Empirical Evidence on the Determinants of TFP and Its Role in the Growth of Innovation-Driven Economies

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This paper provides some empirical evidence for R&D stock, openness, and economic freedom that foster the growth of TFP. However, it finds no empirical evidence for markup price and non-constant returns to scale, implying the growth rate of TFP measured as the Solow residual reflects the true productivity growth. In addition, it also suggests empirical evidence for the enlarged role of TFP in the growth of innovation-driven economies by exploring two dynamic panel models specifying the relationship among TFP, investment, and employment. Based on these main findings, I suggest a few policy implications for Korea to fully utilize the role of TFP in the growth of the Korean economy that is transitioning to or has already transitioned to an innovation-driven economy.

Keywords: Total factor productivity (TFP), Growth, R&D, Openness, Economic freedom

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I. Introduction

Total factor productivity (TFP) has been recognized for a long time as an important source of economic growth. The growth rate of TFP, measured as the Solow residual in the growth accounting, captures

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changes in the amount of output that cannot be explained by changes in traditional factor inputs such as labor and capital. More intuitively, an increase in TFP shifts out the production function at a given quantity of factor inputs so that more output can be produced with the same factor inputs.

Since the growth rate of TFP is measured as a residual including everything but changes in labor and capital, many factors may cause changes in TFP. Technological innovation is said to be an important determinant of TFP. It also comprises many other factors such as institutional changes, changes in societal behavior, changes in factor shares, fluctuations in demand, other omitted variables, and measurement errors. Even if we could guess and name as many factors as possible, these factors are not directly and separately observed or measured but summed together as a residual.[1]

In addition, TFP is measured under the assumptions of constant returns to scale and perfect competition, which are the standard assumptions of a neoclassical model of production. As explained in Hulten (2000), these assumptions are sources of possible bias in TFP. However, the assumption of constant returns to scale is required to estimate the return to capital, which is closely related to the GDP accounting identity and the production function. In practice, the growth rate of TFP is measured using a Cobb-Douglas production function that is homogeneous of degree 1 with respect to labor and capital. When the perfect competition is violated so that price is greater than marginal cost, Hall (1988, 1990) shows that the growth rate of TFP measured as the Solow residual does not reflect the true productivity growth any more.

Kee (2002) relaxes these two assumptions and shows that the traditional TFP measure will have a downward bias in the presence of imperfect competition or decreasing returns to scale technology. She also shows that in the presence of imperfect competition the theoretical difference between primal and dual TFP growth measures will vanish if factor shares in revenue are held constant.[2] This result is contrary to Roeger (1995) showing that markup greater than one could explain the difference between the primal and dual TFP measures based upon U.S.

[1] Abramovitz (1956) put TFP as 'measure of our ignorance.'

[2] The primal TFP growth rate is measured from the production function and the dual one is from the cost function. The constant factor shares are one of stylized facts of empirical studies.

manufacturing data.

As briefly discussed above, TFP is measured under the assumptions of both perfect competition and constant returns to scale; furthermore, as it is measured, it consists of many determinants in addition to what we are really trying to isolate. This paper investigates the validity of two assumptions mentioned above using panel data on 20 OECD countries from 1985 to 2006.[3] It also provides some empirical evidence for major determinants of TFP such as research and development stock, openness to international trade, and economic freedom. In addition, it is also investigated how changes in the TFP affect two major macroeconomic variables, investment and employment.

This paper is organized as follows. Section 2 presents a basic model for the determinants of TFP and regression results with the evidence for economic freedom measures as a determinant of TFP. Section 3 describes how investment and employment will respond to changes in TFP in the short-run versus the long-run. The last section concludes by suggesting some policy implications.

II. Empirical Study on the Determinants of TFP

A. Basic Model

Suppose that the output of an economy is defined as a Cobb-Douglas production function that is homogeneous of degree 1 with respect to factor inputs.

$$Y_t = TFP_t K_t^{1-\theta} L_t^{\theta}, \tag{1}$$

where TFP_t, K_t, L_t, θ, and Y_t denote total factor productivity, capital stock, work hours, labor income share, and total output (GDP), respectively.[4] From equation (1) the growth rate of TFP can be easily deduced as follows:

[3] The major reason that I choose to use OECD country level data instead of industry level data like EU KLEMS data is hard to get industry level data for R&D investment and economic freedom indices, which are major determinants of TFP as will be shown in later section.

