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Physical Technology, Business and Public Sector Corruptions, and Growth: The Sensitivity Analysis Using Korea's Time Series Data for 1986-2008*

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Key words(중심용어): 물리적 기술(Physical Technology), 기업부패(Business Corruption), 공직부패(Public Sector Corruption), Cochrane Orcutt 추정(Cochrane Orcutt Estimation), 오차수정모형(Error Correction Term)

국 문 요 약

1986년부터 2008년까지 한국의 연간 시계열자료로부터 Cochrane-Orcutt 방법을 사용하여 추정한 결과 기업부패와 공직부패는 성장에 유해한 효과를 가지고 있음을 발견하였다. 두 부패지 표들을 비교한 결과로부터 성장에 대해서 기업부패가 공직부패보다 더욱 중요한 요인임을 알 수 있다. Stock-Watson 인과관계 검정결과 두 부패지표들은 인과관계가 있음을 보여주고 있다. 즉, 하나의 부패가 감소하면 다른 하나의 부패도 감소함을 의미한다. 이는 기업부패와 공직부패는 정 책형성에서 한 꾸러미가 되어야 함을 시사한다. 또한 추정결과로부터 물리적 기술의 발전은

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기업부패와 공공부문의 부패를 감소시켜 성장을 더욱 빠른 속도로 제고시킴을 발견하였다. 상호작용 변수가 주어졌을 때 물리적 기술은 공직부패보다 기업부패에 더욱 민감함을 보여주고 있다. 오차수정모형을 추정한 결과 기업부패와 공직부패는 장기성장효과뿐만 아니라 동시성장효과도 가지고 있음을 시사한다.

I. Introduction

A variety of studies shows an inverse relationship between corruption and economic efficiency[1]. For example, Abed and Davoodi (2000, 18 and 32), based on a single cross-sectional data for 25 countries from the 1999 International Monetary Fund fund staff and World Development Indicators (World Bank), present the results of ordinary least squares (OLS) regressions in which anti-corruption index with a scale of 0 to 10 (highly corrupt=0; highly clean=10) is regressed on real per capita growth rate. They find that lower corruption is significantly associated with higher growth; a one unit increase in corruption index increases the growth rate by 2.64% at the 1 percent level. Variations in initial real per capita Gross Domestic Product (GDP), initial life expectancy, the ratio of fiscal balance to GDP, and inflation are controlled for.

On the other hand, the external shocks such as physical technology would tend to reduce corruption. For example, Vinod (1999) claims that innovative uses of the internet for information exchange are hopeful new tools to fight corruption. Zinnbauer (2003) asserts that the internet provides advanced options for cross-checking sources. Together with digital archiving functions, it also raises the likelihood of ex-post discovery and thus the disciplinary power of transparency.

Given that transparency is negatively associated with corruption, it turns out that technological progress reduces corruption[2]. More recently, Sturges (2004) also predicts that the use of the internet contributes to the development of generally applicable principles to reduce corruption. In this respect we hypothesize that the use of physical technology is associated with lower level of corruption.

Corruption implies that the agent (an official) entrusted with carrying out a task by the principal (the public) engages in some sort of malfeasance for private enrichment, which is

1) Corruption is one of the constituent components of social technology which is defined as institutions, organizations, operational capabilities that are necessary in pursuit of a goal or goals (see, for more details, Kang and Lee 2009).

2) Sturges (2004) elaborated what transparency means in terms of establishing a polity in which corruption will not thrive.

difficult to monitor for the principal (Bardhan 1997).

On the basis of this we classify corruption into that by business and that by the public sector. Given the accessible corruption indicators the amount of unfair trade stands as a proxy for business corruption, while the number of exposures (hereafter public sector corruption) as a result of audit and inspection in the public sector is a proxy for public sector corruption.

With unique business and public sector level annual time series data for the period 1986 to 2008 from Korea, we first examine whether both business and public sector corruption affect growth. Then the analysis takes into account the possibility that physical technology reduces both business and public sector corruption, which in turn enhances growth.

We organize the rest of the paper as follows. Section Ⅱ develops the empirical model that highlights the sensitivity of growth with respect to each of business and public sector corruptions, and the indirect sensitivity of growth with respect to physical technology measured as the number of patents through each of business and public sector corruptions. Section Ⅲ describes the data. Section Ⅳ presents and discusses the empirical results. The last section gives the concluding remarks.

