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Estimating Cross-country Technical Efficiency, Economic Performance and Institutions – A Stochastic Production Frontier Approach

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Estimating Cross-country Technical Efficiency, Economic Performance and Institutions – A Stochastic Production Frontier Approach

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Abstract: Growth measurement is a fundamental exercise to understand the source of economic growth. This paper suggests using the stochastic production frontier approach (SPF) to measure country-level technical efficiency for a better comparison of economic performances. The results show that there is a substantial difference in understanding cross-country technical efficiency and traditional total factor productivity growth measurement. By means of the SPF model, it also allows us to seek for the sources of technical efficiency. Institutional arrangements explain the sources of cross-country technical inefficiency. Among various measures of institutions, we find that the role of the State, political institution and openness to international trade are significant factors of global divergent economic performances.

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1 Introduction

The issue of how and how much institutional and governance structure relate to economic performance have been vastly studied by numerous theoretical and, especially, empirical works. Olson (1996) succinctly pointed out that institution is probably one of the most important factors in explaining the consistent growth divergence among countries.

His empirical findings show that not all poor economies grow faster than the rich ones as what the theory of convergence has predicted. Even worse than that, the gap in per capita incomes between the relatively poor and relatively rich countries has increased over time. Prichett (1997) estimates that the proportional gap in per-capita GDP between the richest and poorest countries has grown more than five-fold from 1870 to 1990. The proportional gap between the richest group of countries and the poorest grew from 3 in 1820 to 19 in 1998 (Maddison (2001)).

Over the last decade, research tends to focus on the effect of "institution" on economic growth. Institutional rigidities seem to explain the cruel reality: some poor economies simply cannot catch up with the rich ones.

Traditional growth theories emphasize the role of human capital (Lucas (1988)), technological diffusion (Barro and Sala-i-Martin (1997)), public infrastructure (Barro (1990)) or incentives to innovate (Romer (1990)) based on various theoretical and empirical grounds. All these determinants, however, shed no true light on the *source* of growth – they *are* growth (North 1997).

A better understanding of the source of growth may be efficiency. Countries are "inefficient" in the sense that there is a considerable discrepancy between private benefit and social benefit whenever an economic transaction occurs[1]. Due to a given institutional arrangement, undertaking an economic activity as such may be socially profitable, but individuals rationally will not do it if private cost exceeds private

[1] This discrepancy is caused and shaped by the institutional structure, especially when property rights are poorly defined (North and Thomas (1973)).

benefit. Hence, the gains from trade cannot be realized. In other words, there actually exists a Pareto optimal (more efficient) outcome, but it cannot be achieved. It is, thus, interesting to investigate the institutions that would bring this disparity closer.

In this paper, we claim that productivity measurement is a crucial measure of cross-country growth performance. We suggest that measuring cross-sectional technical efficiency rather than using standard growth measures (such as growth rate of GDP per capita) supports the aforementioned theoretical framework better. We adopt the stochastic production frontier approach to measure technical efficiency. Our results show that economic performance as expressed as technical efficiency (TE) is drastically different from that expressed in total factor productivity (TFP) growth.

We further emphasize the role of institutions as the explanatory factors of economic performance in this paper. We focus on three aspects of institutions that are most relevant to productivity: 1) economic institution provided by the State – measured in terms of the size of government, legal system and regulatory environment; 2) political institution – measured in terms of regime type, its durability and the political rights; 3) the role of international trade – openness to international trade and capital flow.

We find that all three aspects are important in explaining technical efficiency (TE) across countries. We also find that domestic economic and political institutions account TE more than whether the country is openness to trade and its capital flow. In other words, local governance matters more than whether an open economy strategy is adopted.

We divide our discussion in the following sections. In Section 2, we will present a brief literature review on growth empirics, institutions and economic performance. We describe our model and specification in Section 3. Section 4 details the data we used. Section 5 presents the same results and we conclude in Section 6.

2 Literature Review on Growth Empirics, Institutions and Economic Performance

2.1 Growth Models and Productivity Measurement

Neo-classical growth models have always been criticized that they failed to explain productivity growth and technological change. For example, Solow (1956) model assumes that technology is Harrod neutral which only affects the productivity of labour. It predicts that country's real GDP per capita growth negatively correlates with its initial level of income – the convergence hypothesis. Solow (1956), on the contrary, finds that capital accumulation explains only 1/8 and 1/4 of income growth. The rest is explained by productivity growth. Easterly and Levine (2001), based on AK growth model, suggest that 60% of growth is due to change in productivity rather than factor accumulation.