[4] In some literature, equation (1) is defined using capital stock accumulated until the last period instead of current period. However, the empirical results presented below are not quite different from the case of using capital stock accumulated until the last period.

$$\Delta \ln TFP_t \equiv \Delta \ln \left(\frac{Y_t}{K_t}\right) - \theta \Delta \ln \left(\frac{L_t}{K_t}\right) \tag{2}$$

Equation (1) is a special case of a Cobb-Douglas production function that is homogeneous of degree s as in (3), where the R&D stock (R_t) is explicitly included in the production function as a determinant of TFP. The R&D stock proxies the technological progress. In equation (3), the factor income shares satisfy $\alpha + \beta = s$, which implies the assumed production function is homogenous of degree s with respect to factor inputs.

$$Y_t = A e^{\lambda t} R_t^{\gamma} K_t^{\alpha} L_t^{\beta}, \tag{3}$$

where A denotes unidentified other determinants of TFP independent from technological innovation which is proxied by R_t, and λ is the rate of change in other determinants. Equation (4) naturally follows from (3).

$$\Delta \ln (Y_t/K_t) = \lambda + \gamma \Delta \ln R_t + (\alpha - 1) \Delta \ln K_t + \beta \Delta \ln L_t \tag{4}$$

Substituting equation (4) into (2) yields equation (5) as follows:

$$\begin{aligned} \Delta \ln TFP_t &= \lambda + \gamma \Delta \ln R_t + (\beta - \theta) \Delta \ln \left(\frac{L_t}{K_t}\right) + (s-1)\ \Delta \ln K_t \\ &= \lambda + \gamma \Delta \ln R_t + (\mu - 1)\theta \Delta \ln \left(\frac{L_t}{K_t}\right) + (s-1)\ \Delta \ln K_t, \end{aligned} \tag{5}$$

where μ denotes the markup. The second equality in equation (5) comes from $\beta = \mu\theta$, which is from proposition (A2) in Kee (2002). Equation (5) implies that the growth rate of TFP measured as the Solow residual is equal to the growth rate of true productivity when $\mu = 1$ and $s = 1$, that is, the assumptions of perfect competition and constant returns to scale hold. To allow for clearer insight, other determinants of TFP such as openness to trade and economic freedom are not explicitly specified in equation (3) nor below. However, it is a simple extension of equation (3) through (5) to include other determinants possibly identified.

The following fixed effect regression equation is estimated using panel data on 20 OECD countries over the period of 1985~2006, where

c_i and c_t denote country-specific effect and time effect, respectively:[5]

$$\Delta \ln TFP_{it} = c_i + c_t + c_1 \Delta \ln R_{it} + c_2 \theta \Delta \ln \left(\frac{L_{it}}{K_{it}}\right) + c_3 \Delta \ln K_{it} + \varepsilon_{it} \tag{6}$$

The estimated coefficient on $\theta \Delta \ln (L_{it}/K_{it})$ will point out the existence of markup price if the estimated c_2 is statistically greater than 0 implying $\mu - 1 > 0 \Rightarrow \mu > 1$. The estimated coefficient on $\Delta \ln (K_{it})$ indicates the existence of non-constant returns to scale if the estimated c_3 is statistically different from 0 implying $s > 1$ or $s < 1$. Therefore, it can be inferred from the estimated coefficients of c_2 and c_3 whether or not the standard neoclassical assumptions are violated. If these estimated coefficients are not statistically significant, the Solow residual reflects the true productivity growth.

B. Estimation Results of Basic Model

In this section, the regression results of equation (6) will be presented including openness to trade as an additional determinant of TFP. Openness to trade is defined as the ratio of trade to GDP. Two openness variables can be defined as follows: one is the ratio of imports only to GDP ($OM1_{it}$) and the other is the ratio of the sum of imports and exports to GDP ($OM2_{it}$). Even if the conventional openness measure has been usually defined in the literature as the ratio of the sum of imports and exports to GDP, $OM1_{it}$ is additionally defined to examine more specifically whether the openness of the domestic market to other countries fosters TFP growth.[6] In order to examine if the regression results are time invariant, regression results are also presented for two sub-sample periods: 1985~1995 and 1996~2006.

Looking at the table 1 that shows the regression results of equation (6) including two openness measures as additional explanatory variables, there is no empirical evidence for the violation of two standard assump-

[5] See the appendix at the end of this paper for the details about the countries included in the analysis, the data sources, and availability.

[6] Nicoletti and Scarpetta (2003), Dawson (1998, 2006), Gwartney *et al.* (2004) and other literatures show also that less stringent economic regulations or more economic freedom foster the growth of TFP or long-run economic performance indicators such as investment, labor productivity and the growth of GDP. We consider the effect of economic freedom measures as another determinant of TFP in the following subsection.

tions discussed above in any sub-sample periods. Both estimated coefficients on $\theta\Delta\ln(L_{it}/K_{it-1})$ and $\Delta\ln(K_{it-1})$ are not significant even at the 10% level. This implies that the growth rate of TFP measured as the Solow residual reflects the true productivity growth rate and there is no empirical evidence for markup pricing behavior or non-constant returns to scale over the sample period or two sub-sample periods. That is to say, the assumptions maintained to measure the growth rate of TFP for each country are valid over the period of 1985~2006. This result is in direct contrast to the main empirical finding of Kee (2002) that all industries in Singapore's manufacturing sector violated at least one of those two assumptions. Such difference may be due to the level of data used in the regressions. Here, the country level data were used while Kee (2002) used the industry level data.

