox is that if enterprises invest in ICT, the investment is not directly related to the enhancement of productivity but serves as a factor that reduces productivity. To see the productivity paradox in terms of time, counterarguments against the positive relationship between productivity and IT investment were raised in the 1980s and 1990s. Major studies include Steven, R. (1987), who pointed out that one of the reasons why the rate of increase in productivity turns into actual deterioration is an increase in the number of office workers in the service sector and computational resources.

Since the productivity paradox, many studies have found a positive relationship between IT investment and productivity (Kraemer & Dedrick, 1994; Dewan & Kraemer, 1988, 2000; Plice, 2001).[4)] In the case of Korea, Kim (2002) presented an argument against the productivity paradox based mainly on the measurement error hypothesis and the time lag hypothesis. The measurement error hypothesis is based on the logic that the productivity paradox may occur because the effect of using ICT cannot be

3) This is called Productivity Paradox and became an issue between 1980 and 1990. It began from the criticism by Solow, R.(1987) who presented Productivity Paradox for the first time that reads, “You can see the computer age everywhere but in the productivity statistics.”

4) Kraemer and Dedrick(1994) showed that there were positive relationships between IT investments and increases in GDP and productivity based on data from 12 countries in the Asia Pacific region from 1984 to 1990 and Dewan and Kraemer(1988, 2000) expanded the initial region consisting of 12 countries to a region consisting of 36 countries but could not find any characteristic points in developing countries(they found that IT investments had positive relationships mainly with labor productivity). Finally, Plice(2001) analyzed enterprise data centered on six industries in 38 countries and found that countries with large IT capitals(mainly advanced countries) showed 5 ~ 8 times higher ROI(Return on Investment) compared to developing countries.

measured using existing statistical systems, and the time lag hypothesis is based on the logic that productivity cannot be accurately calculated because time lags exist in innovation activities to supplement the development of certain ICT applications. Based on various studies, the present study assesses the recent situation in Korea in terms of the relationship between information and communications equipment investment and TFP by using regional data.

3.1.2. Analysis Model

The Solow residual method is used to estimate TFP. The Solow residual method basically enables the derivation of residuals by estimating the Cobb-Douglas production function. In constructing the production function, the following two equations with related variables are composed to see how communications equipment investment affects TFP as well as the production function based on capital and labor:

$$\mathrm{Y} = K^{a}L^{b}\ (provided\ that, 0 < a < 1, b = 1 - a),$$
Eq. (1)

$$\mathrm{Y} = K^{a}TK^{c}L^{b}\ (provided\ that, 0 < a, b, c < 1, 1 = a + b + c).$$
Eq. (2)

In Eq (1), Y indicates real GDP and K and L represent total physical capital and the amount of labor, respectively. In Eq. (2), TK(telecommunications capital) represents communications capital (communications equipment investment). Communications equipment investment here can be divided broadly into total communications equipment investment, wired communications equipment investment, and wireless communications equipment investment, and these are included in individual models for analysis purposes. Then, by converting the concept of the production function into that of a production function per capita under the constraint that the production scale is constant as a+b=1, abbreviated production functions can be considered as follows:

$$\mathrm{y} = k^{\alpha}\ (y = \frac{Y}{L}, k = \frac{K}{L}),$$
Eq. (3)

$$\mathrm{y} = k^{a}tk^{\beta}\ (y = \frac{Y}{L}, k = \frac{K}{L}, tk = \frac{TK}{L}).$$
Eq. (4)

To obtain TFP through the production functions (3) and (4), a probability coefficient model that allows for heterogeneity across regions while considering similarity is used. Probability coefficient models are typically used when models that consider only the heterogeneity between cross sections are necessary, and Kalman filtering state-space models are used when models that consider the heterogeneity between time periods are necessary. Because fixed-coefficient models consider probabilistic disturbance terms only in the intercept term and probability coefficient models allow for probabilistic disturbance terms in both intercept terms and slopes, a probability coefficient model analysis is considered suitable when setting an uncertain model.

In the case of probability coefficient models, individual regions have different coefficients to accommodate differential effects of individual regions. If all the similarity and heterogeneity of physical, social, and economic structures across regional groups are allowed and individual coefficient values are assumed to be derived from the same distribution, then the following equation can be derived:

$$Y_{i,t} = X_{i,t}\gamma_i + \varepsilon_{i,t} = X_{i,t}(\gamma_i + u_{i,t}) + \varepsilon_{i,t} = X_{i,t}\gamma_i + X_{i,t}u_{i,t} + \varepsilon_{i,t} = X_{i,t}\gamma_i + \omega_{i,t}$$ Eq. (5)

(provided that $\omega_{i,t} = X_{i,t}u_{i,t} + \varepsilon_{i,t}$),

where $\mathrm{E}[\varepsilon_i] = 0$, and the assumption of $\mathrm{E}\varepsilon_i\varepsilon_j' = \sigma_{ij}\Omega_{ij}$, allows for the issue of heteroskedasticity in residual terms and that of first-order autoregression and time series correlation. Then the estimation equations using this can be shown as follows:

$$\ln y_{i,t} = \sum \theta_i \, ln x_{i,t} + \xi_{i,t},$$ Eq. (6)

$$TFP_{i,t} = \sum \theta_i \, ln x_{i,t} + \xi_{i,t}$$, Eq. (7)

where $y_{i,t}$is a value obtained by taking natural logs on the net income of region i; $x_{i,t}$ includes constant terms, capital, labor, and communications capital (total communications equipment investment, wired communications equipment investment, and wireless communications equipment investment); and $\xi_{i,t}$is a residual term that can be regarded as TFP.[5)] In addition, $TFP_{i,t}$in Eq. (7) are factors that affect TFP (Brason & Monoyios, 1977; Baldwin, 1971), including average annual labor hours in the relevant region, capital (physical capital, total communications equipment investment, wired communications equipment investment, and wireless communications equipment investment), and other variables such as terms of trade between regions (export and import ratios and the sum of exports and imports by OECD countries), purchasing power, and dummy variables for continents.[6)]