Ⅱ. The Empirical Model

The primary purpose of this section is to tests for the null hypothesis that the differences in two indicators of corruption are causal to the differentials in growth. Then this section specifies the proposition that the mechanism behind the technology-corruption relationship may also give rise to the corruption-growth relation. Causal relationships between corruption and growth, and between technology and growth via corruption can be written, in a functional form, as (Barro and Sala-i-Martin 2001; Beinhocker 2006; Kang and Lee 2009):

$$g\mathrm{FCY}_t = f(g\mathrm{FCY}_{t-1}, \mathrm{CORRUPTION}_t, \mathrm{CORRUPTION}_t{*}\mathrm{TECH}_t, Z_t,) \cdots\cdots (1)$$

where g denotes the growth rate in each variable (e.g. $g\mathrm{FCY}_t$ denotes the growth rate of FCY_t). FCY_t denotes the total factor cost of national income. $\mathrm{CORRUPTION}_t=(\mathrm{PC}_t, \mathrm{GC}_t)'$ refers to the row vector of two indicators of corruption. PC_t represents the amount of unfair trade as a proxy for business corruption. GC_t represents the number of exposures as a result of audit and inspection in the public sector as a proxy for public sector corruption.

$\mathrm{CORRUPTION}_t{*}\mathrm{TECH}_t$ denotes an interaction variable interacted $\mathrm{CORRUPTION}_t$ with

$TECH_t$. $TECH_t$ denotes the number of patents as the proxy of physical technology.

Vector Z_t includes $TRADE_t/FCY_t$ (the ratio of the sum of exports and imports to the total factor cost of national income), $FISCAL_t/FCY_t$ (the ratio of the consolidated expenditure to the total factor cost of national income), and INV_t/FCY_t (the ratio of the total investment to the total factor cost of national income).

We include a lagged dependent variable (i.e., lagged growth) as an explanatory variable to limit the potential impact of reversed causality (Stel et al. 2005). t represents year.

Equation (1) represents for well-behaved production function exhibiting everywhere diminishing returns to inputs.

An error correction model (ECM) allows us to study the short-run dynamics in the relationship between growth rate and two indicators of corruption. For example,

$$\triangle gFCYt = g(\triangle gFCY_{t-1},\ \triangle CORRUPTION_t,\ \triangle CORRUPTION_t * \triangle THCH_t,\ \triangle Z_t,\ S_{t-1}) \cdots\cdots\cdots (2)$$

where S_{t-1} denotes the error correction term (see Wooldridge 2000, 592). The parameters of the equations are estimated using annual time series for the period of 1986-2008. Furthermore, each equation is also estimated by using a Cochrane-Orcutt procedure which assumes first order serial correlation in the disturbance term.

Ⅲ. Data

Table 1 provides a description of the variables used in the model. Least squares regression assumes that the dependent variable and (less critically) the independent variables are normally distributed. This assumption is reasonably satisfied by the data used in the study. Table 1 contains the commonly used Kolmogorov and Smirnov tests for normality and shows that the tests fail to reject the hypothesis of normal distribution for both growth and two indicators of corruption. Moreover, neither growth nor the two corruption indicators show significant skewness.

Table 1. Definition of variables

Variable	Mean (SD)	Normality K-S (z value)[1]	Test Skewness
FCY[2]= The total factor cost of national income	382,693 (220,086)	Accept H_0 (0.450)	0.280
gFCY[3]=Growth	11.257 (6.128)	Accept H_0 (0.401)	-0.158
PC[4]=Business Corruption	0.321 (0.144)	Accept H_0 (0.731)	0.979
GC[5]=Public Sector Corruption	4.958 (1.965)	Accept H_0 (0.626)	-0.414
TRADE[6]=The sum of exports and imports of goods and services	309,560 (235,264)	Accept H_0 (0.670)	1.063
TRADE/FCY[7]=The sum of exports and imports to the total factor cost of national income	74.462 (15.270)	Accept H_0 (0.520)	1.296
FISCAL[8]=Consolidated Expenditure	103,818 (68,916)	Accept H_0 (0.610)	0.388
FISCAL/FCY[9]=Consolidated Expenditure to the total factor cost of national income	25.345 (3.884)	Accept H_0 (0.909)	0.055
INV[10]=The total investment	132,532 (68,961)	Accept H_0 (0.425)	0.193
INV/FCY[11]=The total investment to the total factor cost of national income	36.053 (4.729)	Accept H_0 (0.766)	0.117
TECH[12]	82.589 (53.995)	Accept H_0 (0.725)	0.329

Notes: 1. Kolmogorov-Smirnov Test. The alternatives are: H_0=the fits of a normal distribution to the sample data is adequate and H_1=the fits of a normal distribution to the sample data is not adequate. By "Accept H_0" we strictly mean "cannot reject H_0". The α risk controlled at 0.01 on a two-tailed test.
2, 6, 8,10. In billion Korean Won.
3. The year-over-year growth rate, expressed as a percentage.
4. In thousand. The number of unfair trade
5. In thousand. The number of exposures as a result of audit and inspection in public sector.
7, 9, 11. Unit: %.
12. In thousand. The number of patents.