The estimated coefficients on the growth rate of R&D stock ($\Delta\ln(R_{it})$) indicating technological innovation are significant at the 5% level at least for both the whole sample period and the sub-sample period of 1996~2006. The regression results indicate that TFP increases about 0.06% as the research and development stock increases by 1%. The estimated coefficients on the change in the imports share in GDP ($\Delta OM1_{it}$) are found to be significant at 1% level in the regression with the whole sample period and two sub-sample periods. As imports share in GDP increases by 1% point, TFP increases by 0.1~0.2%. The regression results also show that the responsiveness of TFP to the openness of the domestic market became smaller in the second sub-sample period of 1996~2006 than the first sub-sample period. However, the estimated coefficient on the conventional openness measure ($\Delta OM2_{it}$) is significant only in the regression with the first sub-sample period of 1985~1995.

From the regression results discussed above, three points can be inferred. First, at the aggregate level, there is no empirical evidence for markup pricing or non-constant returns to scale, which implies that conventionally measured growth rate of TFP represents the true productivity growth rate. Second, the growth rate of R&D stock seemed to become a major determinant of TFP since the mid of 1990s. In addition, the effect on the growth of TFP gets larger and more significant in the second sub-sample period. The last inference that could be made from this analysis is that the openness measure as a determinant of TFP would be more appropriate to be defined as the imports share in GDP and TFP responds less sensitively to the change in openness as the economy grows.[7]

TABLE 1
CROSS-COUNTRY TFP REGRESSION RESULTS, 1985~2006

Variable	1985~1995		1996~2006		1985~2006	
$\Delta\ln(R_{it})$	0.0458	0.0469	0.0636**	0.0597**	0.0612*	0.0637*
	(0.0298)	(0.0313)	(0.0282)	(0.0271)	(0.0197)	(0.0210)
$\theta\Delta\ln(L_{it}/K_{it})$	-0.0011	-0.0011	-0.0024	-0.0024	-0.0022	-0.0022
	(0.0014)	(0.0014)	(0.0029)	(0.0028)	(0.0014)	(0.0014)
$\Delta\ln(K_{it})$	-0.1069	-0.0548	-0.2259	-0.1914	-0.0934	-0.0900
	(0.1029)	(0.1053)	(0.1773)	(0.1815)	(0.0684)	(0.0669)
$\Delta OM1_{it}$	0.2029*	-	0.1133*	-	0.1161*	-
	(0.0653)		(0.0398)		(0.0331)	
$\Delta OM2_{it}$	-	0.0975*	-	-0.0029	-	0.0280
		(0.0278)		(0.0460)		(0.0265)
$\bar{R}^2$	0.35	0.35	0.39	0.37	0.34	0.32
DW-stat	1.74	1.67	2.13	1.98	1.67	1.65
No. of Countries	18	18	20	20	20	20
No. of Obs.	158	158	201	201	359	359

Notes: 1) *, **, and *** indicate statistical significance at the 1%, 5%, and 10%, respectively.
2) Parentheses contain White's standard errors.
3) The dependent variable is $\Delta\ln(TFP_{it})$ and both time and individual fixed effect dummies are included.

C. Economic Freedom and the Growth of TFP

It is not easy to find both theoretical and empirical researches on how much and through which channel reforming regulations or enhancing economic freedom will improve economic performance. However, it might not be too strong to assume that regulations imposed by governments will possibly do deteriorate the economic efficiency of resource allocation as well as the voluntary participation of economic agents in those regulated economic activities. It may be regarded that the economic performance indicators will be affected by the stringency of regulations in an economy. The stringency of regulation can be interpreted as a part of economic freedom given in the economy. Therefore, it can be

[7] Someone may raise a question that human capital and capacity utilization should be considered as determinants of TFP. This research does not consider other determinants than those included in table 1 and 2 because human capital accumulation for each country is hard to measure and capacity utilization rate denoting fluctuation in demand side could be controlled by both individual and time specific dummies.

said in general that the long-run economic performance of an economy will be improved by less stringent regulation and more economic freedom through encouraging more voluntary participation of economic agents and enhancing the efficiency of resource allocation.

Nicoletti and Scarpetta (2003) suggest empirical evidence that pro-competitive regulatory reforms and privatization policies tend to boost the growth of TFP using 18 OECD countries data over the period of 1984~1998. This work appears to be the only research that investigates the direct relationship between TFP and regulatory reform. However, it has a caveat that there is no proxy variable for technological innovation in the specification. This implies that the effect of regulatory reform on the growth of TFP could be overestimated.