In estimating a model of nonstatic panel data in which individual variables have a unit root, the problem of spurious regression can occur between variables. Therefore, the characteristics of individual data should be examined, and panel cointegration tests should be conducted to enable a clear understanding of long-term, balanced relationships between regional economic growth and variables such as capital and

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5) To contain the directivity of the reality in which the formation of communication capitals generally increases, in the present study, among the independent variables used in the Solow residual method for obtaining TFP, physical capitals and communication capitals were included together to reveal that a limitation exists that there may be the problem of multicollinearity among independent variables.
6) The method that obtains TFP after dividing communication capitals in terms of capitals is an application of those models(Mankiw et al.(1992), Islam(1995), Stephen M. and Mukti P.(2000) et a.) that obtain TFP after adding human capitals.

labor. Pedroni (1999a, b) allowed for the heterogeneity of long-term cointegration matrices of individual regions i as well as for that of slopes in all regions i. That is he conducted panel cointegration analyses mainly for intra-group and intergroup statistics. Panel cointegration methods include nonparametric test statistics based on Phillips and Peron (PP) aho statistics, nonparametric statistics based on PP t-statistics, and parametric statistics based on the augmented Dickey-Fuller (ADF) statistics.

3.2. Operational Implications of Variables

Model 1 is based on abbreviated production functions, Model 2 is based on production functions, including total communications equipment investment, Model 3 includes only wired communications equipment investment from total communications equipment investment, and Model 4 considers only wireless communications equipment investment from total equipment investment. Based on the TFP levels estimated from production functions corresponding to respective models, labor hours under the concept of per capita (physical capital, total communications equipment investment, wired communications equipment investment, and wireless communications equipment investment), and energy consumption scales, R&D investment as well as those variables for terms of trade between regions for exports and imports and the degree of openness are used to analyze TFP determinants.

Table 1: Product functions and variables for the estimation of TFP

`	Product function for estimating TFP	Variables for a determinant analysis of TFP
1	f(x)=k, k=K/L	1. Basic variables: capital per person, working time per person (for a year), the export ratio, the import ratio, trade volume, and PPPs 2. Total telecommunications investment and basic variables 3. Line (wired) telecommunications investment and basic variables 4. Mobile (wireless) telecommunications investment and basic variables
2	f(x)=k·tk, k=K/L, tk=TK/K	
3	f(x)=k·ltk, k=K/L, ltk=LTK/K	
4	f(x)=k·mtk, k=K/L, mtk=MTK/K	

<Table 2> shows the data corresponding to each variable set in the analysis. First, the data for the 2003-2013 period from 29 OECD countries (all OECD countries except for Luxemburg, Slovenia, Slovakia, Iceland, and Estonia) include no information on communications equipment investment. Data on GDP, the formation of total fixed capital, the numbers of employees, annual labor hours, and exports and imports by region by OECD country are obtained from the National Statistical Office of the OECD. Data on communications equipment investment are obtained from Gartner, a global communications equipment investment survey firm, and divided into total communications equipment investment, wired communications equipment investment,

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and wireless communications equipment investment for analysis purposes. Dummy variables are divided into four regions: Asia, Europe, North America, and Oceania. Finally, the variables and data cover the 2003-2013 period, and all level variables are actualized based on price levels.

Table 2: Variables and data

Model		Variables	Explanations and sources
Product function model	$lny_{i,t} = \sum \theta_i \, lnx_{i,t} + \xi_{i,t}$	$GDP_{i,t}$	Gross domestic product of OECD countries (OECD statistics 2003-2013, web page)
		$K_{i,t}$	Physical capital of OECD countries (OECD statistics 2003-2013, web page)
		$L_{i,t}$	Economically active populations in OECD countries (OECD statistics 2003-2013, web page)
		$TK_{i,t}$	Telecommunications CAPEX (Gartner, 2003-2013)
		$LTK_{i,t}$	Fixed telecommunications CAPEX (Gartner, 2003-2013)
		$MTK_{i,t}$	Mobile telecommunications CAPEX (Gartner, 2003-2013)
TFP determinant factor model	$TFP_{i,t} = \sum \theta_i \, lnx_{i,t} + \varepsilon_{i,t}$	$K_{i,t}/L_{i,t}$	Physical capital per capita
		$LTP_{i,t}$	Hours of work (OECD statistics 2003-2013)
		$TK_{i,t}/L_{i,t}$	Telecommunications (total, fixed, and mobile) CAPEX per capita based on OECD and Gartner data
		$LTK_{i,t}/L_{i,t}$	
		$MTK_{i,t}/L_{i,t}$	
		$EXPTR_{i,t}$	Export ratio (export volume of each country to the total export volume of OECD countries)
		$IMPTR_{i,t}$	Import ratio (import volume of each country to the total import volume of OECD countries)
		$OPEN_{i,t}$	Trade volume (OECD statistics 2003-2013)

		$PPP_{i,t}$	Purchasing power parity (OECD statistics 2003-2013)
		$DUM_{i,t}$	Dummy variables for four continents (America, Asia, Europe, and Oceania)

4. Empirical Analysis Results

4.1. Cointegration Test Results

Many tests are conducted to secure the robustness of models before their analysis because most of the variables that explain the models constructed in the present study are time series data and there is a need to avoid problems such as a unit root and spurious regression. First, a unit root test of the aforementioned models is conducted, and the results indicate the presence of a unit root in most cases as a limitation of time series data. However, even if there is a unit root in a model, if there are cointegration relationships in the model based on cointegration tests, then the model can be used as is because the existence of cointegration relationships verifies the existence of long-term, balanced relationships in the model. Variables considered in the model set to have cointegration relationships can be used as they are without any differences in results, and the existence of cointegration relationships indicates the existence of long-term, balanced relationships between total production, capital (total capital and communications capital), and labor in the region.

