國 立 交 通 大 學

經營管理研究所

碩 士 論 文

政府治理與國家研發效率：
隨機距離函數法之應用

Public Governance and National R&D Efficiency: An
Application of Stochastic Distance Function Approach

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摘要

本篇文章採用隨機邊界法來衡量政府治理與國家研發之間的關係。資料數據涵蓋 59 個國家，而資料年限為 1998 年、2000 年、2002 到 2008 年。在多投入與多產出的模型中，我們使用了 R&D 人員與 R&D 費用存量做為投入項；產出項則為專利數、科學期刊文章與技術授權金。研究結果發現六個政府治理指標對研發效率有正面的影響，尤其是政府效率指標對研發效率的影響最大。進一步把六項政府治理指標區分成三個面向時，同樣顯示公部門治理對研發效率有正面影響效果。

關鍵詞：研發效率、政府治理、隨機邊界法

Public Governance and National R&D Efficiency: An Application of Stochastic Distance Function Approach

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ABSTRACT

This paper adopts the distance function approach for stochastic frontier analysis (SFA) to estimate the relationship between six governance indexes and research and development (R&D) efficiency across 59 nations during the years of 1998, 2000, and 2002–2008. The multiple inputs and outputs framework which includes R&D manpower, R&D expenditure stocks as inputs and patents, scientific journal articles, royalties and licensing fees (RLF) as outputs. We find that all six indexes have positive effects on R&D efficiency; moreover, the government effectiveness especially plays the most important role. Grouping the six indexes into three dimensions still shows the same result that the public governance significantly improves national R&D efficiency.

Keywords: R&D efficiency, public governance, distance function approach

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1. Introduction

1.1 Research background and motivation

Endogenous growth theory indicates that research and development (R&D) played an indispensable role in fostering the economic growth. Several studies provided evidence for the positive relationship between R&D activities and growth (e.g., Coe and Helpman, 1995; Meliciani, 2000; Zachariadis, 2004; Parisia et al., 2006; Wang, 2007). Griffith et al. (2004) used data from industries across 12 OECD countries during the period 1974-1990, finding country industries lagging behind the productivity frontier catch up particularly fast if they invested heavily in R&D. As R&D activities are the major driving force behind economic and technological progress (Wang and Huang, 2007), the efficiency of R&D and the improvement of R&D performance should not be ignored.

Wei (2000) suggested that bad institutions might slow down the diffusion of new ideas and technologies. Nikos (2006) examined how the quality of political institutions influenced national innovational activity. If we take governance as a kind of institutions, governance should play a key role to create a suitable environment for innovation. In fact, we may infer that good governance have positive effects on R&D efficiency. However, there is still no clear and direct evidence to support the relationships between governance and R&D efficiency. Currently, most researches about the relationship between them only emphasize the partial role of government when reviewing the R&D inefficiency. For example, Conte et al. (2009) analyzed the relative efficiency of the innovation among EU Members and pointed out that the government's structure and policy might contribute to raise efficiency level of R&D spending.

1.2 Research objectives

To our best knowledge, the public governance should be rationally evaluated by many

dimensions in each country. Based on the concept from Worldwide Governance Indicator (WGI), governance should have the ability to formulate and enforce sound policies which also contain regulations and the rules of raw. It ought to give the confidence to the local institution and the people among the interaction of social and economic affairs. It should stand the test about the rotation of political parties and the process which be monitored by the opposition and citizens. As we can see from above, the governance is multidimensional. Due to few studies aim at the relationship between governance and R&D efficiency till now, it is worthy to understand this issue more complete and comprehensive.

1.3 Research procedure

In this study, we employ the distance function approach of SFA to examine the relationship between public governance and R&D efficiency. This approach which proposed by Coelli and Perelman (2000) is not only possesses the advantages of data envelopment analysis (DEA) by considering multiple outputs and being free of behavioral assumptions, but also remedies its drawback of not considering the individual effect of each nation. We provide the following distinct types of empirical evidence. First, this study computes national R&D efficiency in compliance with the multiple input-output R&D production process at the national level. Second, this study uses six governance indicators from WGI to investigate the role of public governance. The six governance indicators are developed by Kaufmann et al. (2010), which compile the governance infrastructure from a broad sample of 215 economies over the period 1996-2011. Third, examining the relationship between governance and national R&D efficiency can provide insightful policy implications for nations in help to achieve better R&D performance, especially from the viewpoint of governance. These should in turn help improve the allocation of R&D resources and foster economic development.

The rest of this paper is organized as follows: Section 2 reviews literature regarding the contribution of R&D efficiency and the impact of a specific policy to R&D efficiency.

Section 3 deals with the empirical methodologies and introduces the dataset. Section 4 conducts model tests and displays the estimated R&D efficiency scores. It also includes the exploration of the impacts of governance indicators on national R&D efficiency. Section 5 concludes remarks and policy implications. Figure 1 is the research flowchart:
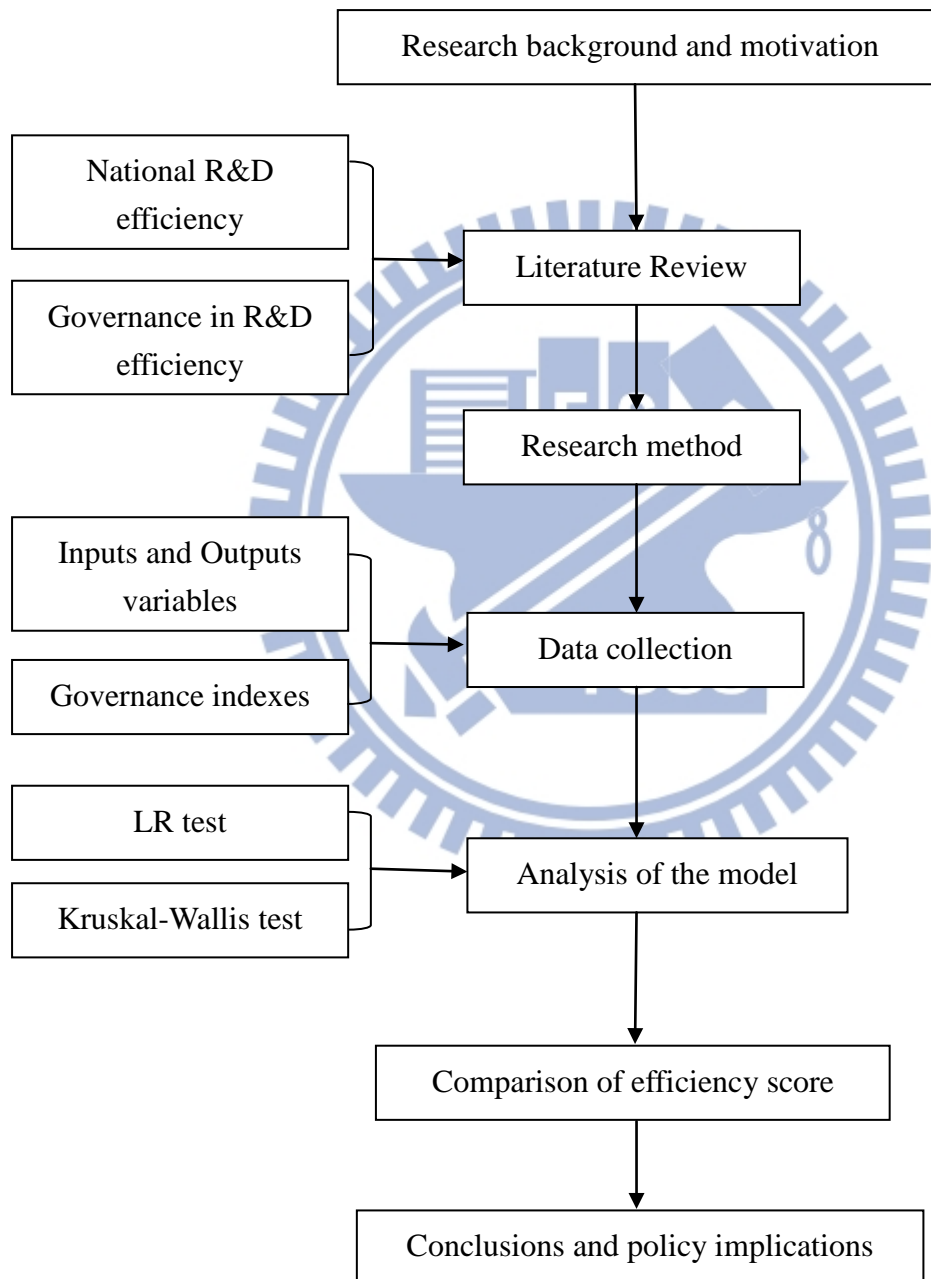
Figure 1 Research Flowchart

2. Literature Review

2.1 Empirical studies on national R&D efficiency

In recent years, national R&D efficiency has been evaluated through the method of DEA and SFA. Following are studies which explore the R&D efficiency. Lee and Park (2005) measured R&D efficiency for 27 nations which included OECD countries and some non-member countries. The input variables were R&D expenditures and researchers; outputs were technology balance of receipts, articles and patents. For Asian country, the results showed that Singapore got top score in total efficiency, and Japan in patent-oriented efficiency. They also found that China, Korea, and Taiwan were relatively inefficient in all these three output efficiencies.