Other literatures such as Dawson (1998, 2006) and Gwartney *et al.* (2004) provide empirical results for the existence of a positive relationship between regulatory reform or economic freedom and economic performance indicators such as GDP growth, investment ratio to GDP, and labor productivity, implicitly assuming a positive relationship between the TFP growth and regulatory reform or economic freedom. They do not explicitly address how much of the TFP growth will be improved by reforming regulations and enhancing economic freedom. They both explain that regulatory reform or economic freedom will directly foster the GDP growth through the improvement of TFP and indirectly through an increase in investment.[8]

In order to grasp the effect of economic freedom or regulatory reform on the TFP growth, equation (6) is estimated with the openness variable defined in subsection 2.1 and a variable measuring the improvement of economic freedom. I define 4 kinds of dummy variables representing the improvement of economic freedom based upon EFW (Economic Freedom of the World) by the Fraser institute. The first dummy variable is ER indicating an improvement of rating for regulation of credit, labor, and business. The second one is EF, which indicates an improvement of rating for overall economic freedom. These two dummies take the value 1 if each rating for the current survey is strictly greater than the last survey. The third and fourth ones are defined using the rank of overall rating for economic freedom. The rank

[8] Nicoletti and Scarpetta (2003) uses industry level OECD STAN data set and the OECD indicators for production market regulation surveyed in 1998. On the other hand, Dawson (1998, 2006) and Gwartney *et al.* (2004) use indices for Economic Freedom of the word surveyed by Fraser Institute since 1975.

TABLE 2
ECONOMIC FREEDOM AS A DETERMINANT OF TFP

Variable		Baseline	Economic Regulation	Freedom Index	Rank	Rank Percentile
$\Delta\ln(R_{it})$		0.0779***	0.0772***	0.0751***	0.0609***	0.0878**
		(0.0432)	(0.0424)	(0.0411)	(0.0338)	(0.0397)
$\theta\Delta\ln(L_{it}/K_{it})$		-0.0021	-0.0024	-0.0023	-0.0021	-0.0027
		(0.0018)	(0.0016)	(0.0017)	(0.0017)	(0.0017)
$\Delta\ln(K_{it})$		-0.1236	-0.1453	-0.1256	-0.1163	-0.1658
		(0.1621)	(0.1602)	(0.1554)	(0.1581)	(0.1413)
$\Delta OM2_{it}$		0.0353*	0.0341*	0.0340*	0.0348*	0.0334*
		(0.0107)	(0.0108)	(0.0100)	(0.0071)	(0.0091)
Economic Freedom Measure	ER dummy	-	0.3339	-	-	-
			(0.3220)			
	EF dummy	-	-	0.4932	-	-
				(0.3528)		
	Rank dummy	-	-	-	0.7327**	-
					(0.2766)	
	5% dummy	-	-	-	-	1.1792*
						(0.3650)
$\bar{R}^2$		0.56	0.57	0.57	0.64	0.61
DW-stat		2.26	2.30	2.08	2.18	2.40
No. of Countries		20	20	20	20	20
No. of Obs.		70	70	70	70	70

Notes: 1) *, **, and *** indicates statistical significance at the 1%, 5%, and 10%, respectively.
2) Parentheses contain white's standard errors.
3) The dependent variable is $\Delta\ln(TFP_{it})$ and both time and individual fixed effect dummies are included.
4) ER-, EF-, and Rank dummy are defined as X dummy$_{it}$ = 1($X_{it} > X_{it-1}$) and 5% dummy is defined as 5% dummy$_{it}$ = 1(Rank Percentile$_{it} \leq$ 0.05).

dummy takes the value 1 for an improvement of overall rank while the 5% dummy takes the value 1 if the rank percentile of individual country is within the top 5%.

All the regression results in table 2 are based on only every 5-year observation from 1985 to 2005 for 20 OECD countries since the indices for economic freedom of the world were published once every 5-year until the year 2000. In table 2, five different regression results are presented: a baseline regression result without any dummy for economic freedom and four regression results specifying each dummy for economic freedom in the baseline regression equation.

The estimated coefficients on the variables included in the baseline equation are not different qualitatively from the empirical findings presented in table 1. There is no evidence for markup or non-constant returns to scale, but the results indicate that TFP growth is boosted by the growth of R&D stock or the increase in openness.[9] These empirical findings are still valid even in other cases including some of economic freedom measures.

The estimated coefficients on the 4 dummies for economic freedom do not suggest clear cut inferences about the role of economic freedom on the growth of TFP. For the cases of dummies generated from the rating scores, it cannot be inferred from the estimated coefficients for both the ER dummy and the EF dummy that greater economic freedom indicated by higher rating than previous observation does foster the TFP growth. For the cases of dummies related to rank, however, the estimated coefficients for the rank dummy and the 5% dummy are positive and statistically significant at the 5% and 1% level, respectively. It can be inferred from this result that the TFP growth is higher on average when the rank for overall evaluation of economic freedom of an economy is improved over previous evaluation or when the economic freedom of an economy is ranked within the top 5%.[10]

Although the regression results of 4 different dummies for economic freedom do not strongly support without exception that the improvement of economic freedom will result in a higher growth rate of TFP, I could find some empirical evidence for the claim that the economic freedom of an economy would be another determinant of TFP. Therefore, policy makers should consider institutional improvements to enhance economic freedom as well as the increase in R&D and openness in order to improve TFP.