For panel cointegration tests, nonparametric test statistics based on PP RHO statistics and parametric statistics based on ADF statistics are used. <Table 3> shows the results of panel cointegration tests using the model. The results provide no support for strong cointegration relationships in the panel data. Although the two statistics are not significant, the panel data are considered to have cointegration relationships by inference because all PP and ADF statistics are significant.

Table 3: Cointegration test results by model

	Panel statistics			Group statistics		
	Panel RHO	Panel PP	Panel ADF	Panel RHO	Panel PP	Panel ADF
Model 1	1.4224	-4.0432***	-4.3188***	3.2136	-7.3017***	-2.8316***
Model 2	2.7216	-7.4287***	-3.3200***	2.1260	-9.2840***	-2.5163***
Model 3	1.9163	-4.4653***	-4.0614***	3.3215	-10.5109***	-2.5338***
Model 4	2.2197	-3.7251***	-3.5826***	4.1763	-15.1920***	-3.4927***

1) ***p<1%, **p<5%, *p<10%.

4.2. Analysis Results by Model

The estimation results for the general Cobb-Douglas production function based on probability coefficient models are shown in <Table 4>. In the abbreviated production functions, capital per capita (total capital, total communications equipment investment, wired communications equipment investment, and wireless communication equipment investment) corresponds to the level of production per capita. The coefficient of the variable for the scale of total capital per capita is significant at the 1% level, and the coefficient stabilizes at 0.38. Although communications equipment investment by type has a negative (-) relationship with OECD GDP, the relationship is not significant.

Table 4: Production function estimation results

	Dependent variable: ln($GDP_{i,t}/L_{i,t}$)			
	Model 1	Model 2	Model 3	Model 4
ln($K_{i,t}/L_{i,t}$)	0.3830***	0.3815***	0.3851***	0.3803***
	(26.2888)	(22.2559)	(23.6787)	(23.8586)
ln($TK_{i,t}/L_{i,t}$)		-0.0169		
		(-1.2170)		
ln($LTK_{i,t}/L_{i,t}$)			-0.0188	
			(-1.1356)	
ln($MTK_{i,t}/L_{i,t}$)				-0.0085
				(-0.9366)
Adjusted R-squared	0.6855	0.6499	0.6682	0.6622

Based on the results for production function models 1~4, their TFP levels are estimated using the Solow residual method. The estimated results for TFP levels considering determinants such as total communications equipment investment, wired communications equipment investment, wireless communications equipment investment, differences in trade between regions (ratios of exports and imports and ratios of exports and imports of each country to those of the whole OECD), and the level of purchasing power are shown in <Table 5>~<Table 8>. The analysis results, including those for dummy variables, are divided into four regions by model and shown in <Table 9> through <Table 12>.

4.3. Analysis of TFP Determinants

4.3.1. Determinant Analysis Model

A. Analysis of TFP Determinants with Capital and Labor

<Table 6> shows the results for eq. (7) with TFP levels estimated considering only basic labor and capital in eq. (6) for effects of individual variables. The basic models are analyzed after commonly setting determinants for TFP levels as capital per capita, annual labor hours, import scales, export scales, terms of trade, and PPP. The following equation is the estimation equation:

$$TFP_{i,t} = \beta_1 \ln\left(\frac{K_{i,t}}{L_{i,t}}\right) + \beta_2 lnLTP_{i,t} + \beta_3 lnIMPTR_{i,t} + \beta_4 lnEXPTR_{i,t} + \beta_5 lnOPEN_{i,t} + \beta_6 lnPPP_{i,t} + \xi_{i,t} .$$

Eq. (8)

<Table 7> shows the results after dummy variables are added by region (continent). However, because the number of determinant variables has to be limited because of limitations in time series data, scales of imports and exports, which are similar to trade terms, are excluded to meet the maximum number of determinant variables that may be obtained, and continents are broadly divided into Asia, America, Oceania, and Europe. In addition, dummy variables are included. Therefore, the estimation equation is as follows:

$$TFP_{i,t} = \beta_1 \ln\left(\frac{K_{i,t}}{L_{i,t}}\right) + \beta_2 lnLTP_{i,t} + \beta_3 lnOPEN_{i,t} + \beta_4 lnPPP_{i,t} + \beta_5 DUM_{ASIA,i,t} + \beta_6 lnDUM_{AMERICA,i,t} + \beta_7 lnDUM_{OSEANIA,i,t} + \beta_8 lnDUM_{EU,i,t} + \xi_{i,t}.$$

Eq. (9)

In <Table 5>, the first rows in Models 1-1, 1-2, 1-3, and 1-4 show data for the 2003-2013 period; the second rows, for the 2003-2010 period; and the third rows, for the 2006-2013 period. This is because the analyses are conducted for these periods.[7] First, for the common characteristics of the first rows by model, average annual labor hours and TFP levels show significant negative (-) relationships at the 1~10% levels. The level of purchasing power by

OECD country has a negative (-) relationship with the TFP level, and the relationship is significant at the 1%. These results suggest that every one-unit decrease in average annual labor hours per capita in an OECD country produces a minimum of a 0.2622-unit increase in TFP and a maximum of a 0.5708-unit increase. In addition, every one-

7) Although dividing the periods not to overlap with each other may produce accurate criteria for review of analysis results in more details, since there was a limitation that variables did not sufficiently satisfy the standard for variables as the number of variables of the data used in this analysis was 8 at the minimum and 9 at the maximum, the analysis was conducted even if some sections overlapped with each other. This is judged to have been intended to approach the data in the total period divided into those in the first half and those in the latter half separately to check changes occurred between the two periods.

unit decrease in the level of purchasing power in an OECD country produces a minimum of a 0.0668-unit increase in TFP and a maximum of a 0.1123-unit increase.