Wang and Huang (2007) used three-stage DEA to evaluate the relative efficiency of R&D activities across 30 countries. The inputs were R&D capital stocks and manpower while outputs were patents and academics. The results showed that less than one-half of the countries were fully efficient in R&D activities and more than two-thirds were at the stage of increasing returns to scale.

Sharma and Thomas (2008) used DEA to measure 22 countries which were grouped as developed and developing types. They chose gross domestic expenditure on R&D, the number of researchers, annual population estimates and gross domestic product by expenditure as inputs and patents granted to residents and publications as outputs. Japan, the Republic of Korea and China were found to be efficient at the stage of constant returns to scale. Japan, Republic of Korea, China, India, Slovenia and Hungary were in the stage of variable returns to scale.

Chen et al. (2011) compared national R&D efficiency across 24 countries and investigated how the innovation environment affected different output-oriented R&D

efficiency indices. The input variables were total R&D manpower and R&D expenditure stock while output variables were patents, scientific journal articles and royalty and licensing fees. Their results showed that R&D intensity, intellectual property rights protection, knowledge stock, and human capital accumulation all had significantly positive effects on efficiency indices.

National R&D efficiency could be measured by another method such as SFA. Here list three studies which use SFA to deal with the issue related to national R&D efficiency. Wang (2007) evaluated the relative efficiency of R&D activities across 30 countries. He constructed a production function, then used R&D capital stock, and manpower as inputs, and used weighting scheme which combine patents and academic publications into single one as output. The result showed that after taking the environmental effect into account, the means of efficiency scores increased from 0.65 to 0.85.

Fu and Yang (2009) used SFA to construct an international patenting frontier. They selected R&D inputs and human capital as key inputs and considered patents as a proxy for output. In terms of patenting efficiency, Japan and the USA had been the world leaders in the 1990s, then the UK was ranked the lowest among the G7 countries and showed little sign of catch-up in this respect either.

Hu et al. (2011) studied the relationship between R&D efficiency and the national innovation system, using a multiple input-output framework to compute R&D efficiency cross 24 nations. In their study, R&D expenditure stock and R&D manpower were inputs, while patents, scientific journal articles and royalties and licensing fees were outputs. They found intellectual property rights protection, technological cooperation among business sectors, knowledge transfer between business sectors, higher education institutions, agglomeration of R&D facilities, and involvement of the government sector in R&D activities could significantly improve national R&D efficiency.

Table 1 shows previous discussed national R&D efficiency by using DEA and SFA.

When comparing the national R&D efficiency, it is more suitable to take multiple outputs into consideration for avoiding partial view of national R&D performance. Based on previous studies above mentioned, this study chooses R&D expenditure stock and R&D manpower as inputs, while patents, scientific journal articles and royalties and licensing fees (RLF) as outputs which all have been widely adopted.

Since the non-parametric approach of DEA and parametric approach of SFA are two principal methods to measure efficiency, both of them respectively have its own advantage. DEA approach can take multiple outputs into account and there is no need to specify a functional form for production function. On the other hand, SFA approach can capture the statistical noise and be used to conduct conventional test of hypotheses (Coelli et al., 2005). In order to retain the advantages of two approaches as much as possible, we adopt the distance function to conduct a multiple input-output framework within SFA.
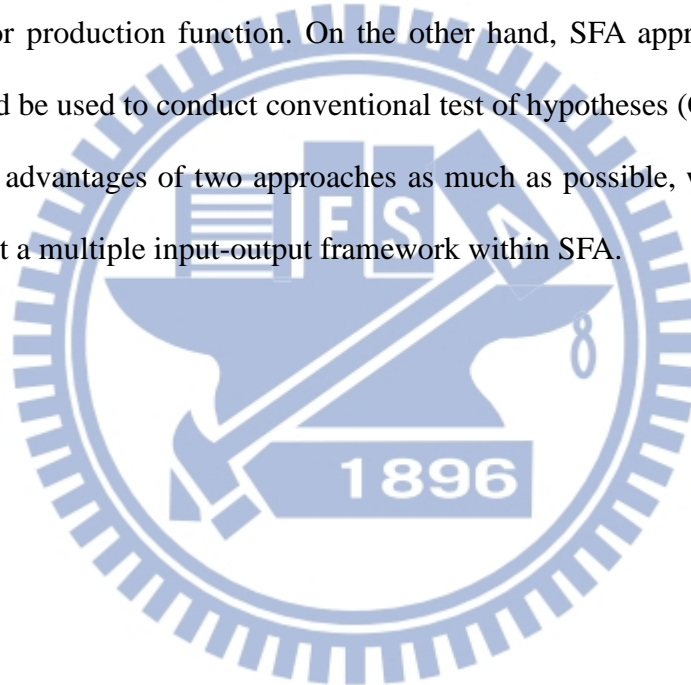
Table 1

Literature review of national R&D efficiency

Author	Input indicators	Output indicators	Key Results
Method of data envelopment analysis (DEA)			
Chen et al. (2011)	• R&D expenditure stock • R&D manpower	• Patents • Publications • Royalty and licensing fees	R&D intensity, intellectual property rights protection, knowledge stock, and human capital accumulation all had significantly positive effects on efficiency indices.
Sharma and Thomas (2008)	• R&D expenditure • Researchers • Population • GDP	• Patents • Publications	Some of the developing nations can serve as benchmarks for their efficient use of R&D resources.
Wang and Huang (2007)	• R&D capital stock • R&D manpower	• Patents • Publications	There are less than one-half of the countries were fully efficient in R&D activities and more than two-thirds were at the stage of increasing returns to scale.
Lee and Park (2005)	• R&D expenditure • R&D manpower	• Patents • Publications • Technology balance of receipts	Singapore got top score in total efficiency, and Japan in patent-oriented efficiency. China, Korea, and Taiwan were relatively inefficient in all three output efficiencies.
Method of stochastic frontier analysis (SFA)			
Hu et al. (2011)	• R&D capital stock • R&D manpower	• Patents • Publications • Royalty and licensing fees	Intellectual property rights protection, technological cooperation, knowledge transfer, higher education institutions, agglomeration of R&D facilities, and involvement of the government sector in R&D activities can improve national R&D efficiency.
Fu and Yang (2009)	• R&D inputs • Human capital	• Patents	In terms of patenting efficiency, Japan and the USA had been the world leaders in the 1990s, then the UK was ranked the lowest among the G7 countries
Wang (2007)	• R&D capital stock • R&D manpower	• Combine patents and publications into single one	After taking the environmental effect into account, the means of efficiency scores increased from 0.65 to 0.85.

2.2 The role of public governance in R&D activities

Méon and Weill (2005) studied the relationship between governance and macroeconomic technical efficiency which showed that better governance was associated with more efficient. Lio and Hu (2009) adopted Kaufmann et al. (2006) to investigate the relationship between six governance indicators and agricultural efficiency. Chang and Hu (2013) used Kaufmann et al. (2008) to investigate the relationships among six governance indicators and environmental efficiency, operational efficiency, and unified efficiency. Regarding as the relationship between public governance and national R&D activities, most of previous studies focus on the influence of single policy, and discuss this issue into four parts as follows.

First, the degree of democracy and the liberalization of investment environment– To promote the economic development, the more rights that people can take part in the public sector, the more freedoms they can express themselves. More rights and freedoms may help creativity and innovation. Ishtiaq and Carlos (2005) suggested that government should adjust corresponding policy according to the external conditions. When a country was far from the technological frontier, the government could promote economic development through relieving the centralization of economic and political control. On the other hand, highly political and economic freedom has often been seen while a country approaches to technical frontier.

In previous studies, Adkins et al. (2002) studied the impact of institutions on economics and showed that more economics freedom result in more aggregate efficiency. Recently, Altay and Çelebioğlu (2011) stated that there were positive relationships among per capita GDP, democracy and economic freedom in European countries. Zouhaier and Karim (2012) explored the 11 countries among Middle East and North Africa. They found a positive impact of democracy on investment. Although there is no direct evidence focus on the relationship between democracy and R&D activities, we suggest that the degree of democracy may have

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positive influence on national R&D efficiency.

Second, the stability and the effectiveness of government – Because uncertainty to the future benefit is likely to limit investment in innovation and venturing for entrepreneurs (Baker et al., 2005), political instability may also limit national R&D activities. Nikos (2006) pointed out that political stability and accountability of governmental actions should be positively related to patent protection. When discussing the reason why R&D allocated inefficient, the effectiveness of government may play an important part. In fact, government effectiveness at least includes many details such as quality of public services and the credibility of the government's promise to such policies and so forth. Wang (2007) proposed that bureaucracy might cause some influences on R&D efficiency. He also mentioned that the discrepancies in the level of knowledge-based economies across countries. It implies that there is still room for improvement regarding the effectiveness of policies.