Endogenous growth theory, like Romer (1986; Lucas (1988), considers the effects of variables such as trade, human capital and endogenous technology on output growth, and the different mechanisms of technology diffusion. Limam and Miller (2004) argue that the sources of TFP growth may be different between developed and developing countries. In advanced countries, technological innovations provide the main source of TFP growth. Acquiring and absorbing foreign technology are the main sources in developing countries. In other words, a methodology allows us to decompose productivity and efficiency may prove helpful.

Our measurement is mostly derived from Fare, Grosskopf et al. (1994). Their work decomposes productivity into changes in efficiency (catching up) and changes in technology (innovation). Each country is compared to a frontier. How much a country getting closer to the "world frontier" is measuring the "catching up" effect; how much the world frontier shifts meaning "technical change" or "innovation".

Standard growth empirics, say, using growth rate of GDP per capita, are not sufficient to capture the productivity measurement. Temple (1999) realized that estimating stochastic production frontiers (SPF) may be a promising elaboration. This method allows us to decompose growth into input changes, efficiency change and technical progress. This research is innovative in deriving rates of productivity on a comparable basis for a wide range of countries. We describe the fundamentals of SPF in the next section.

2.2 Fundamentals of Stochastic Production Frontier

Stochastic production frontier (SPF) is a measurement of production frontier across cross-sections while incorporating stochastic assumptions. It uses a mixture of one-sided and/or two-sided (e.g. normal) errors. The error term is composed of two parts. A one-sided component captures the effects of inefficiency relative to the stochastic frontier. A two-sided component permits random variation of the frontier across cross-sections, and captures the effects of measurement error, other statistical 'noise', and random shocks outside the cross-sections' control.

Thus, given quantities of inputs, there is a maximal output possible, but this maximal level is random (to be precise, which is randomly distributed as a function) rather than exact. This assumes that some inputs or external effects have maximal possible effects, but others have potentially unbounded effects, e.g. weather. Stochastic frontier expresses maximal output, given some set of inputs, as a distribution (typically normal) rather than a point[2].

Based on Fare, Grosskopf et al. (1994)'s definition of productivity, we will measure the economic performance of each country relative to the world best possible output, given the available resources and technology at a particular time period. This comparative measurement of economic performance against the world production frontier is technical efficiency.

2.2.1 Basic SPF Model

The production function can be specified in a general form as follows:

[2] Compared to deterministic frontiers, which ignore the stochastic effect on production frontier, but they are more consistent with economic theory. The chief advantage of deterministic frontier seems clearly to be the availability of a measure of exact technical inefficiency for each observation instead of a distribution. However, their major disadvantage is that they are bound to be confounded by statistical 'noise', whereas stochastic frontiers are more realistic, which take statistical 'noise' into account.

$$y_i = a_i f(x_i;\beta) \qquad\qquad 0 < a_i \le 1 \qquad (2.2.1)$$

where i denotes i-th cross-section; y denotes the unit of output; x is a (1 x k) vector as known functions of inputs of production and other explanatory variables; β is a vector of technology parameters to be estimated.

Rewrite (2.2.1) in log-form:

$$\ln y_i = \ln f(x_i;\beta) - u_i \qquad (2.2.2)$$

where $u_i = -\ln a_i \ge 0$ represents technical inefficiency.

Following Aigner, Lovell et al. (1977) and Meeusen and Broeck (1977), the stochastic production frontier function (thereafter abbreviated as SPF) can be extended as:

$$y_i = f(x_i;\beta)\exp(v_i - u_i) \qquad (2.2.3)$$

Assume $v \sim iid\ N(0,\sigma_v^2)$ which is a stochastic error independently distributed of u. It accounts for the measurement such as the effects of weather, strikes, luck etc, on the value of the output variable together with the combined effects of unspecified input variables in the production function. It is simply treated as random disturbances.

u is assumed to be a non-negative random variables associated with technical inefficiency of production and is independently distributed. Therefore, u is assumed to have a particular distribution and truncate it at ≤ 0[3].