III. The Effects of TFP on Investment and Employment

It has been discussed up to this point what will determine the total

[9] In table 2, I tabulate the regression results with the openness measure defined as the change in the ratio of trade amount to GDP ($\Delta OM2_{it}$). When the imports share in GDP ($\Delta OM1_{it}$) is included instead, the regression results are almost the same except for the magnitude of the estimated coefficient on the openness measure. The estimated coefficients on $\Delta OM2_{it}$ is about half of those on $\Delta OM1_{it}$.

[10] I tried other dummies related to rank percentile such as 10% and 20% dummy but those are not significant even at 10% level.

factor productivity of an economy. I can infer from the results of section 2 that the growth of TFP is boosted by the growth of R&D stock, higher openness to international trade, and institutional improvements to enhance economic freedom. As shown in equation (1), TFP growth causes GDP growth directly for every given stock of capital and labor. This implies that the increase in TFP shifts out the production possibility frontier (PPF) in the space of capital and labor. As the PPF shifts according to a change in TFP, the combination of capital and labor can be altered. That is to say, changes in TFP might result in different quantities of capital and/or labor being optimal.

In the related literature, it is hard to find research work addressing the relationships among TFP, investment, and employment using country-level aggregate data. Most of the literature focuses on investigating those relationships with firm-level data. Specially, it focuses on the relationship between innovation in technology and employment. For example, Peters (2004), Brower *et al.* (1993), and Hall *et al.* (2007) classify the firm level innovation in technology into two categories, process innovation and product innovation, and they analyze the effect of each innovation on the growth of employment.[11] However, their findings contradict each other. Peters (2004) found, using firm level survey data named Community Innovation Survey, that process innovation reduces employment in German firms while product innovation increases it. However, Hall *et al.* (2007) concluded that they could not find any empirical evidence for the substitution effect of process innovation on employment in Italian firms over the period of 1995~2003. On the other hand, Brower *et al.* (1993) presented empirical evidence for both the positive effect of product innovation on employment and the negative effect of overall innovation measured by R&D on employment during the1980's in Netherlands. Besides these results, Zimmerman (1991) and Piva and Vaivarelli (2005) also suggested contradicting results. Zimmerman (1991) presented the negative relationship between overall innovation and employment using German firm level cross section data while Piva and Vaivarelli (2005) found a small but significantly positive effect of overall innovation on the employment of Italian firms.

Exploring the relationship between TFP and important macro-variables

[11] Process innovation is technological improvements or new technology to produce existing products while product innovation means those to products that could not be produced with old technology before new innovation.

such as investment and employment, I might deduce about the role of TFP in the growth of innovation-driven economies and find some grounds for the adequacy of policies to improve TFP. For this purpose, two dynamic panel models with equation (7) and (8) are set up, using 20 OECD countries' annual observations from 1985 to 2006.

$$\Delta \ln GFCF_{it} = \alpha_1 \Delta \ln GFCF_{it-1} + \alpha_2 \Delta \ln TFP_{it} + \alpha_3 \frac{EXGS_{it-1}}{GDP_{it-1}} + \alpha_4 \frac{GDP^S{}_{it-1}}{GDP_{it-1}} + \eta_{1i} + \mu_{1t} + \varepsilon_{1it}, \tag{7}$$

$$\Delta \ln EMP_{it} = \beta_1 \Delta \ln EMP_{it-1} + \beta_2 \Delta \ln TFP_{it} + \beta_3 \Delta \ln GFCF_{it} + \beta_4 \frac{EXGS_{it-1}}{GDP_{it-1}} + \beta_5 \frac{GDP^S{}_{it-1}}{GDP_{it-1}} + \eta_{2i} + \mu_{2t} + \varepsilon_{2it}, \tag{8}$$

where $GFCF$, EMP, $EXGS$, and GDP^S denote gross fixed capital formation, total employment, the sum of imports and exports of goods and services, and service sector GDP. In addition, $\eta_{\cdot i}$ and $\mu_{\cdot t}$ are individual country specific fixed effect and year specific fixed effect while $\varepsilon_{\cdot it}$ are random errors satisfying usual orthogonal condition for GMM estimation suggested by Arellano and Bond (1991) that will be employed in this section.

Besides the variables in equation (7) and (8), I include the 1-period lagged openness ($EXGS_{it-1}/GDP_{it-1}$) and the lagged service sector's GDP share ($GDP^S{}_{it-1}/GDP_{it-1}$) to control for individual countries' characteristics that could affect the impact of key explanatory variables on dependent variables. Since equations (7) and (8) are usual dynamic panel models including 1-period lagged dependent variables as an explanatory variable to assess long-run effects later, usual fixed effect estimation results are inconsistent as pointed out by Nickell (1981) even if explanatory variables other than 1-period lagged dependent variables are exogenous. However, it may not be even ascertained that TFP, investment, and employment do not have simultaneity at all in period t, which implies they are not exogenous. Therefore, in order to get consistent estimates, GMM method suggested by Arellano and Bond (1991) is applied using predetermined endogenous variables properly as instrumental variables. Before looking at the estimated coefficients in detail, I first examine the Sargan test results for the null hypothesis of the validity of instrumental variables used in the estimation. The

reported p-values for Sargan test statistics in table 3 indicate no evidence for rejecting the null hypothesis even at the significance level of 10%.[12]