Third, the quality of regulation and the rule of law – Blayse and Manley (2004) identified six main factors which driving innovation for the business and policy maker, and one of them was a country's regulations or standards. Nikos (2006) pointed out the higher the efficiency of the judiciary system, the better the patent's protection. However, if government blocking innovation or adopting policies that were bad for growth, some countries will remain poor (Azam and Phillip, 2007). Government regulation through norms and standards is one of the motivations stimulating innovation (Milou and Niels, 2007). If the government has an ability to formulate and implement sound policies and regulations, it may improve R&D efficiency and thus accelerate the growth. Furthermore, sound policies and regulations are inducements when exploring the influences on R&D activities.

Fourth, the control of corruption – Mauro (1995) engaged in an empirical analysis of corruption by investigating the relationship between investment and corruption for 58 countries. He showed that corruption was negatively associated with investment. Some other studies also showed a negative relationship between corruption and foreign direct investment

(Asiedu, 2006; Voyer and Beamish, 2004; Habib and Zurawicki, 2002; Wei, 2000). Such a phenomenon will fail to induce knowledge spillover which pertains to the flow of R&D staff and technology. At the same viewpoint, Marcelo (2008) illustrated the relationship between corruption and product innovation in an industry. The conclusion showed that corrupt practices led to lower rate of innovation. Accordingly, better control of corruption is also associated with rising levels of innovation (Sergey and William, 2009). In this research, the control of corruption will be also taken into account when measuring the relationship between public governance and national R&D efficiency.

Considering the multidimensional of governance, this paper use governance indicators which developed by Kaufmann et al. (2010). The indicators not only reflect governance-related issues from six categories but also help us to clarify the comprehensive relationship between public governance and national R&D efficiency rather than focus on a single policy. Six indicators include voice and accountability, political stability and absence of violence, government effectiveness, regulatory quality, rule of law, as well as control of corruption. The specific definitions will be introduced in sub section 3.3.

3. Methodology and Data

This study applies the distance function approach of SFA to evaluate the national R&D efficiency by considering multiple outputs. In national R&D production process, R&D expenditure stock and R&D manpower are the inputs, thus patents, royalties and licensing fees (RLF), and scientific journal articles are the outputs. This approach are more flexible since it can estimates the production function of multiple outputs without needing to specify a behavioral objectives such as profit maximization or cost minimization (Coelli et al., 2005). More important of all, this approach can simultaneously estimate the parameters of the distance function to evaluate national R&D efficiency and the efficiency effects of public governance.

3.1 The distance function approach for R&D efficiency

We use output expanding approach to measure the distance, which is the maximal proportional expansion of output vector given the input vector. According to Shephard's (1970) specification, the output distance function can be defined as follows:

$$Q(X, Y) = \min \left\{ \varphi : \left(\frac{Y}{\varphi} \right) \in V(X) \right\}, \tag{1}$$

finding the minimum φ such that $\left(\frac{Y}{\varphi} \right)$ belongs to $V(X)$, where $0 \leq \varphi \leq 1$. $V(X)$ presents the output set of the production technologies that describe the set of output vectors that are feasible for each input vector X. That is:

$$V(X) = \{Y : X \text{ can produce } Y\}, \tag{2}$$

This gives the minimum amount by which an output vector can be deflated and remains producible with a given vector. The output distance function $Q(X, Y)$ is non-decreasing, positively linearly homogenous and convex in Y, and non-increasing in X (Kumbhakar and Lovell, 2000). $Q(X, Y) \leq 1$ and $Q(X, Y) = 1$ represent how Y belongs to the production

possibility set of $(Y \in V(X))$ and Y is located on the frontier of the production possibility set of X respectively. The formulation of the output distance function defined in Equations (1) and (2) can be specified as:

$$Q(X, Y) = f(X, Y, \tau) \cdot e^v \tag{3}$$

where τ is a vector of unknown coefficients to be estimated, term v is the random disturbance term, capturing the statistical noise, which is assumed to be iid $N(0, \sigma_v^2)$.

An appropriate functional form $f(\cdot)$ in Equation (3) should ideally be flexible, easy to calculate, and permit the imposition of homogeneity. A commonly used functional form of production is the translog form, which satisfies the above criteria and has been widely adopted in previous studies (Grosskopf et al., 1996; Coelli and Perelman, 2000). The Cobb–Douglas form is the alternative functional form that satisfies only the latter two criteria, because of the restrictive elasticity of substitution and scale property. This study used the likelihood ratio (LR) test to identify whether the Cobb–Douglas functional form or the translog specification was the most adequate. The translog distance function with H outputs and K inputs in the year t is specified as:

$$\ln Q_{nt} = \alpha_0 + \sum_{h=1}^{H} \alpha_h \ln y_{nt}^h + \frac{1}{2} \sum_{h=1}^{H} \sum_{s=1}^{H} \alpha_{hs} \ln y_{nt}^h \ln y_{nt}^s + \sum_{k=1}^{K} \beta_k \ln x_{nt}^k$$

$$+ \frac{1}{2} \sum_{k=1}^{K} \sum_{p=1}^{K} \beta_{kp} \ln x_{nt}^k \ln x_{nt}^p + \sum_{h=1}^{H} \sum_{k=1}^{K} \gamma_{hk} \ln y_{nt}^h \ln x_{nt}^k + v_{nt}$$

$$n = 1,...,N \quad \text{and} \quad t = 1,...,T \tag{4}$$

where n denotes the n-th DMU in the sample. The restriction of linear homogeneity in outputs requires:

$$\sum_{h=1}^{H} \alpha_h = 1, \sum_{h=1}^{H} \alpha_{hs} = 0, h = 1, ..., H; \text{ and } \sum_{h=1}^{H} \gamma_{hk} = 0, k = 1, ..., K. \tag{5}$$

Furthermore, the restriction of symmetry requires:

$$\alpha_{hs} = \alpha_{sh}, h, s = 1, ..., H, \quad \text{and} \quad \beta_{kp} = \beta_{pk}, k, p = 1, ..., k. \tag{6}$$

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One essential problem in estimating Equation (4) is that the dependent variable $\ln Q_{nt}$ is unobservable. Fortunately, we can solve this problem by imposing the linear homogeneity in outputs (Lovell et al., 1994; Färe and Primont, 1995):

$$\ln\left(\frac{Q_{nt}}{y_{nt}^H}\right) = \alpha_0 + \sum_{h=1}^{H-1} \alpha_h \ln\hat{y}_{nt}^h + \frac{1}{2}\sum_{h=1}^{H-1}\sum_{s=1}^{H-1} \alpha_{hs}\ln\hat{y}_{nt}^h \ln\hat{y}_{nt}^s + \sum_{k=1}^{K} \beta_k \ln x_{nt}^k$$
$$+ \frac{1}{2}\sum_{k=1}^{K}\sum_{p=1}^{K} \beta_{kp} \ln x_{nt}^k \ln x_{nt}^p + \sum_{h=1}^{H-1}\sum_{k=1}^{K} \gamma_{hk}\ln\hat{y}_{nt}^h \ln x_{nt}^k + v_{nt}$$
$$n = 1,...,N \quad \text{and} \quad t = 1,...,T \tag{7}$$

where $\hat{y}_{nt}^h = \frac{y_{nt}^h}{y_{nt}^H}, h = 1, \dots, H-1.$ Equation(7) can be rewritten as:

$$-\ln y_{nt}^H = \alpha_0 + \sum_{h=1}^{H-1} \alpha_h \ln\hat{y}_{nt}^h + \frac{1}{2}\sum_{h=1}^{M-1}\sum_{s=1}^{M-1} \alpha_{hs}\ln\hat{y}_{nt}^h \ln\hat{y}_{nt}^s + \sum_{k=1}^{K} \beta_k \ln x_{nt}^k$$
$$+ \frac{1}{2}\sum_{k=1}^{K}\sum_{p=1}^{K} \beta_{kp} \ln x_{nt}^k \ln x_{nt}^p + \sum_{h=1}^{H-1}\sum_{k=1}^{K} \gamma_{hk}\ln\hat{y}_{nt}^h \ln x_{nt}^k + v_{nt} - \ln Q_{nt}$$
$$n = 1,...,N \quad \text{and} \quad t = 1,...,T. \tag{8}$$

We next replace the unobservable component $-\ln Q_{nt}$ by the non-negative random term u_{nt} that is assumed to be independently distributed, truncated at zero of $N(u, \sigma_u^2)$, and independently distributed of v_{nt}. The predicted value of the output distance for the n-th DMU, $\dot{Q}_{nt} = \exp(-u_{nt})$, is unobservable, because u_{nt} only appears as part of the composed error term, $\varepsilon_{nt} = v_{nt} + u_{nt}$. The conditional expectation of u_{nt}, given $\varepsilon_{nt} = v_{nt} + u_{nt}$, is used to obtain the predicted value of the output distance function. The output distance would hence be predicted as:

$$\dot{Q}_{nt} = E\left[\exp(-u_{nt})\,|\,\varepsilon_{nt}\right] \tag{9}$$

which is consistent with the Farrell output-oriented measure of technical efficiency (Kumbhakar and Lovell, 2000). Equations (8) and (9) can be estimated using the maximum

likelihood method (Coelli and Perelman, 2000).