Source: 2, 6, 10. Korea National Statistical Office and Korea Institute for Industrial Economics and Trade.
4. *Annual Statistical Reports,* The Korea Fair Trade Commission.
5. *Annual Audit Reports,* The Board of Audit and Inspection of Korea.
8. *Consolidated Central Government Financial Statistics,* Ministry of Strategy and Finance.
12. *Application by year,* Korean Intellectual Property Office.

In the literature, the most commonly used measure of trade globalization is the ratio of sum of imports and exports to GDP (e.g., Yucel 2009). In this study, TRADE/FCY (i.e., trade intensity) can be viewed as the measure of globalization, which refers to integration of goods markets through international trade and not to capital market integration (e.g., Aka 2006). In the literature, the most commonly used measure of the size of government is a ratio of

government expenditure to the GDP (e.g., Grossman 1988). Following beyond literature, the ratio of consolidated expenditure to the total factor cost of national income can be calculated as the proxy of the size of government.

The Korea's financial crisis at the end of 1997 was reflected in the gFCY variable. The level of government regulation was reflected in the FISCAL/FCY variable. The physical capital was reflected in the INV/FCY variable (Haavelmo 1960, 3; Bloom et al. 2004, 7).

Ⅳ. Estimated Results

This study has dealt with the functional form issue using the Beggs tests and the Box-Cox transformation framework in Table 2 and has found the double-natural logarithmic transformation suitable.

Table 2. Non-Nested Test of Double Logarithmic versus Linear Models of Growth: OLS estimates

Equation[1]	Beggs[2]		Box-	Cox[3]
	Logarithmic model (H_1)	Linear model (H_0)	Logarithmic model (H_1)	Linear model (H_0)
(1)	t=0.466 Reject H_0	t=1.193 Accept H_0	RSS=0.105 Reject H_0	RSS=1.553
(2)	t=0.986 Reject H_0	t=1.708 Accept H_0	RSS=0.204 Reject H_0	RSS=2.485

Notes: 1. Equation (1) includes the business corruption (PC_t), whereas equation (2) includes the public sector corruption (GC_t).

2. Beggs (1988, 95) proposes testing natural logarithmic versus linear models by augmenting the linear equation with the exponential of the prediction of the dependent variable from the natural logarithmic equation and the natural logarithmic model with the prediction of the dependent variable from the linear model run by OLS. The null hypothesis (H_0) of the linear form of a model against the double natural logarithmic model is not rejected if the absolute value of the t-statistic on the added regressor of the linear model is less than the critical value, whereas the alternative hypothesis (H_1) of the double natural logarithmic model against the linear model is not rejected if the t-statistic on the added regressor of the double natural logarithmic model is less than the critical value. The regression results indicate that both the null and alternative hypotheses are not rejected, implying that the tests are inconclusive. The value of *lng*FCY in 1997 Asian financial crisis appears to be less than zero. Therefore, the prediction of the double natural logarithmic model for the non-nested tests is obtained by relying upon the first-order Taylor series approximation $ln(1+X) \approx X$; $lngFCY = ln(1+gFCY-1) \approx gFCY-1$.

3. The Box-Cox procedure as described by Maddala (1977, 317). For example, the Box-Cox procedure for the growth function (1) involves dividing each $gFCY_t$ by the geometric mean of the $gFCY_t$'s; the exponential of the mean of the natural logarithm of $gFCY_t$. Then we estimate the two equations (double natural logarithmic and linear) and choose the one with the smaller residual sum of squares (RSS).

Although the equation (1) is estimated by the Cochrane-Orcutt (CO) as well as the ordinary least square (OLS) methods, the OLS estimation is analyzed over the Cochrane-Orcutt estimations because the standard errors of the estimates (SEE) in the former are smaller than those in the latter. The use of SEE is also based on the overall model performance.