In short, we can interpret the above as follows: if $u_i = 0$, then ε (sum of 2-sided errors, u+v) = v, the error term is symmetric, and the data do not support a technical inefficiency story. However, if u > 0, then ε = v – u is negatively skewed, and there is evidence of technical inefficiency in the data. In other words, the production process is subject to 2 random disturbances, namely u and v.

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[3] Among numerous cross-sectional models on SPF, there are few specifications of u commonly used. Aigner, Lovell et al. (1977) and Meeusen and Broeck (1977) assume $u_i \sim iid\ N^+(0,\sigma_u^2)$.

Since it is assumed that $u_i \geq 0$, it implies for each cross section, its output must lie on or below its frontier $[f(x_i;\beta)+v_i]$. Any deviation implies technical and economic inefficiency. Therefore, the frontier is stochastic with random disturbance $v_i \leq or \geq 0$. Technically speaking, we can estimate the variances of v_i, u_i for each cross-section.

We realize that SPF is not a perfect methodology and encounters several shortcomings. As Førsund, Lovell and Schmidt (1980) mentioned, although this technique captures a more realistic world, unfortunately there is no way to determine whether the observed performance of a particular observation is due to inefficiency or to random variation in the frontier. What we are estimating is simply the mean inefficiency over the sample, but not its "true" value.

Besides, as Coelli, Rao et al. (1998) realized, using SPF approach, the specification of the functional form for the production function matters for the results. In other words, different specification of the functional form will alter the results[4]. Not surprisingly, the efficiency level is only relative to the best cross-section in the sample. Including extra cross-sections may alter the efficiency scores.

2.3 Institutions and Economic Performance

SPF approach also allows us to incorporate factors to explain inefficiency. We will consider institutional factors in this article. Studies on the relationship between institutions and economic growth are numerous. We are only interested in three aspects of institutions, namely:

1) Economic Institution provided by the State – the size of government, legal system and regulatory environment;

Stevenson (1980) assumes $u_i \sim iid\ N^+(\mu,\sigma_u^2)$ whereas Greene (1990) assumes $u_i \sim iid\ gamma$ [3]. Maximum likelihood estimation is most prevalently employed.

[4] Giannakas et al (2003) demonstrated Monte Carlo simulations indicating that the bias in the mean efficiency measures from stochastic frontier methods due to misspecification of functional form is sizeable. It can suggest a high level of inefficiency (10-30%) of output for the most efficient producers.

2) Political Institution – political regime, its durability and political rights ;and
3) International Trade – openness to trade and capital flow.

2.3.1 Size of Government, Legal System and Regulatory Environment and Growth

The size of government (measured in terms of the level of government consumption) seems to have a fairly robust negative effect on economic growth. Barro (1990) finds that the level of government consumption excluding education and defense as a share of GDP has a negative effect on the growth of GDP per capita. Landau (1986) finds a highly significant negative effect of government consumption as a share of GDP on the growth rate of GDP per capita even when the sample includes both OECD and developing countries.

On the other hand, it almost comes into an academic conclusion that property rights positively relate to economic growth. Among others, Scully (1988), Knack and Keefer (1995), Knack and Keefer (1997), Acemoglu and Johnson (2003) and Sachs (2003), covered both theoretical and empirical aspects of the claim. As Hernando (1993) mentioned, only those developing countries spend energies on ensuring property rights and protected by law rather than continue to focus on macroeconomic policy will grow better. Property rights, he argued, are essential for financing economic growth. Among the most recent empirical literature on property rights and growth, Claessens and Laeven (2002) use sectoral value added data for a number of cross-sections and find evidence that countries with better property rights leading to higher growth through improved asset allocation. The results are robust to various techniques and specifications.

In our studies, we use two indicators to capture the role of property rights. First we employ whether an impartial court exists to proxy for the quality of legal system. Second, we use the indicator of intellectual property rights to measure the degree of security of private property rights.

It is one of the roles of the State to shape the regulatory environment. According to the World Bank's World Business Environment Survey (2000), various regulations and credit markets constraints are the leading constraints for investment around the world, especially in industrialized and transition economics. Regulations hamper growth via Schumpeter (1911) creative destruction mechanism. Kirzer (1979) also argues that the tendency for regulation is to serve the interests of regulators. Regulation generates economic confusion and inefficiency.