The relationships between the scale of total capital per capita and the TFP level is the same regardless of whether there is communications capital in the model. First, when the model includes no communications capital, the TFP level and the scale of total capital per capita have a significant negative (-) relationship at the 1% level. When communications capital exist in the model, the scale of total capital per capita has a negative (-) relationship with the TFP level, but the relationship is not significant. In addition, most of the added communications capital by type has a significant negative (-) relationship with the TFP level.

The scale of imports relative to GDP by country has a negative (-) relationship with the TFP level, and the data in rows 2 and 3 by model (data divided by period) are significant. When the data for the 2003-2010 period and those for the 2006-2013 period are separately seen, the former show higher sensitivity to TFP. Further, the relationship between the ratio of exports to GDP and TFP is not clear (nonsignificant). Finally, the ratio of exports and imports by country to total exports and imports of the OECD, that is, the degree of openness, has a positive (+) relationship with TFP, but most relationships are not significant.

<Table 6> shows the results for eq. (9) for effects of regions (Asia, America, Europe, and Oceania) based on dummy variables. Despite attempts to use all variables in this analysis, limitations in the estimation of time series data allowed only for basic variables. The estimation results for major variables are consistent with those in <Table 5> and generally significant. For the effects of regions, dummy variables and TFP levels have negative (-) relationships, and America shows the highest sensitivity, followed by Europe, Oceania, and Asia, in that order.

Table 5:TFP determinant analysis results (1)

Variables	Dependent variable: TFP with K and L											
	Model 1-1			Model 1-2			Model 1-3			Model 1-4		
	03～13	03～10	06～13	03～13	03～10	06～13	03～13	03～10	06～13	03～13	03～10	06～13
log(K/L)	-0.1073***	-0.1406***	-0.0293	-0.0204	-0.0685***	-0.0187	-0.0521**	-0.1044***	-0.0522**	-0.0325	-0.0724***	0.0091
	(-5.7847)	(-5.8056)	(-1.3721)	(-0.9855)	(-2.6531)	(-0.7762)	(-2.5597)	(-3.9986)	(-2.3684)	(-1.5958)	(-2.8854)	(0.3845)
log(LTP)	-0.5708***	-0.6198***	-0.4552***	-0.3071**	-0.3313**	-0.3862***	-0.5158***	-0.4724***	-0.5928***	-0.2655**	-0.2630*	-0.3307**
	(-4.1561)	(-3.8412)	(-3.2706)	(-2.4422)	(-2.1818)	(-2.9028)	(-4.0847)	(-3.1207)	(-4.6392)	(-1.9855)	(-1.6675)	(-2.3608)
log(TK/L)				-0.0670***	-0.0601***	-0.0342**						
				(-6.0082)	(-4.4276)	(-2.4405)						
log(LTK/L)							-0.0821***	-0.0244	-0.0584***			
							(-5.4792)	(-1.1850)	(-3.9609)			
log(MTK/L)										-0.0385***	-0.0395**	-0.0059
										(-5.3413)	(-4.9539)	(-0.5765)
log(IMPTR)	-0.0998	-0.2425	-0.2214*	-0.1499	-0.3817*	-0.2420**	-0.0998	-0.3038*	-0.2269*	-0.1128	-0.3374	-0.2195**
	(-0.8158)	(-1.4000)	(-1.9619)	(-1.2726)	(-2.2686)	(-2.0441)	(-0.8045)	(-1.7586)	(-1.8265)	(-1.0005)	(-2.1147)	(-2.0237)
	0.051	-	0.080	0.052	-	0.047	0.048	-	0.014	0.085	-	0.111

log(EXPTR)	9	0.0811	3	3	0.1875	7	1	0.1536	5	5	0.1347	3
	(0.4942)	(-0.4795)	(0.7843)	(0.5237)	(-1.1605)	(0.4526)	(0.4570)	(-0.9239)	(0.1324)	(0.8846)	(-0.8701)	(1.1281)
log(OPEN)	0.2079	0.4893	0.1767	0.2122	0.7065**	0.2344	0.1892	0.6032*	0.2763	0.1476	0.6122**	0.1218
	(0.9359)	(1.4567)	(0.8406)	(0.9963)	(2.1853)	(1.0707)	(0.8420)	(1.8134)	(1.2058)	(0.7213)	(1.9889)	(0.6021)
log(PPP)	-0.1220***	-0.0952***	-0.0876***	-0.0801***	-0.0673***	-0.0677***	-0.0768***	-0.0627***	-0.0612***	-0.1128***	-0.0892***	-0.0859***
	(-6.5307)	(-4.4954)	(-5.0907)	(-6.1101)	(-4.3964)	(-5.1508)	(-5.6094)	(-4.0211)	(-4.5995)	(-6.7235)	(-4.7012)	(-5.2945)
Adjusted R-squared	0.6138	0.6388	0.3210	0.5217	0.5701	0.3461	0.6211	0.5125	0.5037	0.5252	0.5954	0.2968

1) ***p<1%, **p<5%, *p<10%.

2) Figures in parentheses refer to t-values.