We further specify the efficiency model as follows:

$$-u_{nt} = \tau_0 + \tau_i \, \text{Governance}_{nt} + \omega_{nt} \tag{10}$$

where $-u_{nt} = \ln Q_{nt}$, 'Governance' is the relevant variables of governance and the random disturbance ω_{nt} is assumed to be independently distributed as truncated at zero of N ($-(\tau_0 + \tau_i \, \text{Governance}_{nt})$, σ_u^2). Since the one-step model is more adequate, this study can simultaneously estimate the parameters of distance function and the efficiency model (Wang and Schmidt, 2002).

3.2 Description of inputs and outputs

This study utilizes unbalanced panel data around fifty-nine countries including thirty-three European, ten Asian, nine North and South American, five Africa and two Oceania during the period of 1998, 2000, 2002–2008.[1] Two inputs were R&D expenditure stock, and R&D manpower including full-time researchers and technicians. Due to the unavailability of data on R&D expenditure stock, this study uses the perpetual inventory method to convert R&D expenditure flow into R&D expenditure stock.

The R&D expenditure stock is defined as follows:

$$R_t = R_{t-1}(1 - \theta) + E_{t-1} \tag{11}$$

where R_t and R_{t-1} are the respective R&D expenditure stock in the current year and previous year, θ is the depreciation rate of stock, and E_{t-1} is the R&D expenditure flow in

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[1] Fifty-nine countries are Argentina, Australia, Austria, Belgium, Bosnia and Herzegovina, Brazil, Bulgaria, Canada, Chile, China, Croatia, Cyprus, Czech Republic, Estonia, Ethiopia, Finland, France, Germany, Greece, Guatemala, Hungary, Iceland, India, Ireland, Italy, Japan , Kenya, Latvia, Lithuania, Luxembourg, Macedonia, FYR, Madagascar, Malaysia, Malta, Mexico, Moldova, Morocco, Netherlands, New Zealand, Norway, Pakistan, Paraguay, Philippines, Poland, Portugal, Romania, Russia, Singapore, Slovak Republic, Slovenia, South Africa, South Korea, Spain, Sweden, Thailand, Tunisia, Ukraine, United Kingdom, and United States.

the previous year. If the R&D series starts in year t = 1 and the pre-sample accumulation of stock is given by Equation (11) with R&D growing at a fixed rate of g and the R&D expenditure flow in this year is equal to (1+g) times the R&D expenditure flow in previous year, then the R&D expenditure stock at the beginning of the first year is defined by the following equation:

$$R_1 = E_0 + (1 - \theta)E_{-1} + (1 - \theta)^2 E_{-2} + \cdots$$

$$= \sum_{w=0}^{\infty} E_{-w}(1 - \theta)^w$$

$$= E_0 \sum_{w=0}^{\infty} \left[\frac{1 - \theta}{1 + g}\right]^w \text{, since } E_{w-1} = \frac{1}{1 + g} E_w$$

$$= \frac{E_1}{g + \theta} \text{ ,} \tag{12}$$

The depreciation rate of R&D expenditure assumes 15 percent (Hall and Mairesse, 1995; Mairesse and Hall, 1996). Moreover, the growth rate is set to be an individual nation's average annual rate of growth of E_t (Guellec and van Pottelsberghe de la Potterie, 2004).

The three outputs included patents, royalties and licensing fees (RLF), and scientific and technical journal articles. We adopted the number of patent application by inventor's country of residence. RLF represents authorized use of intangible, nonproduced, nonfinancial assets and proprietary right and they are one of the commercial outputs for a nation's R&D activities. Scientific and technical journal articles include a variety of categories such as physics, biology, chemistry, mathematics, clinical medicine, biomedical research, engineering and technology, earth and space sciences. Table 2 displays the summary statistics of two inputs and three outputs.

Table 2

Summary statistics of inputs and outputs

	Name	Mean	SD	Max	Min
Input variables					
x^1	Total R&D manpower [a] (per thousand people)	180.56	338.89	1965.36	0.48
x^2	R&D expenditure stocks [b] (million US$ in year 2005)	87510.30	270485.39	1737927.36	6.42
Output variables					
y^1	Patents [b]	21467.17	65059.69	384201.00	1.00
y^2	Scientific journal articles [b]	14311.18	32825.59	212883.00	5.90
y^3	Royalties and licensing fees [b] (million US$ in year 2005)	2803.91	10234.46	83450.48	0.004

Source: [a] United Nations Educational, Scientific and Cultural Organization. [b] World Bank: World Development Indicators database.

3.3 Variable description of efficiency model

The determinants that we use are governance variables taken from the six governance indicators developed by Kaufmann et al. (2010). The governance index ranges from -2.5 to +2.5, which -2.5 means the poorest and +2.5 means the excellent performance. They drew together data covering over 200 countries since 1996, and classify them into six broad dimensions of governance described as follows.

'Voice and Accountability' (VA) captures perceptions of the extent to which a country's citizens are able to participate in selecting their government, as well as freedom of expression, freedom of association, and a free media. This indicator relate to the degree of democratization. The data sources also include the transparency of government policy making, public action in the economic field as well as economic policy.

'Political Stability and Absence of Violence' (PS) measures perceptions of the likelihood that the government will be destabilized or overthrown by unconstitutional or violent means,

including politically-motivated violence and terrorism. The main concept of this index is on a nation's social unrest and internal or external conflict.

'Government Effectiveness' (GE) captures perceptions of the quality of public services, the quality of the civil service and the degree of its independence from political pressures, and the credibility of the government's commitment to such policies. This index measure the ability that government could produce good policy and how satisfaction to the outcome of effort.

'Regulatory Quality' (RQ) captures perceptions of the ability of the government to formulate and implement sound policies and regulations that permit and promote private sector development. It includes measures of unfair market mechanism such as price control, trade barriers, well function of financial institution, and whether individuals are easy to start a business.

'Rule of Law' (RL) captures perceptions of the extent to which agents have confidence in and abide by the rules of society, and in particular the quality of contract enforcement, property rights, the police, and the courts, as well as the likelihood of crime and violence. For the economic and social interactions, this index measure how the government is well enough to unsure excellent in judicial system, police services, combating violence, and importantly, the extent that property rights are protected.

'Control of Corruption' (CO) captures perceptions of the extent to which public power is exercised for private gain, including both petty and grand forms of corruption, as well as capture of the state by elites and private interests. It measures different kind of binary such as trade, utilities and procurement.

In addition to the six indicators, we group the governance indicators into three dimensions. There are 'Selection of the Authority' (SAU) which measured by the mean of 'Voice and Accountability' (VA) and 'Political Stability and Absence of Violence' (PS), 'Government Action' (GAC) which measured by the mean of 'Government Effectiveness' (GE) and 'Regulatory Quality' (RQ), 'Respect for Institutional Framework' (RIN) which measured by

the mean of 'Rule of Law' (RL) and 'Control of Corruption' (CO). Table 3 shows the statistics and brief definitions of all described variables.

Table 3

Definitions and source of main variables in the efficiency model

Variable	Definitions	Mean	SD
VA	Index of 'Voice and Accountability'	0.77	0.76
PS	Index of 'Political Stability and Absence of Violence'	0.51	0.72
GE	Index of 'Government Effectiveness'	0.92	0.85
RQ	Index of 'Regulatory Quality'	0.89	0.74
RL	Index of 'Rule of Law'	0.76	0.90
CO	Index of 'Control of Corruption'	0.80	1.01
SAU	Selection of the authority, measured by the mean value of VA and PS	0.64	0.69
GAC	Government action, measured by the mean value of GE and RQ	0.91	0.78
RIN	Respect for institutional framework, measured by the mean value of RL and CO	0.78	0.94

Notes: Index ranges from -2.5 to +2.5. The higher score means the better performance.

4. Empirical Result

4.1 Estimation results of distance function

From Tables 4 to 7, this study displays the results of distance function and the efficiency model. Concerning for the fitness of distance function, we do the LR test to judge whether translog functional form is more suitable than Cobb-Douglas form. Due to all the test statics[2] from Model 1 to 10 is quite larger than critical value 23.209 ($\chi^2_{10, 0.01}$), the null hypothesis that the distance function is Cobb-Douglas form could be rejected. Note that almost all the square terms and interaction terms of inputs and outputs in the distance function are significant, also implying that translog functional form[3] is adequate in this study.

All the σ^2 and γ parameters in each model are significant, implying that the sum of the variance of the error component and the ratio of the variance of u_{nt} to error component are substantial. It suggests that the random variables of v_{nt} and u_{nt} should be considered in the R&D efficiency evaluation. Besides, high coefficient of γ means the variance of technical inefficiency is the main source of total variance for technical inefficiency and random noises.

Due to using the specific output dealing with multiple outputs in estimating, we are curious about whether different y_{nt}^H shown in equation (7) will influence the efficiency scores or not. There are three outputs in the study, so y_{nt}^H may be patents, scientific journal articles, and RLF. If the choice of y_{nt}^H causes different results of efficiency scores, then biased estimation will occur. In view of this, testing whether different y_{nt}^H will cause different results is necessary before discussing the estimated efficiency score. Utilizing Kruskal-Wallis test, we find that all test statistics during the sampling period are far smaller than critical value in

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[2] The test statics from model 1 to model 10 are 291.6660, 267.8861, 278.7963, 288.81059, 300.4463, 301.3283, 280.5699, 285.2410, 300.2511 and 277.8885 individually. All of them are much larger than the critical value 23.209 ($\chi^2_{10, 0.01}$).