Empirical studies (e.g. Fisman and Sarria-Allende (2004) and Bertrand and Kramarz (2002)) show (at either firm or industrial level) that regulatory barrier negatively affect firms' dynamics, which may induce inefficiency by keeping the less efficient firms in the industry. Stiglitz and Weiss (1981) and Myers and Majluf (1984) models show that credit constraints also accounts partly for the firm dynamics. On the other hand, Scarpetta, Hemmings et al. (2002)'s empirical work argue that labour market regulation also affects firm entry and exit.

In our estimations, we use two indices to measure the regulatory environment. We are interested in two forms of regulations – credit market and labor market regulation[5].

2.3.2 Political Regime, Political Rights and Durability and Growth

The idea of political regime determines growth comes from Olson (1993). He argues that the State acts as a 'stationary bandit' or 'roving bandit'. Based on his model, political stability (as a proxy for "stationary bandit") leads to economic growth via the effect of investment made by the State.

Barro (1991), along this line, measured political instability as a proxy for roving bandit. It turned out to be significantly and negatively explaining the rate of economic growth. Alesina and Perotti (1996) took into account the impact of political

[5] Despite the fact that quantitative data on entry regulation is available, comprehensive survey only covers year 2000 onwards. Therefore, the time span of the data sit is far from enough for our estimation purpose.

instability on investment, they find that increasing instability significantly depresses the level of investment in their sample.

Regime type may not only impose a direct impact on growth, but also shape the economic environment. Persson (2001) empirically shows that electoral rules and political regimes systematically influence the choice of fiscal instruments as well as the incidence of corruption. Hence, political regimes and its durability may indirectly affect institutional variables and the choice of economic policies.

Scully (1988) is among the first to determine the relationship between political rights and efficiency. He disaggregated the studies into measures of political, civil and economic liberties and their effects on efficiency and growth rate. His hypothesis is that the choice of the institutional framework of the economy has consequences for the allocation of resources (efficiency) in the economy. His measurement on the compound growth rates of per capita output and Farrell-type efficiency for 115 market economies over the period 1960-80 shows that the institutional framework has statistically significant effect on the efficiency and growth rate of economies.

2.3.3 Openness to International Trade and Growth

Islam (2004) claims that opening boarders for economic exchange subjects countries to greater competition from an increased flow of goods and services or from new goods and services, and opportunities are presented through access to larger markets and the realization of potential economies of scale and scope. Prospective returns to trade in goods and services also change as a result of greater information/technology flows across boarders. Countries borrow and adopt good ideas and countries find new designs / processes (technology) in order to compete better on world or domestic markets. Harrison (1995) and Greenaway, Morgan et al. (2002) are two recent empirical literatures supporting the association between openness to trade and economic growth. Edwards (1998), on the other hand, investigates the relationship between openness and productivity. His results are robust to show the positive relationship in terms of various estimation techniques and specification. Hall and Jones (1999) also show that high productivity growth economies share the feature of trade openness.

Barro (1994) employs the black market premium on foreign exchange as a proxy for government distortions of financial markets. We will also consider the same variable. Its coefficient in Barro's growth model estimated for about 100 countries is significantly negative, thereby suggesting that distortions of markets are adverse for economic growth. We also use this proxy and see if it will affect efficiency.

3 The Model and Specification

We, in principle, follow Battese and Coelli (1993) model. In their setting, they incorporate technical efficiency model in the stochastic production frontier model to perform a simultaneous one-stage approach.

Following (2.2.3), the stochastic production frontier is defined as:

$$Y_{it} = x_{it}\beta + \mathrm{E}_{it} \tag{3.1}$$

where $\mathrm{E}_{it} = V_{it} - U_{it}$ and $i = 1,...,N$ and $t = 1,...T$

V_{it} is assumed to be $iid\ N(0,\sigma_V^2)$, independently distributed of the U_{it} which are non-negative random errors, associated with technical inefficiency of production.

Technical efficiency model is specified as:

$$U_{it} = z_{it}\delta + W_{it} \tag{3.2}$$

where W_{it} is random variable and is defined by truncation of the normal distribution with zero mean and variance σ^2 and $W_{it} \geq -z_{it}\delta$. Technical inefficiency (U_{it}) is assumed to be independently distributed for all t and i and is obtained by truncation (at zero) of the normal distribution with mean $z_{it}\delta$ and variance σ^2. z_{it} is a (1 x m) vector of country specific institutional environment which may vary over time. δ is an (m x 1) vector of unknown coefficients of the country-specific inefficiency variable.