Table 6:TFP determinant analysis results (2)

	Dependent variable: TFP with K and L			
	Model 1-1	Model 1-2	Model 1-3	Model 1-4
	03～13	03～13	03～13	03～13
log(K/L)	-0.0917***	-0.0423**	-0.0509***	-0.0602***
	(-6.0141)	(-2.4158)	(-2.9833)	(-3.6016)
log(LTP)	-0.3447***	-0.2727**	-0.3560***	-0.2285*
	(-2.5980)	(-2.1030)	(-2.7630)	(-1.7116)
log(TK/L)		-0.0514***		
		(-4.4832)		

log(LTK/L)			-0.0602***	
			(-4.0330)	
log(MTK/L)				-0.0290***
				(-3.8553)
log(OPEN)	0.1361***	0.1108***	0.1167***	0.1182***
	(8.8359)	(7.2052)	(7.5475)	(7.5780)
log(PPP)	-0.1597***	-0.1217***	-0.1259***	-0.1455***
	(-8.0467)	(-7.5420)	(-7.4603)	(-7.9227)
Dum(asia)	-0.2276	-0.0510	-0.0621	-0.1399
	(-1.0238)	(-0.2969)	(-0.3416)	(-0.6925)
Dum(america)	-0.8317***	-0.5652***	-0.5877***	-0.7087***
	(-3.3795)	(-2.9487)	(-2.9027)	(-3.1610)
Dum(Europe)	-0.6839***	-0.4282**	-0.4523**	-0.5618***
	(-3.0531)	(-2.4496)	(-2.4507)	(-2.7499)
Dum(Osean)	-0.6140**	-0.3853*	-0.3807*	-0.5366**
	(-2.3620)	(-1.9095)	(-1.7835)	(-2.2703)
Adjusted R-squared	0.4011	0.4035	0.3956	0.4144

1) ***p<1%, **p<5%, *p<10%.

2) Figures in parentheses refer to t-values.

B. Analysis of TFP Determinants with Information and Communications

<Table 7> through <Table 9> show the results for effects of determinants on estimated values of TFP based on communications capital. <Table 7> considers total communications capital, <Table 8> show the results only for wired communications capital, and <Table 9> shows the results only for wireless communications capital. According to the results in <Table 7>, TFP has negative (-) relationships with capital

per capita, average annual labor hours, and the degree of purchasing power, and these relationships are significant. Every one-unit decrease in average annual labor hours per capita produces an increase in the TFP level by 0.2677 ~ 0.5418 unit, and every one-unit decrease in purchasing power produces an increase in the TFP level by 0.0778 ~ 0.1246 unit.

Models 2-2, 2-3, and 2-4 consider communications capital and show that total communications capital, wired communications capital, and wireless communications capital have negative (-) relationships with TFP and that most of these relationships are significant. Finally, the scale of imports has a negative (-) relationship with TFP, and the degree of openness has a positive (+) relationship with TFP. The results in <Table 8> are generally consistent with those in <Table 7>. <Table 9> also shows results similar to those in <Table 7> and <Table 8>. <Table 10> through <Table 12> show the results for data using dummy variables for effects of regions (Asia, America, Europe, and Oceania). These results are consistent with those in <Table 6>. With communications equipment manufacturing shifting from Europe, America to China, Japan, and Korea in recent decades, Asia has the strongest effect on TFP, whereas America has the weakest effect.

Table 7:TFP determinant analysis results (3)

	Dependent variable: TFP with K, L, and TK											
	model 2-1			Model 2-2			Model 2-3			Model 2-4		
	03~13	03~10	06~13	03~13	03~10	06~13	03~13	03~10	06~13	03~13	03~10	06~13
log(K/L)	-0.0897***	-0.1221***	-0.0053	-0.0188	-0.0670**	-0.0171	-0.0448**	-0.1031***	-0.0424*	-0.0260	-0.0686***	0.0173
	(-4.9935)	(-5.1685)	(-0.2484)	(-0.9104)	(-2.5931)	(-0.7117)	(-2.2205)	(-3.9844)	(-1.9309)	(-1.2845)	(-2.7293)	(0.7345)
log(LTP)	-0.5418***	-0.5487***	-0.4072***	-0.3071**	-0.3313**	-0.3862**	-0.4950***	-0.4931***	-0.5506***	-0.2677**	-0.2666*	-0.3417**
	(-4.0527)	(-3.4832)	(-2.9632)	(-2.4422)	(-2.1818)	(-2.9028)	(-3.9610)	(-3.2734)	(-4.3241)	(-2.0138)	(-1.6832)	(-2.4569)
log(TK/L)				-0.0501***	-0.0432***	-0.0173						
				(-4.4924)	(-3.1823)	(-1.2330)						
log(LTK/L)							-0.0678***	-0.0210	-0.0428***			
							(-4.6095)	(-1.0340)	(-2.9099)			
log(MTK/L)										-0.0274***	-0.0304***	0.0072

										(-3.8090)	(-3.8412)	(0.7086)
log(IMPTR)	-0.1081	-0.2654	-0.2116*	-0.1499	-0.3817**	-0.2420**	-0.1127	-0.3208*	-0.2314*	-0.1134	-0.3375**	-0.2162**
	(-0.9047)	(-1.5720)	(-1.9149)	(-1.2726)	(-2.2686)	(-2.0441)	(-0.9125)	(-1.8426)	(-1.8693)	(-1.0179)	(-2.1105)	(-2.0193)
log(EXPTR)	0.0541	-0.0922	0.1013	0.0523	-0.1875	0.0477	0.0453	-0.1620	0.0199	0.0867	-0.1333	0.1185
	(0.5280)	(-0.5593)	(1.0094)	(0.5237)	(-1.1605)	(0.4526)	(0.4320)	(-0.9656)	(0.1824)	(0.9078)	(-0.8587)	(1.2159)
log(OPEN)	0.2095	0.5193	0.1430	0.2122	0.7065**	0.2344	0.2043	0.6322*	0.2724	0.1464	0.6125**	0.1103
	(0.9654)	(1.5864)	(0.6945)	(0.9963)	(2.1853)	(1.0707)	(0.9132)	(1.8840)	(1.1932)	(0.7243)	(1.9846)	(0.5519)
log(PPP)	-0.1246***	-0.0962***	-0.0898***	-0.0801***	-0.0673***	-0.0677***	-0.0778***	-0.0635***	-0.0629***	-0.1149***	-0.0914***	-0.0862***
	(-6.7257)	(-4.6284)	(-5.2589)	(-6.1101)	(-4.3964)	(-5.1508)	(-5.6951)	(-4.0407)	(-4.7444)	(-6.8021)	(-4.7404)	(-5.2857)
Adjusted R-squared	0.6232	0.6299	0.3010	0.4837	0.5435	0.3141	0.6244	0.5628	0.4511	0.4775	0.5825	0.2898

1) ***p<1%, **p<5%, *p<10%.