The estimated value of adjusted R^2 (Adj.R^2) in the OLS is greater than those in the CO estimations (see, e.g., Gupta et al. 2001).

The regression results suggest that less business corruption as measured by the amount of unfair trade and public sector corruption, as measured by the number of exposures as a result of audit and inspection in the public sector, are proportionately associated with more growth. For example, the OLS estimates suggest that 1 per cent decreases in business and public sector corruptions raise growth by 3.232 and 4.891 per cent, respectively. In a comparison between business and public sector corruptions, the latter has a minor effect on growth (t=2.512).

In Table 3, both OLS and Cochrane-Orcutt (CO) estimates suggest that the number of patents as a proxy for physical technology reduces both business and public sector corruptions. Given the interaction term, technological progress is more sensitive to business corruption than to public sector corruption. The results imply that the growth increases at a faster rate with reduced business and public sector corruptions as physical technology is developed.

In Table 3, the OLS estimates suggest that *ln*(TRADE/FCY) is positively and significantly related to *lng*FCY. This result is consistent with Yucel (2009). For example, Yucel conducts a Granger causality tests using monthly time-series data for Turkey over the period 1989 to 2007. His results show that Turkey's trade globalization measured as the ratio of the sum of the exports and imports to GDP Granger causes growth at 5% significance level. His finding also supports the theoretical approach in which trade globalization can be positively affecting on developing countries economic performances.

The estimated coefficient of *ln*(FISCAL/FCY) maintains the expected negative sign and is statistically significant at the 5 per cent level on a two-tailed test. The finding implies that the economic growth appears to be higher when the size of government is smaller. This result is consistent with Grossman (1988). Employing annual time- series data covering the period 1929-1982 for the United States, Grossman finds in the non-linear model estimated using two staged least squares that the ratio of government expenditure to the GDP as a proxy for the size of government is negatively and significantly related to growth (t-statistics=2.577); the negative impact of government arising from the welfare loss generating distortions and the unproductive use of resources in rent-seeking activities is

significant. This result is also in line with the Higgs' argument of the failure of big government (Higgs 2010).

Table 3. Estimates of the growth equation[1]

Independent Variables	Dependent Variable:[2]			$lngFCY_t$
	OLS		CO	
	(1)	(2)	(1)	(2)
$lngFCY_{t-1}$	-0.346 (0.125)**	-0.407 (0.175)**-0.241neu ation is estimated by using a Cochrane-Orcutt procedure which assumes first order serial correlation in the disturbance	-0.358 (0.132)**	-0.392 (0.184)*
$lnPCt$	-3.232 (0.632)***	-	-3.223 (0.651)***	-
$lnGCt$	-	-4.891 (1.947)**	-	-5.127 (2.077)**
$lnPC_t * lnTECH_t$	1.730 (0.442)***	-	1.700 (0.460)***	
$lnGC_t * lnTECH_t$	-	0.956 (0.422)**	-	0.995 (0.444)**
$ln(TRADE/FCY)_t$	4.733 (1.571)***	2.012 (2.268)	5.232 (1.941)**	1.262 (2.895)
$ln(FISCAL/FCY)_t$	-13.969 (3.022)***	-11.584 (4.394)**	-15.067 (3.905)***	-10.125 (5.618)*
$ln(INV/FCY)_t$	7.886 (1.855)***	6.009 (2.566)**	7.490 (2.090)***	6.547 (2.914)**
Constant	-9.751 (13.307)	11.614 (20.362)	-6.766 (15.125)	8.223 (22.356)
R^2 (Adj.R^2)	0.848(0.783)	0.705(0.579)	0.847(0.777)	0.703(0.566)
Joint F	(1,14)=13.048***	(1,14)=5.586**	(1,13)=12.031***	(1,13)=5.132**
D.W.	1.693	1.116	1.751	1.013
SEE	0.693	0.966	0.713	0.995

Notes: 1. Values in parentheses are the estimated absolute standard errors of the regression coefficients. ***, **, and * denote significance at the 1%, 5%, and 10% levels on a two-tailed test, respectively.

2. Two regressions are estimated by using the Cochrane-Orcutt (CO) procedure assuming first order serial correlation in the disturbance term. The number of iterations is 10.

The estimated coefficient of ln(INV/FCY) maintains a positive sign and is statistically significant. The results are consistent with the usual findings of previous studies that more investment is associated with higher growth. For example, using cross-country panel data on 85 countries covering 1990-2000, Gwartney et al. (2006) found that both private and public investments as a share of GDP is positively and significantly related to average annual growth rate of GDP per capita (t-values are 3.93 and 2.82, respectively).