Table 3 presents the estimation results of equations (7) and (8) for each corresponding sample period. For the whole sample period of 1985~2006, TFP growth and higher openness increase investment while the estimated coefficient on the last year's GDP share of the service sector is insignificant. The short-run effect of TFP on investment is estimated as 1.6 and statistically significant at the 1% level. The long-run effect of TFP on investment is estimated as 1.5. However, it should be used with a caution since the coefficient on the lagged investment is not significant. For the first sub-sample period of 1985~1995, the lagged investment turned out to have a statistically non-zero coefficient and the long-run effect of TFP on investment is estimated as 1.3 while the short-run effect is 0.9. For the second sub-sample period of 1996~2006, the long-run effect of TFP is estimated as 1.4 while the short-run effect is about 1.9. Therefore, it may be inferred that the long-run effect of TFP on investment is approximately 1.3~1.5, which implies that investment is elastically responsive to the improvement of TFP. In addition, the regression results show that the short-run effect of TFP on investment is estimated larger for the second sub-sample period than the first one, which indicates that the role of TFP increases in the growth of economy around OECD area.

The long-run effect of TFP on employment is quite ambiguous except for the second sub-sample period of 1996~2006 since the short-run effects of TFP on employment are insignificant for both the whole sample period and the first sub-sample period of 1985~1995. For the second sub-sample period, the long-run effect of TFP on employment is about 0.5, which implies that the response of employment is quite inelastic to the change in TFP. However, the estimated coefficient on TFP is negative for the first sub-sample period even if it is not significant. This could be thought of as evidence for the enlarged role of TFP in the growth of innovation-driven economies. In addition, the increase in TFP could boost employment indirectly through the increase in investment.

The long-run effect of investment on employment is estimated at

[12] Sargan test statistic follows asymptotically a chi-square distribution with the number of over identifying restrictions as its degrees of freedom.

TABLE 3

THE EFFECTS OF TFP ON INVESTMENT AND EMPLOYMENT

	Explanatory Variables	Period		
		1985~1995	1996~2006	1985~2006
Investment equation	$\Delta\ln(GFCF_{it-1})$	0.3056*	-0.3435**	-0.0607
		(0.0568)	(0.1668)	(0.2122)
	$\Delta\ln(TFP_{it})$	0.9248*	1.8923**	1.6206*
		(0.3407)	(0.8009)	(0.5572)
	$GDP^{S}_{it-1}/GDP_{it-1}$	0.2357	0.7268	0.0829
		(0.4105)	(0.9410)	(0.4849)
	$EXGS_{it-1}/GDP_{it-1}$	0.4988*	-0.0409	0.1698***
		(0.1472)	(0.1029)	(0.0948)
	Sargan P-value	0.104	0.198	0.161
	No. of Counties	18	20	20
	No. of Obs.	141	199	340
Employment equation	$\Delta\ln(EMP_{it-1})$	0.0246	0.2068**	0.1365***
		(0.0494)	(0.0826)	(0.0765)
	$\Delta\ln(TFP_{it})$	-0.1308	0.3629**	0.1271
		(0.1453)	(0.1478)	(0.1148)
	$\Delta\ln(GFCF_{it-1})$	0.1095*	0.0372	0.0687***
		(0.0307)	(0.0288)	(0.0391)
	$GDP^{S}_{it-1}/GDP_{it-1}$	-0.0346	0.0465	0.0129
		(0.2500)	(0.1450)	(0.1263)
	$EXGS_{it-1}/GDP_{it-1}$	0.0799*	0.0111	0.0398**
		(0.0253)	(0.0247)	(0.0163)
	Sargan P-value	0.165	0.209	0.118
	No. of Counties	18	20	20
	No. of Obs.	141	199	340

Notes: 1) *, **, and *** indicates statistical significance at the 1%, 5%, and 10%, respectively.
2) Parentheses contain white's standard errors.
3) Both time and individual fixed effect dummies are included.

0.08 implying a very inelastic response of employment to the change in investment for the whole sample period of 1985~2006. This estimated long-run elasticity of employment with respect to investment seems to be dominated by the first sub-sample period of 1985~1995 since the short-run effect of investment is not significantly different from zero for the second sub-sample period of 1996~2006. This implies that the role of investment to increase employment becomes smaller after the mid of 1990s.