2) Figures in parentheses refer to t-values.

Table 8: TFP determinant analysis results (4)

	Dependent variable: TFP with K, L, and LTK											
	model 3-1			Model 3-2			Model 3-3			Model 3-4		
	03~13	03~10	06~13	03~13	03~10	06~13	03~13	03~10	06~13	03~13	03~10	06~13
log(K/L)	-0.0911***	-0.1324***	-0.0082	-0.0190	-0.0692***	-0.0186	-0.0542***	-0.1065***	-0.0543**	-0.0271	-0.0707***	0.0161
	(-4.9910)	(-5.5073)	(-0.3834)	(-0.9234)	(-2.6571)	(-0.7797)	(-2.6626)	(-4.0788)	(-2.4634)	(-1.3431)	(-2.8118)	(0.6868)
log(LTP)	-0.5181***	-0.5862***	-0.4262***	-0.3170**	-0.3502**	-0.3975***	-0.5158***	-0.4724***	-0.5928***	-0.2696**	-0.2659*	-0.3555**
	(-3.8525)	(-3.6566)	(-3.1133)	(-2.5279)	(-2.2773)	(-3.0072)	(-4.0847)	(-3.1207)	(-4.6392)	(-2.0361)	(-1.6735)	(-2.5727)
log(TK/L)				-0.0551***	-0.0558***	-0.0149						
				(-4.9089)	(-4.1326)	(-1.0484)						
log(LTK/L)							-0.0632***	-0.0055	-0.0396***			
							(-4.2196)	(-0.2676)	(-2.6826)			
log(MTK/L)										-0.0327***	-0.0378***	0.0045

										(-4.5471)	(-4.8028)	(0.4452)
log(IMPTR)	-0.0900	-0.2326	-0.2046*	-0.1390	-0.3678**	-0.2350**	-0.0998	-0.3038*	-0.2269*	-0.1031	-0.3250**	-0.2087*
	(-0.7630)	(-1.3586)	(-1.8713)	(-1.1896)	(-2.1576)	(-2.0112)	(-0.8045)	(-1.7586)	(-1.8265)	(-0.9319)	(-2.0265)	(-1.9678)
log(EXPTR)	0.0616	-0.0770	0.1033	0.0578	-0.1814	0.0518	0.0481	-0.1536	0.0145	0.0905	-0.1287	0.1216
	(0.6082)	(-0.4604)	(1.0386)	(0.5834)	(-1.1074)	(0.4984)	(0.4570)	(-0.9239)	(0.1324)	(0.9541)	(-0.8264)	(1.2590)
log(OPEN)	0.1830	0.4746	0.1331	0.1934	0.6893**	0.2206	0.1892	0.6032*	0.2763	0.1307	0.5956*	0.0985
	(0.8542)	(1.4290)	(0.6528)	(0.9155)	(2.1033)	(1.0208)	(0.8420)	(1.8134)	(1.2058)	(0.6513)	(1.9242)	(0.4977)
log(PPP)	-0.1252***	-0.0996***	-0.0885***	-0.0804***	-0.0688***	-0.0666***	-0.0768***	-0.0627***	-0.0612***	-0.1159***	-0.0935***	-0.0851***
	(-6.7617)	(-4.6632)	(-5.1883)	(-6.1255)	(-4.4008)	(-5.1151)	(-5.6094)	(-4.0211)	(-4.5995)	(-6.8371)	(-4.7898)	(-5.2332)
Adjusted R-squared	0.5784	0.6364	0.3029	0.4776	0.5885	0.3087	0.6006	0.5031	0.4680	0.4884	0.6127	0.2903

1) ***p<1%, **p<5%, *p<10%.

2) Figures in parentheses refer to t-values.

Table 9: TFP determinant analysis results (5)

	Dependent variable: TFP with K, L, and MTK											
	model 4-1			Model 4-2			Model 4-3			Model 4-4		
	03~13	03~10	06~13	03~13	03~10	06~13	03~13	03~10	06~13	03~13	03~10	06~13
log(K/L)	-0.0970***	-0.1260***	-0.0164	-0.0200	-0.0662**	-0.0193	-0.0447**	-0.1025***	-0.0422*	-0.0298	-0.0697***	0.0118
	(-5.3639)	(-5.3187)	(-0.7739)	(-0.9661)	(-2.5765)	(-0.8001)	(-2.2164)	(-3.9647)	(-1.9230)	(-1.4639)	(-2.7783)	(0.4979)
log(LTP)	-0.5617***	-0.5606***	-0.4189***	-0.3017**	-0.3200**	-0.3834***	-0.4928***	-0.4905***	-0.5459***	-0.2655**	-0.2630*	-0.3307**
	(-4.1650)	(-3.5525)	(-3.0302)	(-2.3989)	(-2.1256)	(-2.8777)	(-3.9453)	(-3.2612)	(-4.2968)	(-1.9855)	(-1.6675)	(-2.3608)
log(TK/L)				-0.0561***	-0.0460***	-0.0266*						
				(-5.0441)	(-3.3839)	(-1.9178)						
log(LTK/L)							-0.0754***	-0.0283	-0.0505***			
							(-5.1227)	(-1.3910)	(-3.4363)			
log(MTK/L)										-0.0300***	-0.0310***	0.0026