Thus, technical efficiency of production can be defined as:

$$TE_{it} = \exp(-U_{it}) = \exp(-z_{it}\delta - W_{it}) \quad (3.3)$$

Estimation outputs are obtained from the FRONTIER 4.1 program Coelli (1996)[6].

3.1 Specification

Our estimation composes of two parts: first, the stochastic production frontier model; second, the technical inefficiency model. As defined above, we specify our estimation as follows:

$$\begin{aligned} \ln Y_{it} &= \beta_0 + \beta_i \ln K_{it} + \beta_2 \ln L_{it} + \beta_3 africa_i + \beta_4 easia_i + \beta_5 mideast_i \\ &+ \beta_6 eca_i + \beta_7 sas_i + \beta_8 latin_i + \beta_9 time_t + v_{it} - u_{it} \end{aligned} \quad (3.4)$$

where $v_{it} \sim iid\ N(0, \sigma_v^2)$ is a random disturbance. u_{it} is cross-country technical inefficiency. β_0 is the constant term in production function to capture technical progress. The specification of the SPF model also includes regional dummies: namely Africa (***africa***), East Asia (***easia***), Middle East (***mideast***), Europe and Central Asia (***eca***), South Asia (***sas***) and Latin American (***latin***) countries respectively. It captures the possibility that countries adopt technology in a different manner. Hence, regional dummies capture the cross-country difference in terms of technology. We also incorporate the time trend (***time***) to capture the possibility that production frontier shifts over time.

We specify the technical inefficiency model as follows[7]:

$$u_{it} = \delta_1 gov + \delta_2 politic + \delta_3 openness + w_{it} \quad (3.5)$$

where w_{it} is random disturbance with truncated normal distribution. *gov* is a set of variables measures policy environment, including the size of government, security of property rights and regulatory environment. *politic* is a set of variables measures the

[6] The programme follows a three-step procedure in estimating the maximum likelihood estimates of the parameters of a stochastic frontier production function. The three steps involve: 1) OLS estimates of the production are obtained, such that all coefficients (except the intercept) will be unbiased. 2). A two-phrase grid search of γ ($= \frac{\sigma_u^2}{\sigma_u^2 + \sigma_v^2}$) is conducted. 3) The values selected in the grid search are used as starting values in an iterative procedure to obtain the final maximum likelihood estimates

[7] The specification of the TE model is allowed to have an intercept term. In our case, the Log-likelihood Ratio (LR) test accepts the null hypothesis that the intercept term equals to zero.

political regime, its durability, political rights and political constraints. *openness* is a set of variables measures the openness to international trade and international capital market. δ_j is a vector of coefficients of the respective area of measurement to be estimated.

4 Data

We have a balanced panel dataset for 80 cross-sections[8] from 1980 to 2000 with total observations up to 1680. We are interested in this period because this is when globalization has been taking place. Information and capital freely flow since then.

We obtain output (Real GDP) (***Y***) and capital (***K***) data from Penn World Table (ver 6.1) (Heston, Summers et al. (2002) , which are PPP adjusted (instead of using constant price) to facilitate cross-country comparison. Real GDP is obtained from real GDP per capita multiplied by population. Capital stock is obtained from investment data. [Details in calculating capital stock from investment data is presented in Appendix 8.1.] Total investment is measured as real total output (***Y***) multiplied by investment share of real GDP per capita in PWT. Labour force (***L***) is obtained from World Development Indicators from World Bank Group (2002).

Since both ***Y*** and ***K*** series are non-stationary[9], we take a 5-year average for ***Y***, ***K*** and ***L***[10] for each cross-section. It is an imperfect solution to deal with stationarity, but it allows us to get rid of the business cycle effect and the series are then less likely to be serially correlated (Islam (1995)). Our dataset, as a result, collapses to 320

[8] List of cross-sections can be referred to Appendix Table 8.2-1.
[9] Unit root test results, as well as, other diagnostic test results are available upon request.
[10] In terms of estimating the production function, we have attempted to correct for cross-sectional and period heteroskedasticity. Various robust methods to obtain the coefficient standard errors are also estimated. The coefficients do not have significant change. We have carried out formal Wald hypothesis test to test the null hypothesis that the original idiosyncratic errors are serially uncorrelated. Our test statistics show that we cannot reject the null hypothesis. However, since we have a number of cross-sections much bigger than the number of periods, we cannot apply the cross-section and/or period SUR method to take it into account. A more complete stochastic frontier model for panel data, which takes this into account, is pending for further research.

observations, with 80 cross-sections and 4 periods. We consider the logarithm form of Cobb-Douglas production function[11].