It is evident from the Stock-Watson tests for causality (Stock and Watson 1989) that two causal relationships between each pair of corruptions exist; reducing one is likely to result in reductions in the other, implying that business and public sector corruptions may be one package in policy formulation. For example, we reject the null that $ln GC_t$ does not cause $ln PC_t$ conditional on $ln TECH_t$ (the estimated absolute t-value=2.078). We also reject the null that $ln PC_t$ does not cause $ln GC_t$ conditional on $ln TECH_t$ (the estimated absolute t-value=2.785).

The estimated ECM results in Table 4 under the columns (1) and (2), the OLS and CO estimates suggest that both the ECM coefficients of business corruption (PC) and public sector corruption (GC) are negative and significant. An implication of this is that each of business and public sector corruptions has a contemporaneous effect as well as a long-term effect. For example, a 1% decrease in business corruption moves growth up 3.232% immediately, with another 0.267%~0.286% increase over future time periods for a total effect of 3.499%~3.518 (see Table 3).

The models do not seem to suffer from autocorrelation; D.W.=1.965 and 2.194, respectively. A negative and statistically significant error correction term is taken as evidence for the presence of cointegration (Balazs et al. 2007).

Table 4. Estimates of the Error Correction Terms[1]

	Error(0.083)***or rection Term					
	(1)			(2)		
	St-1	F	D.W.	St-1	F	D.W.
OLS	-0.267 (0.155)*	35.985***	1.965	-0.370 (0.083)***	60.774***	2.194
CO	-0.286 (0.159)*	20.170***	1.911	-0.364 (0.084)***	38.097***	2.150

Notes: 1. See Notes 1 in Table 3. In the regression equations (1) and (2) using OLS, the estimated D.W. (Durbin-Watson) value lies between d_U (2.290) and the value of $4-d_U$ (1.710). Therefore, the null hypothesis of no autocorrelation is not rejected at the 5% level of significance (the number of observations=21), implying that models are correctly specified.

V. Concluding Remarks

With Korea's annual data from 1986 to 2008, this study presents empirical evidence of the sensitivity of each of business and public sector corruptions to the growth. This study also investigates the proposition that the mechanism behind the technology-corruption relationship may also give rise to the corruption-growth relation.

The regression results are found to be consistent with the hypothesis that business corruption and public sector corruption have detrimental effects on growth. The results imply that each of business and public sector corruptions plays an important role in accounting for growth in Korea. In a comparison between two indicators of corruption, business corruption is more important factor than public sector corruption in explaining the growth. The Stock-Watson causality test indicates that two causal relationships between each pair of corruptions exist; reducing one is likely to result in reductions in the other, implying that business and public sector corruptions may be one package in policy formulation.

It is also evident that growth is enhanced at a faster rate with reduced business and public sector corruptions as physical technology is developed. Given the interaction term, physical technology is more sensitive to business corruption than to public sector corruption. Therefore, the policy implication is that the investment in the physical technology should be encouraged to reduce the level of both business and public sector corruptions in Korea. Furthermore, policy makers should also detect *Chaebol*'s unfair trade practices, the proxy of business corruption.

The results from the estimated error correction model suggest that each of business and public sector corruptions has a contemporaneous effect as well as a long-term effect.

Each of globalization and investment has a beneficial effect on growth, whereas the size of government has a negative effect.

Our results are subject to a number of constraints that should be taken into account before one attains a strong conviction in the above conclusions. For example, given the date limitations, ideal measure of the business corruption is not obtained. Hopefully, the conclusion reached here will stimulate further research and discussion in resolving these issues.

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Abstract

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With Korea's annual data from 1986 to 2008, the regression results are found to be consistent with the hypothesis that business corruption and public sector corruption have detrimental effects on growth. In a comparison between two indicators of corruption, business corruption is more important factor than public sector corruption in explaining the growth. The Stock-Watson causality test indicates that two causal relationships between each pair of corruptions exist; reducing one is likely to result in reductions in the other, implying that business and public sector corruptions may be one package in policy formulation. It is also evident that growth is enhanced at a faster rate with reduced business and public sector corruptions as physical technology is developed. Given the interaction term, physical technology is more sensitive to business corruption than to public sector corruption. The results from the estimated error correction model suggest that each of business and public sector corruptions has a contemporaneous effect as well as a long-term effect.

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