										(-4.1620)	(-3.8890)	(0.2606)
log(IMPTR)	-0.1077	-0.2643	-0.2174*	-0.1511	-0.3850**	-0.2443**	-0.1080	-0.3162*	-0.2298*	-0.1128	-0.3374**	-0.2195**
	(-0.8871)	(-1.5584)	(-1.9390)	(-1.2741)	(-2.3015)	(-2.0438)	(-0.8732)	(-1.8184)	(-1.8579)	(-1.0005)	(-2.1147)	(-2.0237)
log(EXPTR)	0.0518	-0.0926	0.0892	0.0504	-0.1905	0.0428	0.0470	-0.1608	0.0194	0.0855	-0.1347	0.1113
	(0.4970)	(-0.5595)	(0.8770)	(0.5008)	(-1.1872)	(0.4028)	(0.4477)	(-0.9602)	(0.1781)	(0.8846)	(-0.8701)	(1.1281)
log(OPEN)	0.2125	0.5182	0.1623	0.2155	0.7105**	0.2428	0.1970	0.6255*	0.2704	0.1476	0.6122**	0.1218
	(0.9633)	(1.5763)	(0.7769)	(1.0055)	(2.2114)	(1.0987)	(0.8795)	(1.8667)	(1.1855)	(0.7213)	(1.9889)	(0.6021)
log(PPP)	-0.1224***	-0.0942***	-0.0889***	-0.0794***	-0.0663***	-0.0676***	-0.0774***	-0.0633***	-0.0627***	-0.1128***	-0.0892***	-0.0859***
	(-6.6028)	(-4.5584)	(-5.2058)	(-6.0889)	(-4.4000)	(-5.1532)	(-5.6854)	(-4.0396)	(-4.7509)	(-6.7235)	(-4.7012)	(-5.2945)
Adjusted R-squared	0.6351	0.6293	0.3074	0.5055	0.5344	0.3352	0.6308	0.5631	0.4655	0.4945	0.5714	0.2883

1) ***p<1%, **p<5%, *p<10%.

2) Figures in parentheses refer to t-values.

Table 10:TFP determinant factor estimation (6)

	Dependent variable: TFP with K, L, and TK			
	Model 2-1	Model 2-2	Model 2-3	Model 2-4
	03～13	03～13	03～13	03～13
log(K/L)	-0.0744***	-0.0423**	-0.0428**	-0.0557***
	(-4.9603)	(-2.4158)	(-2.5265)	(-3.3536)
log(LTP)	-0.2946**	-0.2727**	-0.3150**	-0.2335*
	(-2.2668)	(-2.1030)	(-2.4629)	(-1.7572)
log(TK/L)		-0.0514***		
		(-4.4832)		
log(LTK/L)			-0.0431***	
			(-2.8999)	
log(MTK/L)				-0.0187**
				(-2.4947)
log(OPEN)	0.1298***	0.1108***	0.1118***	0.1197***
	(8.4421)	(7.2052)	(7.1650)	(7.7094)
log(PPP)	-0.1610***	-0.1217***	-0.1264***	-0.1474***
	(-8.2101)	(-7.5420)	(-7.5579)	(-7.9820)
Dum(asia)	-0.2067	-0.0510	-0.0559	-0.1418
	(-0.9367)	(-0.2969)	(-0.3101)	(-0.6955)
Dum(america)	-0.8160***	-0.5652***	-0.5813***	-0.7185***
	(-3.3415)	(-2.9487)	(-2.8949)	(-3.1761)
Dum(Europe)	-0.6671***	-0.4282**	-0.4468**	-0.5698***

	(-3.0026)	(-2.4496)	(-2.4420)	(-2.7645)
Dum(Osean)	-0.6091**	-0.3853*	-0.3879*	-0.5374**
	(-2.3625)	(-1.9095)	(-1.8338)	(-2.2533)
Adjusted R-squared	0.3753	0.4035	0.3563	0.3884

1) ***p<1%, **p<5%, *p<10%.

2) Figures in parentheses refer to t-values.

Table 11:TFP determinant factor estimation (7)

	Dependent variable: TFP with K, L, and LTK			
	Model 3-1	Model 3-2	Model 3-3	Model 3-4
	03～13	03～13	03～13	03～13
log(K/L)	-0.0856***	-0.0428**	-0.0530***	-0.0575***
	(-5.7219)	(-2.4461)	(-3.1059)	(-3.4769)
log(LTP)	-0.3426***	-0.2932**	-0.3560***	-0.2410*
	(-2.6207)	(-2.2636)	(-2.7630)	(-1.8193)
log(TK/L)		-0.0423***		
		(-3.7086)		
log(LTK/L)			-0.0414***	
			(-2.7700)	
log(MTK/L)				-0.0249***
				(-3.3474)
log(OPEN)	0.1362***	0.1122***	0.1167***	0.1196***
	(9.0482)	(7.3677)	(7.5475)	(7.7660)

log(PPP)	-0.1637***	-0.1218***	-0.1259***	-0.1487***
	(-8.2094)	(-7.5270)	(-7.4603)	(-8.0113)
Dum(asia)	-0.2231	-0.0456	-0.0621	-0.1383
	(-0.9905)	(-0.2645)	(-0.3416)	(-0.6730)
Dum(america)	-0.8417***	-0.5624***	-0.5877***	-0.7190***
	(-3.3811)	(-2.9256)	(-2.9027)	(-3.1562)
Dum(Europe)	-0.6908***	-0.4246**	-0.4523**	-0.5698***
	(-3.0491)	(-2.4216)	(-2.4507)	(-2.7454)
Dum(Osean)	-0.6188**	-0.3745*	-0.3807*	-0.5366**
	(-2.3523)	(-1.8497)	(-1.7835)	(-2.2337)
Adjusted R-squared	0.4083	0.3978	0.3774	0.4120

1) ***p<1%, **p<5%, *p<10%.