[3] Coelli et al. (2005) indicated that translog functional form is usually preferable in the literature.

Table 8. Consequently, there are no differences between y_{nt}^H when estimating efficiency scores.

4.2 Estimation results of efficiency function

This study adopt one-step model to estimate the distance and efficiency function simultaneously. As shown from Tables 4 to 6, this study first examines the influence of six governance indexes on efficiency respectively. In order to understand governance more complete and comprehensive, three governance dimensions are run independently and then all together which be shown in Table 7.

As Models 1 and 2 show in Table 4, both of VA and PS are positively significant coefficients, implying that the dimension of selection of the authority have positive effect on national R&D efficiency. If countries are not only democratic, but also express few limitations on expression, association, and media, it will improve national R&D efficiency. Whether the public actions in the economic fields are transparent enough also positively influence R&D efficiency. The results consist with the concept that economic freedom promotes aggregate efficiency. And this result is described in Section 2. On the other hand, the more stability on political situation or the less conflicts on ethnicity, religion, and vexed issues, the higher R&D efficiency will be.

From the results of Models 3 and 4 are shown in Table 5, both GE and RQ show positive and significant coefficients, suggesting that the dimension of government action have positive influence on countries' R&D efficiency. The more effective on government, such as high quality of public service, policy formulation and implementation, the higher R&D efficiency will be performed. Responding to Section 2, bureaucracy may causes influences on R&D efficiency, and further, this study proves that it will causes negative effect on R&D efficiency. The other dimension of government action, the regulatory quality, will also improves national

Table 4

The result of one-step model for distance and efficiency function - the dimension of Selection of the Authority

Variables	Model (1) VA		Model (2) PS	
	Coefficients	S.E.	Coefficients	S.E.
Distance function				
constant	-2.6169***	0.4107	-2.4170***	0.3831
$\ln \hat{\mathbf{y}}^1$	0.0202	0.1303	0.1012	0.1258
$\ln \hat{\mathbf{y}}^2$	0.8563***	0.1432	0.7472***	0.1361
$\ln \hat{\mathbf{y}}^1 \ln \hat{\mathbf{y}}^1$	0.1031***	0.0277	0.0814***	0.0280
$\ln \hat{\mathbf{y}}^1 \ln \hat{\mathbf{y}}^2$	-0.0793***	0.0236	-0.0666***	0.0236
$\ln \hat{\mathbf{y}}^2 \ln \hat{\mathbf{y}}^2$	0.1169***	0.0288	0.1133***	0.0286
$\ln \hat{\mathbf{x}}^1$	-0.6143***	0.1902	-0.5582***	0.1753
$\ln \hat{\mathbf{x}}^2$	-0.4880***	0.1643	-0.5254***	0.1541
$\ln \hat{\mathbf{x}}^1 \ln \hat{\mathbf{x}}^1$	0.1908***	0.0486	0.1679***	0.0482
$\ln \hat{\mathbf{x}}^1 \ln \hat{\mathbf{x}}^2$	-0.1330***	0.0374	-0.1243***	0.0360
$\ln \hat{\mathbf{x}}^2 \ln \hat{\mathbf{x}}^2$	0.1037***	0.0333	0.0999***	0.0321
$\ln \hat{\mathbf{y}}^1 \ln \mathbf{x}^1$	-0.1165***	0.0419	-0.0524	0.0401
$\ln \hat{\mathbf{y}}^1 \ln \mathbf{x}^2$	0.0646**	0.0265	0.0313	0.0249
$\ln \hat{\mathbf{y}}^2 \ln \mathbf{x}^1$	0.1680***	0.0417	0.1095***	0.0397
$\ln \hat{\mathbf{y}}^2 \ln \mathbf{x}^2$	-0.0923***	0.0277	-0.0586**	0.0256
Efficiency Function				
Constant	-0.4542***	0.1466	-0.1132	0.2523
Governance variable	0.4150***	0.0792	0.4318***	0.1234
σ^2	0.2393***	0.0607	0.3225***	0.1050
Γ	0.9437***	0.0292	0.9497***	0.0268
Log-likelihood	-93.7372		-100.5689	

Notes: *significance at 10%; **significance at 5%; ***significance at 1%. The results of the distance function were estimated by using RLF as y_{nt}^H. Number of observations = 369.

R&D efficiency, implying that price regulation and trade barriers are against R&D efficiency. Conversely, if the regulatory quality is beneficial to people, such as easy to starting business, mature regulation on anti monopoly, it will leads to positive impact on national R&D efficiency.

Table 5

The result of one-step model for distance and efficiency function - the dimension of Government Action

Variables	Model (3) GE		Model (4) RQ	
	Coefficients	S.E.	Coefficients	S.E.
Distance function				
constant	-2.9267***	0.4077	-7.6100***	0.4103
$\ln \hat{\mathbf{y}}^1$	-0.2001	0.1345	-0.1261	0.1273
$\ln \hat{\mathbf{y}}^2$	1.0456***	0.1493	1.0198***	0.1434
$\ln \hat{\mathbf{y}}^1 \ln \hat{\mathbf{y}}^1$	0.1065***	0.0271	0.0996***	0.0292
$\ln \hat{\mathbf{y}}^1 \ln \hat{\mathbf{y}}^2$	-0.0650***	0.0238	-0.0602**	0.0255
$\ln \hat{\mathbf{y}}^2 \ln \hat{\mathbf{y}}^2$	0.0853***	0.0295	0.0870***	0.0300
$\ln \hat{\mathbf{x}}^1$	-0.6100***	0.1929	-0.7454***	0.1831
$\ln \hat{\mathbf{x}}^2$	-0.4747***	0.1639	-0.3380**	0.1619
$\ln \hat{\mathbf{x}}^1 \ln \hat{\mathbf{x}}^1$	0.2329***	0.0500	0.1883***	0.0478
$\ln \hat{\mathbf{x}}^1 \ln \hat{\mathbf{x}}^2$	-0.1580***	0.0378	-0.1181***	0.0369
$\ln \hat{\mathbf{x}}^2 \ln \hat{\mathbf{x}}^2$	0.1191***	0.0331	0.0830**	0.0329
$\ln \hat{\mathbf{y}}^1 \ln \mathbf{x}^1$	-0.1434***	0.0390	-0.1308***	0.0390
$\ln \hat{\mathbf{y}}^1 \ln \mathbf{x}^2$	0.0925***	0.0252	0.0803***	0.0247
$\ln \hat{\mathbf{y}}^2 \ln \mathbf{x}^1$	0.1901***	0.0398	0.1812***	0.0395
$\ln \hat{\mathbf{y}}^2 \ln \mathbf{x}^2$	-0.1126***	0.0268	-0.1118***	0.0261
Efficiency Function				
Constant	-0.6722***	0.1014	-0.7155***	0.0900
Governance variable	0.5128***	0.0800	0.4669***	0.0701
σ^2	0.2107***	0.0393	0.1758***	0.0357
γ	0.9479***	0.0296	0.9327***	0.0362
Log-likelihood	-81.7119		-78.9796	

Notes: *significance at 10%; **significance at 5%; ***significance at 1%. The results of the distance function were estimated by using RLF as y_{nt}^H. Number of observations = 369.

The last dimension is shown in Models 5 and 6. Both coefficients of RL and CO are also positively significant. The results infer that greater respect for institutional framework can improve R&D efficiency. Namely, the more confidence in social rules for every citizens, the better performance in national R&D efficiency will be. Besides, if the corruptions are appropriately

Table 6

The result of one-step model for distance and efficiency function - the dimension of Respect for Institutional Framework

Variables	Model (5) RL		Model (6) CO	
	Coefficients	S.E.	Coefficients	S.E.
Distance function				
constant	-2.8209***	0.3970	-2.5738***	0.4030
$\ln \hat{\mathbf{y}}^1$	-0.1242	0.1289	-0.1314	0.1377
$\ln \hat{\mathbf{y}}^2$	0.9976***	0.1439	0.9784***	0.1521
$\ln \hat{\mathbf{y}}^1 \ln \hat{\mathbf{y}}^1$	0.1182***	0.0262	0.1070***	0.0275
$\ln \hat{\mathbf{y}}^1 \ln \hat{\mathbf{y}}^2$	-0.0793***	0.0226	-0.0718***	0.0240
$\ln \hat{\mathbf{y}}^2 \ln \hat{\mathbf{y}}^2$	0.1044***	0.0284	0.0975***	0.0299
$\ln \hat{\mathbf{x}}^1$	-0.5980***	0.1858	-0.4972***	0.1928
$\ln \hat{\mathbf{x}}^2$	-0.4988***	0.1604	-0.6029***	0.1629
$\ln \hat{\mathbf{x}}^1 \ln \hat{\mathbf{x}}^1$	0.2235***	0.0473	0.2470***	0.0493
$\ln \hat{\mathbf{x}}^1 \ln \hat{\mathbf{x}}^2$	-0.1556***	0.0365	-0.1787***	0.0375
$\ln \hat{\mathbf{x}}^2 \ln \hat{\mathbf{x}}^2$	0.1208***	0.0325	0.1429***	0.0329
$\ln \hat{\mathbf{y}}^1 \ln \mathbf{x}^1$	-0.1406***	0.0381	-0.1323***	0.0397
$\ln \hat{\mathbf{y}}^1 \ln \mathbf{x}^2$	0.0855***	0.0246	0.0824***	0.0260
$\ln \hat{\mathbf{y}}^2 \ln \mathbf{x}^1$	0.1910***	0.0385	0.1827***	0.0402
$\ln \hat{\mathbf{y}}^2 \ln \mathbf{x}^2$	-0.1117***	0.0259	-0.1037***	0.0272
Efficiency Function				
Constant	-0.5694***	0.0947	-0.4961***	0.1166
Governance variable	0.4509***	0.0679	0.4677***	0.0829
σ^2	0.2003***	0.0376	0.2313***	0.0467
γ	0.9492***	0.0295	0.9508***	0.0295
Log-likelihood	-77.8541		-83.4505	

Notes: *significance at 10%; **significance at 5%; ***significance at 1%. The results of the distance function were estimated by using RLF as y_{nt}^H. Number of observations = 369.

controlled, then it will improve national R&D efficiency. This result supports the concept that corruption is harmful to R&D activities.