The results discussed above suggest that TFP began playing a larger role in fostering investment and employment after the mid of 1990s

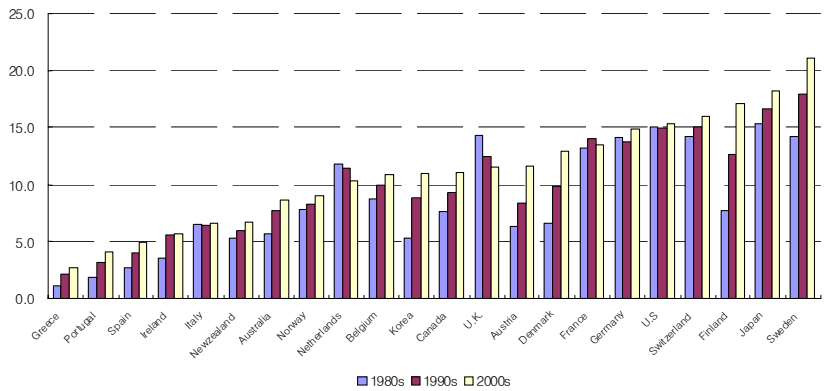
and as a result, a larger role in the growth of innovation-driven economies. Moreover, the employment effect of investment became weaker for the second sub-sample period than the first sub-sample period while the employment effect of TFP became significant and larger than the first sub-sample period even if it is not significant for the whole sample period. These findings help give more credits to policies to improve TFP because the standalone investment in an innovation-driven economy would not yield the employment effect or the growth effect as much as in a factor input-driven economy.

IV. Conclusion

This paper has examined what determines total factor productivity, how sensitively investment and employment respond to a change in TFP, and how their responsiveness has changed after the mid of 1990s. TFP measured as the Solow residual could be affected by many factors. I first considered R&D stock, openness to international trade, and economic freedom as the important determinants of TFP and found empirical evidence for those key determinants boosting TFP. It is also shown that the growth rate of TFP measured as the So low residual reflect the true productivity growth by presenting empirical evidence for perfect competition and constant returns to scale. Then I suggested empirical evidence for the enlarged role of TFP in the growth of innovation-driven economy by exploring two dynamic panel models specifying the relationship among TFP, investment, and employment.

I conclude this paper suggesting a few policy implications for Korea that is transitioning to or has already transitioned to an innovation-driven economy from a factor input-driven economy. According to the paradigm shift of the growth toward an innovation-driven one, the Korean government should consider policies to fully utilize the role of TFP in her growth.

First, more R&D investment should be made continuously. Korean R&D intensity, R&D investment share in GDP, has been ranked in a leading group during recent years. In 2006, the Korean R&D intensity was 3.23% following Sweden (3.73%), Finland (3.45%), and Japan (3.39%). However, Korea has a short history of R&D relative to other major OECD countries and so is the accumulated stock level. As shown in figure 1, the average GDP share of R&D stock for each period is ranked in a middle group in the 2000s even if the R&D intensity is highly ranked. In addition, the R&D investment increases at a lower



(UNIT: %)

FIGURE 1

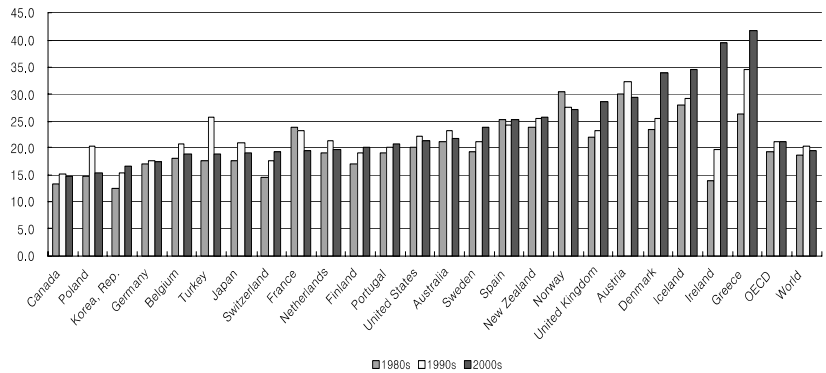
INTERNATIONAL COMPARISON OF THE AVERAGE GDP SHARE OF R&D STOCK

rate after 1998 in Korea. Therefore, the Korean government should consider extending both the R&D direct subsidies and tax credits to foster R&D activities.

Second, Korea should open her domestic market more widely to the world. Specially, Korea's service sectors such as telecommunication, transportation, finance, education, legal, medical sectors, and so on should improve their competitiveness through opening their domestic markets to the world.[13] Figure 2 shows, as a measure of the openness of the service sector, the average share of the service sector in total trade amount for each period.[14] Korea's openness of service sector is below the OECD or world average for any period as shown in figure 2 while Korea is known to have a very high GDP share of international

[13] In the past, these services were considered as non-tradable so that there was no international agreement on trade in services until 1994. However, 'General Agreement on Trade in Services' enacted in 1995 started to form an international agreement even if it needs to be developed to better one like one on trade in commodities.

[14] Trade in services statistics does not fully reflect 4 modes of services defined in GATS. Mostly, cross border supply (mode 1) and consumption abroad (mode 2) consist of statistics for trade in services. The importance of services traded by commercial presence (mode 3) and presence of a natural person (mode 4) gets larger as the globalization proceeds further. However, the data encompassing all 4 modes of supply of services are hardly available so that I proceed the discussion with the usual data for trade in services.