2) Figures in parentheses refer to t-values.

Table 12:TFP determinant factor estimation (8)

	Dependent variable: TFP with K, L, and MTK			
	Model 4-1	Model 4-2	Model 4-3	Model 4-4
	03～13	03～13	03～13	03～13
log(K/L)	-0.0777***	-0.0404**	-0.0427**	-0.0575***
	(-5.1392)	(-2.2992)	(-2.5183)	(-3.4408)
log(LTP)	-0.2958**	-0.2626**	-0.3156**	-0.2285*
	(-2.2610)	(-2.0236)	(-2.4666)	(-1.7116)
log(TK/L)		-0.0396***		

		(-3.4446)		
log(LTK/L)			-0.0513***	
			(-3.4479)	
log(MTK/L)				-0.0205***
				(-2.7275)
log(OPEN)	0.1289***	0.1091***	0.1112***	0.1182***
	(8.3142)	(7.0728)	(7.1324)	(7.5780)
log(PPP)	-0.1589***	-0.1213***	-0.1262***	-0.1455***
	(-8.1306)	(-7.5392)	(-7.5470)	(-7.9227)
Dum(asia)	-0.2068	-0.0498	-0.0545	-0.1399
	(-0.9435)	(-0.2914)	(-0.3027)	(-0.6925)
Dum(america)	-0.8077***	-0.5608***	-0.5782***	-0.7087***
	(-3.3287)	(-2.9381)	(-2.8814)	(-3.1610)
Dum(Europe)	-0.6610***	-0.4248**	-0.4443**	-0.5618***
	(-2.9938)	(-2.4410)	(-2.4299)	(-2.7499)
Dum(Osean)	-0.6076**	-0.3893*	-0.3890*	-0.5366**
	(-2.3721)	(-1.9379)	(-1.8399)	(-2.2703)
Adjusted R-squared	0.3717	0.3753	0.3637	0.3886

1) ***p<1%, **p<5%, *p<10%.

2) Figures in parentheses refer to t-values.

5. Conclusions and Implications

This study estimates diverse production functions by using regional data for the 2003-2013 period for 29 OECD countries (all OECD countries except for five with no data on communications equipment investment and related determinants) based on the level of TFP obtained through these production functions. First, the estimation of production functions is divided into a case in which general capital and labor are considered, that in which total communications capital is considered in addition to conventional capital and labor, that in which wired communications capital is considered, and that in which wireless communications capital is considered. Although abbreviated production functions are applied, the results are not significant. Therefore, abbreviated production functions are excluded, and general production function estimation equations are used. Then the variables influencing the TFP level estimated in the four models are set, and the period is divided into subperiods (2003-2013, 2003-2010, and 2006-2013) to analyze the data.

The results can be summarized as follows: First, Model 1 through Model 4 show that TFP has negative (-) relationships with labor and capital. That is, an increase in labor hours per capita reduces productivity, which implies that the gradual development of diverse capital and the enhancement of the efficiency of technologies that constitute capital are changing the working environment into that in which productivity can be enhanced without increasing labor hours. In addition, given the tendency of employees' working hours to decrease, production environments are changing into those in which TFP can increase even when working hours decrease. In addition, this can be interpreted as the gradual enhancement of the qualitative level of labor through education such that the quality of labor increases in terms of the production of value-added products. In terms of capital, the economic structure of subject countries has become such that TFP cannot increases any further even if capital increases because OECD countries, which are advanced countries, have already achieved the maximum production scale.

Second, across all industries, communications equipment investment has a negative relationship with TFP regardless of the type of communications equipment investment. Therefore, communications equipment investment has attributes of intermediary goods and requires additional technological growth and time to be used as goods that can create value added. If TFP can be interpreted as value added (products minus net labor and capital), then communications equipment investment per se may increase value added, and this can be interpreted as providing support for the productivity paradox in the IT context. The first reason is that, although communications equipment investment per se has considerable influence on the provision of communications services and communications devices by inputting capital and labor in many industrial areas, the technological level and marketability necessary to create new value added by using such services and products have yet to be secured, and communications products are provided only as final goods.

Third, given that imports and the degree of openness have negative (-) and positive (+) relationships, respectively, with TFP, most of the OECD countries are dependent more on imports than on exports because their income levels are high, and imports, not exports, have a negative (-) relationship with TFP. In addition, this indicates that an increase in the degree of openness changes the environment into something in which TFP can increase gradually through the transfer of diverse production elements. Fourth, Asia has a strongest positive relationship with TFP, whereas America has a strongest negative relationship. Given that goods and services are produced using capital and labor, this suggests that not America but Asia, which has many intermediate countries and developing countries, has a more efficient environment when it is combined with communications capital.

This study has a limitation in that the scale of communications equipment investment is used as a proxy for communications capital when production functions are estimated and determinants are analyzed. That is, the study fails to construct stocks of perfect concept. In addition, another limitation is that the scale of communications equipment investment is surveyed with major firms in OECD countries and therefore the results are not generalizable to the full range of communications equipment investment in relevant countries. In addition, because total capital and communications capital are included in the models, there is a potential issue of multicollinearity. Further, because the development and diffusion of communications technologies have occurred over a relatively long period of time, that is, because of the difficulty in securing time series data, the study does not provide a diverse range of analyses. Nevertheless, the results are meaningful in that the data are analyzed according to the purpose of the study by using the scale of investment of major communications firms for the OECD region and the data are set as proxy variables for meaningful conclusions through this process.

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