After examining six governance indexes respectively, this study further uses the classification from Kaufmann et al. (2010) and groups them into three dimensions, SAU, GAC and RIN. In Table 7, the results show that all coefficients of three variables respectively display positive and significant.

As the result shows in the three variables continue to be put together. SAU, GAC and RIN still have positive coefficients but GAC is the only one significant. Reviewing the results from Tables 4 to 6, all governance indexes significantly influence national R&D efficiency. In Table 5, the magnitude of coefficient show that GE's coefficient which is 0.5128 is larger than the other five indexes. In Table 7, GAC's coefficient which is 0.5134 is also larger than the other two indexes. The magnitude infers that the government action especially GE plays an important role in promoting R&D efficiency.
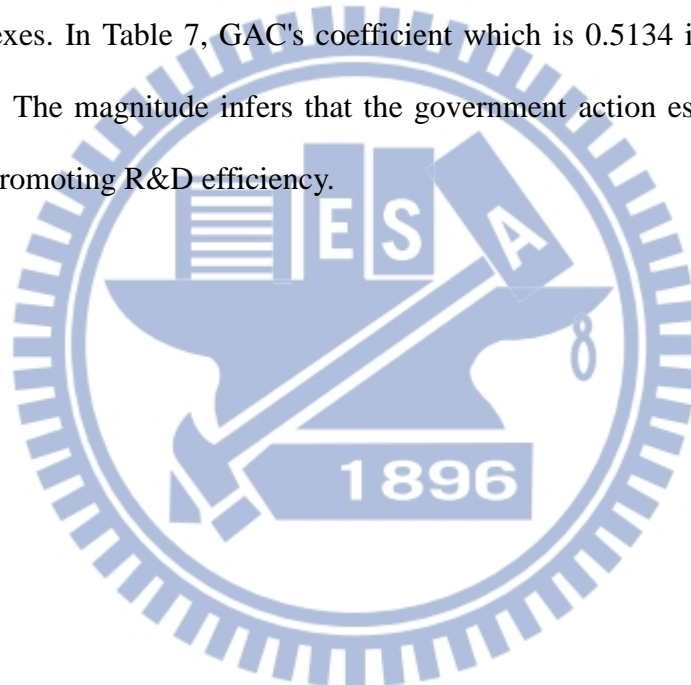
Table 7

The result of one-step model for distance function and efficiency function - three governance dimensions

	Model (7)	Model (8)	Model (9)	Model (10)
Variables	Coefficient	Coefficient	Coefficient	Coefficient
Distance function				
constant	-2.6398***	-3.0805***	-2.7291***	-2.9846***
	(0.4172)	(0.4037)	(0.3967)	(0.4146)
$\ln \hat{\mathbf{y}}^1$	0.0102	-0.1849	-0.1446	-0.1801***
	(0.1343)	(0.1286)	(0.1310)	(0.1286)
$\ln \hat{\mathbf{y}}^2$	0.8580***	1.0566***	1.0044***	1.0476***
	(0.1469)	(0.1445)	(0.1461)	(0.1445)
$\ln \hat{\mathbf{y}}^1 \ln \hat{\mathbf{y}}^1$	0.0889***	0.1034***	0.1122***	0.1051***
	(0.0284)	(0.0279)	(0.0269)	(0.0284)
$\ln \hat{\mathbf{y}}^1 \ln \hat{\mathbf{y}}^2$	-0.0652***	-0.0611***	-0.0744***	-0.0641***
	(0.0249)	(0.0242)	(0.0234)	(0.0247)
$\ln \hat{\mathbf{y}}^2 \ln \hat{\mathbf{y}}^2$	0.1044***	0.0832***	0.0988***	0.0869***
	(0.0299)	(0.0292)	(0.0290)	(0.0295)
$\ln \hat{\mathbf{x}}^1$	-0.6562***	-0.6989***	-0.5579***	-0.6636***
	(0.1927)	(0.1855)	(0.1879)	(0.1943)
$\ln \hat{\mathbf{x}}^2$	-0.4658***	-0.3923**	-0.5447***	-0.4367***
	(0.1665)	(0.1603)	(0.1605)	(0.1686)
$\ln \hat{\mathbf{x}}^1 \ln \hat{\mathbf{x}}^1$	0.1495***	0.2061***	0.2347***	0.2107***
	(0.0554)	(0.0490)	(0.0487)	(0.0551)
$\ln \hat{\mathbf{x}}^1 \ln \hat{\mathbf{x}}^2$	-0.1135***	-0.1356***	-0.1671***	-0.1438***
	(0.0401)	(0.0371)	(0.0370)	(0.0407)
$\ln \hat{\mathbf{x}}^2 \ln \hat{\mathbf{x}}^2$	0.0945***	0.0998***	0.1322***	0.1097***
	(0.0343)	(0.0326)	(0.0325)	(0.0350)
$\ln \hat{\mathbf{y}}^1 \ln \mathbf{x}^1$	-0.0919**	-0.1417***	-0.1404***	-0.1426***
	(0.0416)	(0.0388)	(0.0385)	(0.0389)
$\ln \hat{\mathbf{y}}^1 \ln \mathbf{x}^2$	0.0550**	0.0900***	0.0870***	0.0904***
	(0.0265)	(0.0247)	(0.0249)	(0.0247)
$\ln \hat{\mathbf{y}}^2 \ln \mathbf{x}^1$	0.1487***	0.1907***	0.1908***	0.1923***
	(0.0416)	(0.0398)	(0.0392)	(0.0398)
$\ln \hat{\mathbf{y}}^2 \ln \mathbf{x}^2$	-0.0841***	-0.1161***	-0.1106***	-0.1156***
	(0.0277)	(0.0263)	(0.0263)	(0.0263)
Efficiency function				
constant	-0.4627***	-0.7262***	-0.5581***	-0.6864***
	(0.1400)	(0.0890)	(0.0992)	(0.1017)
SAU	0.4875***			0.0238
	(0.0916)			(0.1031)
GAC		0.5134***		0.3255**
		(0.0753)		(0.1648)
RIN			0.4731***	0.1666
			(0.0751)	(0.1569)
σ^2	0.2264***	0.1874***	0.2093***	0.1902***
	(0.0559)	(0.0348)	(0.0392)	(0.0356)
γ	0.9319***	0.9387***	0.9476***	0.9387***
	(0.0362)	(0.0338)	(0.0313)	(0.0359)
Log-likelihood	-92.6155	-77.9529	-79.1361	-77.1731

Notes: *significance at 10%; **significance at 5%; ***significance at 1%. The result of the distance function were estimated by using RLF as y_{nt}^H. Number of observations = 369. Standard error in parentheses.

Table 8

Result of the Kruskal-Wallis test

Year	1998	2000	2002	2003	2004	2005	2006	2007	2008
Test statistics	0.002	0.003	0.000	0.002	0.002	0.002	0.001	0.001	0.011
Null hypothesis	Accept	Accept	Accept	Accept	Accept	Accept	Accept	Accept	Accept

Notes: The null hypothesis is that there is no difference between y_{nt}^{H} when estimating efficiency scores. The critical value of the χ^2 distribution with d.f. 2 is 5.991 at 5% level.

4.3 The result of national R&D efficiency

After exploring the governance indexes, this study further classifies efficiency scores into two groups and five regions which reported on table 9. On the top part of the table, the efficiency scores of OECD members are much larger than non-OECD members. For each groups, the average efficiency scores are 0.7456 and 0.4973 separately. In Figure 2, the difference between two groups in 1998 is slightly lower than 0.2. Except for first year, all differences between OECD and non-OECD members are between 0.2148 and 0.2758. The average difference during the period is 0.2483.