(UNIT: %)

FIGURE 2

INTERNATIONAL COMPARISON OF THE OPENNESS OF SERVICE SECTOR

trade. Korea's average share of trade amount in GDP is around 80% since 2000. However, the OECD average share for the same period is only 45%. This means that almost 85% of Korea's international trade has been focused on the import and export of goods, which implies, in turn, that there is plenty of room for improving Korea's TFP through opening the service sector to the world more widely and drastically.

Lastly, Korea should not be afraid of institutional changes to enhance economic freedom that could improve her TFP and eventually causes the Korean economy flourish. According to the recently published 'Doing Business 2009' by the World Bank, however, the rank for Korea of the overall ease of doing business goes down from 22nd in 2008 to 23rd in 2009 among 181 countries, implying the relative stringency of regulations in Korea will be stronger in 2009 than 2008. Sub-fields whose ranks are way below the overall rank are starting a business, employing workers, registering property, protecting investors, and paying taxes. Specially, the relative stringency of regulations related to both starting a business and employing workers seems to be sharply worsening.[15] As shown in subsection 2.3, the growth of TFP will be leveled up by the improvement of the rank of economic freedom. Therefore, those fields ranked way lower than the overall rank need strong and decisive

[15] The rank of starting a business is worsened from 107th in 2008 to 126th in 2009 and the one of employing workers is worsened from 122nd in 2008 to 152nd in 2009.

regulatory reform.

What are founded from the pattern of growth can be summarized as follows. The growth of an economy will slow down as the scale of economy becomes bigger, where the role of TFP increases while the traditional factor inputs play a smaller role in the growth of innovation driven economies. Therefore, policies to improve TFP should be implemented more extensively since the growth of GDP will be enhanced directly by TFP itself and indirectly by increases in investment and employment induced by the improvement of TFP.

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Appendix: Data Sources and Availability

A. List of Countries: 20 OECD Countries

Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Ireland, Italy, Japan, Korea, Netherlands, New Zealand, Portuga1, Spain, Sweden, Switzerland, United Kingdom, United States.

B. Data Sources and Availability

Variable	Description	Sources
$\Delta \ln(TFP_{it})$	Growth rate of TFP	OECD Productivity Database
$\Delta \ln(K_{it})$	Growth rate of capital	OECD Productivity Database
$\Delta \ln(L_{it})$	Growth rate of labor hour	OECD Productivity Database
θ	Labor income share	OECD Productivity Database
$\Delta \ln(R_{it})$	Growth rate of R&D stock	OECD Main Science and Technology Indicators
$OM1_{it}$	GDP share of imports	Word Bank World Development Indicators
$OM2_{it}$	GDP share of imports and exports	Word Bank World Development Indicators
$\Delta \ln(GFCF_{it})$	Growth rate of gross fixed capital formation	Word Bank World Development Indicators
$\Delta \ln(EMP_{it})$	Growth rate of Employment	OECD Stats Portal
$EXGS/GDP$	GDP share of imports and exports	Word Bank World Development Indicators
GDP^S/GDP	GDP share of service sector	Word Bank World Development Indicators
ER Dummy	ER dummy$_{it}$ = 1(ER$_{it}$ > ER$_{it-1}$)	Fraser Institute Economic Freedom of the World
EF Dummy	EF dummy$_{it}$ = 1(EF$_{it}$ > EF$_{it-1}$)	Fraser Institute Economic Freedom of the World
Rank Dummy	Rank dummy$_{it}$ = 1(Rank$_{it}$ < Rank$_{it-1}$)	Fraser Institute Economic Freedom of the World
5% Dummy	5% dummy$_{it}$ = 1(Rank Percentile$_{it}$ > 0.05)	Fraser Institute Economic Freedom of the World

Notes on Availability:

1) TFP and its related data for Korea are not available in OECD productivity database. Author calculate the growth rate of TFP with OECD method using capital stock series from KIET (Korea Industrial Economics and Trade) and labor data from NSO (National Statistical Office).
2) OECD Productivity Database includes 19 counties data basically since 1985. However, data for some countries are available from 1990 (New Zealand), 1991 (Spain), 1992 (Switzerland and Germany), or 1996 (Austria and Portugal).

3) Based on the perpetual inventory method, R&D stock data are calculated by author using R&D investment data from OECD MSTI. The stock data are available in PPP constant million dollars from 1981 to 2006 or the last available for 22 OECD countries that are 20 OECD countries listed above with Greece and Norway.
4) Dummy variables for economic freedom are generated from EFW by Fraser Institute. EFW are available every 5-year from 1975 to 2000 and every year since 2000. ER is the rating score for regulation of credit, labor, and business. EF is the rating for overall economic freedom. Rank denotes the rank of overall rating for economic freedom. Rank percentile is the rank of overall rating divided by the total number of countries surveyed.

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