Table 9

National R&D efficiency across groups and regions

	1998	2000	2002	2003	2004	2005	2006	2007	2008	Ave.
Groups										
OECD	0.7541	0.7565	0.7526	0.7212	0.7424	0.7413	0.7486	0.7559	0.7375	0.7456
Non-OECD	0.5590	0.4953	0.5130	0.4943	0.4781	0.4654	0.4737	0.4738	0.5227	0.4973
Regions										
Africa	--	0.3905	0.2671	0.3136	0.2818	0.3683	0.1633	0.4390	--	0.3177
America	0.7038	0.6793	0.6599	0.6025	0.5536	0.5884	0.5970	0.6148	0.6169	0.6240
Asia	0.6067	0.5891	0.5857	0.5363	0.5965	0.5381	0.6254	0.5234	0.6224	0.5804
Europe	0.6998	0.6968	0.6975	0.6685	0.6785	0.6730	0.6623	0.6770	0.6575	0.6790
Oceania	0.9145	0.8995	0.8239	0.9347	0.8285	0.9328	0.8149	0.9267	0.8109	0.8763

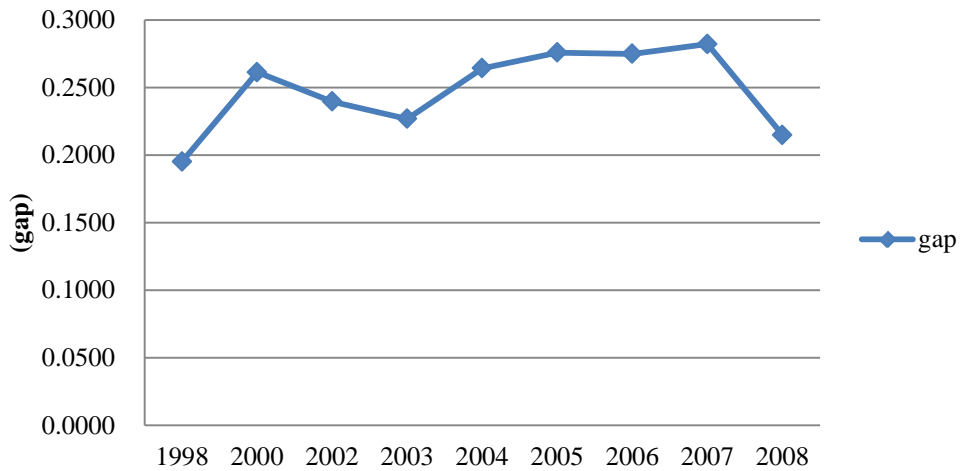*Notes:* Because of unbalanced panel data, there are two missing values in Africa.

Figure 2 Gaps in average efficiency score between OECD and Non-OECD members

From a regional perspective, it can be observed that Oceania gets the highest efficiency score and Africa gets the lowest one whose averages are 0.8763 and 0.3177 respectively. Europe and America particularly have not too much different on average efficiency scores and Asia's average efficiency score is a bit lower than the two regions. The gap in average efficiency score between Europe and America is only 0.055. For the last five years, the gaps are decreasing from 0.1249 to 0.0407, and the figure of decreasing tendency is shown below.
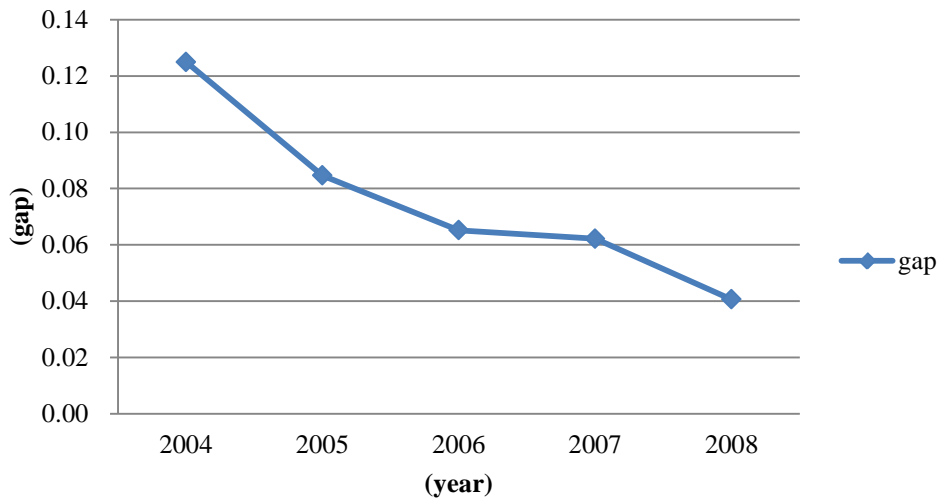

Figure 3 Gaps in average efficiency score between Europe and America

From each countries point of view, the efficiency scores and total ranks are shown in table 10. Ranking by scores, Chile, Ireland, and New Zealand are the top three countries in all of 59 countries. All their efficiency scores are above 0.93. Contrary to those countries, Philippines, Ukraine and Morocco are the last three countries. All their efficiency scores are below 0.22. The average difference of the efficiency score between top and last three countries is up to 0.79.

Table 10

National R&D efficiency and ranking

Nations	Mean	Rank	Nations	Mean	Rank
Argentina	0.4946	37	Macedonia, FYR	0.4419	42
Australia	0.8467	12	Madagascar	0.2635	56
Austria	0.6945	23	Malaysia	0.3822	49
Belgium	0.7477	21	Malta	0.9025	4
Bosnia and Herze	0.4740	39	Mexico	0.4182	45
Brazil	0.3967	48	Moldova	0.4282	44
Bulgaria	0.6484	28	Morocco	0.1633	59
Canada	0.7504	20	Netherlands	0.8889	6
Chile	0.9559	1	New Zealand	0.9314	3
China	0.4790	38	Norway	0.7742	18
Croatia	0.6648	24	Pakistan	0.3367	53
Cyprus	0.8586	11	Paraguay	0.4714	40
Czech Republic	0.6518	26	Philippines	0.2173	57
Estonia	0.7633	19	Poland	0.7949	16
Ethiopia	0.4513	41	Portugal	0.6312	30
Finland	0.6423	29	Romania	0.4062	46
France	0.5598	34	Russia	0.3494	50
Germany	0.6201	32	Singapore	0.8316	14
Greece	0.8653	10	Slovak Republic	0.5438	35
Guatemala	0.2972	55	Slovenia	0.7751	17
Hungary	0.8370	13	South Africa	0.6174	33
Iceland	0.6628	25	South Korea	0.8260	15
India	0.6282	31	Spain	0.7406	22
Ireland	0.9357	2	Sweden	0.8857	7
Italy	0.8746	9	Thailand	0.3976	47
Japan	0.6500	27	Tunisia	0.3493	51
Kenya	0.4390	43	Ukraine	0.2026	58
Latvia	0.3166	54	United Kingdom	0.8847	8
Lithuania	0.5061	36	United States	0.8935	5
Luxembourg	0.3438	52			

Notes: The observation periods are 1998, 2000, 2002–2008 and the scores are estimated from Table 8.

Figures 3 to 6 post the comparison between top and last three countries, and all nations' mean for six governance indexes. Exploring the top and last three countries' governance indexes, Chile, Ireland and New Zealand are much higher than total mean[4] , but Philippines, Ukraine and Morocco are completely not the case. The results show no exceptions among the six indexes. On average, we observe that nations with better governance also get higher efficiency scores.
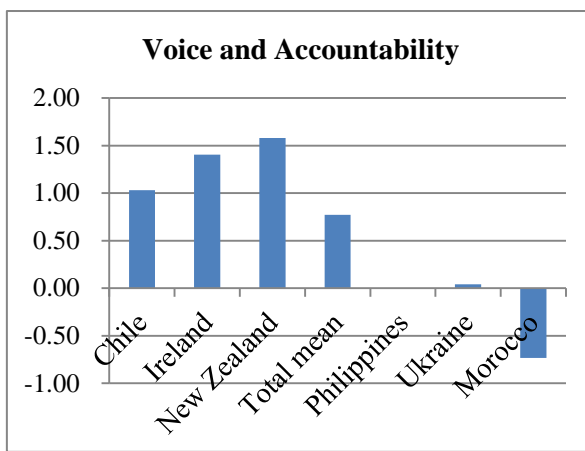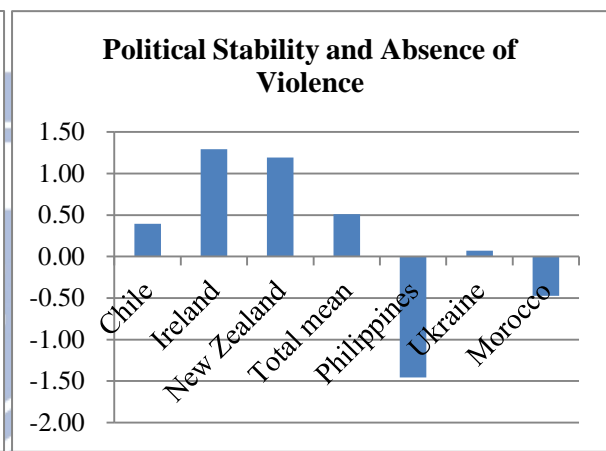
Voice and Accountability

Figure 4 Governance index of VA

Political Stability and Absence of Violence

Figure 5 Governance index of PS

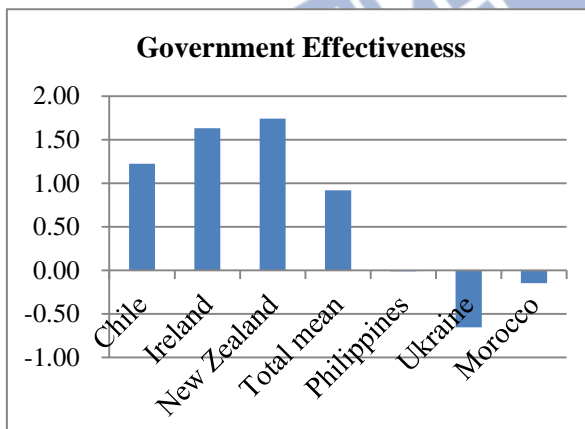### Government Effectiveness

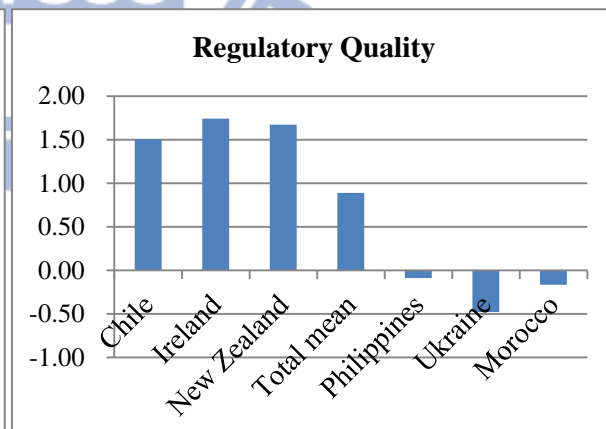Figure 6 Governance index of GE

Regulatory Quality

Figure 7 Governance index of RQ

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[4] Table 3 shows the descriptive statistics of total mean calculated from 59 countries.
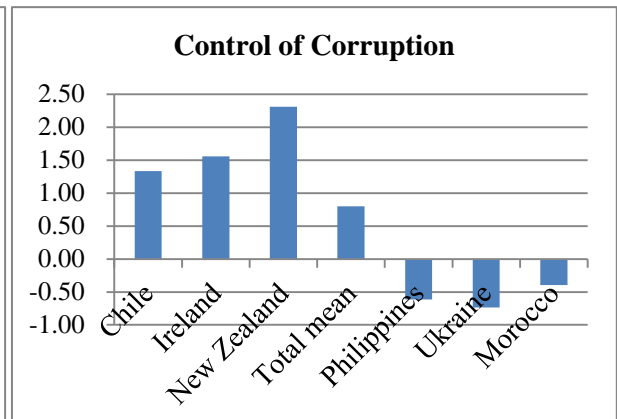
Figure 8 Governance index of RL	Figure 9 Governance index of CO

From Models 1 to 6, we observe that six governance indexes increase national R&D efficiency. Taking governance indexes into account, we further find the countries which got high R&D efficiency scores also have high governance indexes. The results indicate the importance of public governance. And the results also manifest that it is essential to improve countries' public governance if they get lower R&D efficiency scores.
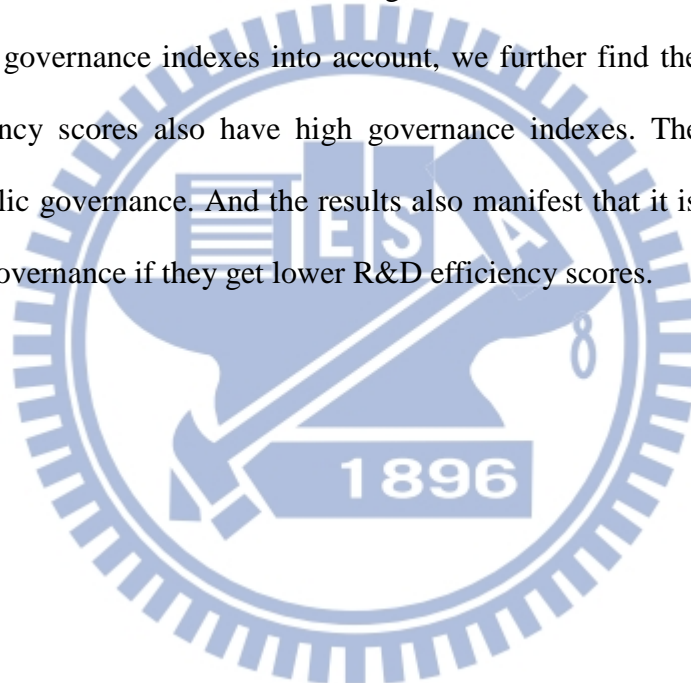
5. Conclusions and policy implications

Numerous studies had showed that R&D efficiency indeed improved the economic growth. In viewing of this, finding the factors which can promote R&D efficiency become a critical issue. Concerning the public governance, so far, most of prior studies focused on single policy. However, public governance contains many aspects. It may give the partial views if we just exam the single policy. Therefore, this study aims at government administration and uses six governance indicators developed by Kaufman et al. (2010), providing a comprehensive analysis between the public governance and national R&D efficiency.

This study adopts SFA approach and one-step model, estimating the parameters of distance function and efficiency function simultaneously. Through LR test, we show that translog specification is more suitable than Cobb-Douglas function form. Through Kruskal–Wallis test, we provide the evidence that there is no difference if we regard any of the three outputs as y_{nt}^H.

The empirical results show that six governance indexes all have positive influences on R&D efficiency. In the dimension of 'selection of the authority', VA and PS increase the R&D efficiency. VA mainly measures the level of economic freedom and democracy. If economic policies which include fiscal, taxation, exchange rate are transparent enough, investor will increase the motive on R&D activities because of the friendly aggregate environment. Democracy and science are mutually reinforcing. Science can survive only if it is free economy. It will not only add creativity but the imagination of democracy (Shiv, 1998). For PS, if political situation is stable enough, the staffs who want to dedicate to R&D activities could face fewer future uncertainties which result from political turbulence. It is also the cause that staffs will take PS into consideration when doing the R&D activities.

'Government action' which contains GE and RQ will all increase the R&D efficiency. Besides, GE especially plays the most important role among the six indexes. This suggests

that putting emphasis on the quality of public services, the quality of civil services, and the credibility of government's commitment will increase much more R&D efficiency. In order to improve R&D efficiency, this result give a direction that we can pay more attention on GE. For RQ, according to the definition, to enhance regulatory quality is beneficial to the development of private sector. If private sector is prosperous, it will trigger R&D activities much easily.

The last dimension, 'respect for institutional framework'. Including RL and CO, increases the R&D efficiency likewise. If countries have a sound judicial system, it will help the interaction of social and economic. And the interaction is under people's trust and obedience to the social rules. A sound judicial also covers the laws related to R&D. Under the protection of the laws, it can encourage more staffs to do R&D activities. For CO, as above mentioned, control of corruption positively related to foreign direct investment. Considering the effect of knowledge spillover, from our empirical results, if the corruption is better controlled, it can induce more R&D efficiency. The result is consistent with the statement that corrupt is not beneficial to innovation (Mareco, 2008).

Observing nations' efficiency scores by groups, OECD members are quite higher than Non-OECD members. Classifying countries into five regions, Oceania get the highest score and Africa gets the lowest one. Europe and America get almost the same scores whose average difference is only 0.055. Asia gets fourth place among five regions whose efficiency score is 0.5804.

Comparing efficiency scores by nations, Chile, Ireland, and New Zealand are the top three countries that the efficiency scores are above 0.93. However, Philippines, Ukraine and Morocco are the last three countries that the efficiency scores are below 0.22. We further observe that top three countries' governance indexes are appreciably higher than total mean; nevertheless, the last three countries' indexes are all lower than total mean. It infers that good governance will have positive effects on national R&D efficiency. And it conveys the same

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concept to the results of models 1 to 6, highlighting the importance of public governance once again.

For an effective promotion of democracy, socio-economic development must be a central component (Julian and Franziska, 2009). In the socio-economic development, R&D activities are prerequisites in the era of competition and globalization. Through innovation, nations could unceasingly create new values which lead to economic growth. To increase the R&D efficiency, government should improve the public governance. Each index that mentioned in this study are the right direction to work for. Government should make a self-examination whether there is still room for improvement from every aspects. The government effectiveness is the most important factor in this study. For improving R&D efficiency, it is worth spending more attention on GE.

At the empirical level, we propose some aspects for future research. First, this study estimates the R&D efficiency and governance indexes from the view point of overall nations. It should be interesting to take deeply analysis by individual countries. As a result, policymakers could further understand the weaknesses through the comparison of each nation. Second, utilizing unbalanced panel data, this study collects 59 countries. In fact, some regions just include few nations. For example, Oceania includes two nations and Africa includes five nations. Complete analysis will be shown by adding more nations. Third, the inputs and outputs are dynamic process. It means the first year's inputs may not exactly reflect in the first year's outputs. If future studies could take objective time lag into consideration, the results will be closer to reality.

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