Our justification on the choice of institutional variables relies on the assumption that they are NOT factors of production, but they determine how the production process takes place and how resources are allocated. We base on the assumption that countries with better economic and political institutions are more technical efficient because resources are better allocated. However, institutions cannot be treated directly as production inputs. It does not, nevertheless, rule out the possibility that it induces more input accumulation.

We use six measures to proxy these three aspects of institutions. First, we measure the size of government in terms of government consumption over total consumption ***(GOV)*** and the size of transfer and subsidies over GDP ***(TRS)***. Both are expressed in percentage and can be obtained from Gwartnet, Lawson et al. (2002).

In terms of legal system and property rights, we use the index of impartial court ***(COURT)*** to proxy for the quality of legal system. We also use the index of intellectual property rights ***(PROPR)*** to signify the level of intellectual property rights in the country. We also incorporate the interactive term of these two indices to capture the possible non-linear relationship. We hypothesize that intellectual property rights can only be enforced and it can thus reduce technical inefficiency if there exists an impartial court to enforce the rights. The two indicies range from 1 to 10, where 10 means there exists an impartial court and intellectual property rights and the data are obtained from Gwartnet, Lawson et al. (2002).

[11] We did attempt to include human capital to explain technical inefficiency in our model. Even though the sign of the coefficient is negative as unexpected, it is not significant and LR hypothesis test accepts the null that the coefficient of human capital equals zero. Islam (1995) suggests a possible reason for this unexpected result. He claims that it may be due to the discrepancy between the theoretical variable human capital (***H***) in the production function and the actual variable used in regressions. The conventional measure of human capital is the use of enrollment rate. However, it is just a partial measure and did not account for differences in the quality of schooling. He also argued that many countries (especially developing countries) appear to have much progress in the level of human capital. However, the output levels have actually not increased by that much.

Besides, we capture the regulatory environment in two perspectives: one is credit market regulation index[12] ***(CREDIT)*** and labour market regulation index[13] ***(LABOR)***. The index ranges from 1 to 10, with higher score implying less regulation in the economies and the data is from Gwartnet, Lawson et al. (2002).

We measure the regime type of each cross-section as ***REGIME***. It ranges from -10 to 10 which represents the regime from authoritative to democratic. We are also interested in the durability ***(DURABLE)*** of the regime type which is measured by the number of years since the last regime transition. We also measure the executive constraints ***(XCONST)*** – an operational (de facto) independence of chief executive. It is an index with higher score implying that there are more constraints on the chief executive. All three variables can be obtained from POLITY IV database (Marshall, Jaggers et al. (2003)).

Finally, we also measure the political rights that citizens possess ***(PR)***. Political rights range from 1 to 7 where 1 indicates political rights are better secured. It includes several characteristics: 1) free and fair elections; 2) who are elected rule; 3) there are competitive parties or other political groupings, and; 4) the opposition plays an important role and has actual power[14]. Data is obtained from Freedom House (2004).

We use three variables to proxy the openness to trade. First, we consider whether citizens are free to own foreign currency bank account domestically and abroad ***(FOREIGN)*** to proxy the free flow of capital. Second, we use the index of measuring the level of regulatory trade barriers ***(TRADEB)***, in terms of hidden import barriers and the cost of importing. The index scores higher if there are less trade barriers. Finally we use the black market exchange rate premium ***(BLACK)*** which is

[12] Credit market regulation measures: 1) the percentage of deposits held in privately owned banks; 2) how much competition domestic banks face from foreign banks; 3) percentage of credit extended to private sector; 4) negative real interest rate; 5) interest rate control.
[13] Labour market regulation measures 1) the impact of minimum wage; 2) hiring and firing practices determined by private contract; 3) share of labour force whose wages are set by collective bargaining; unemployment benefit preserves the incentive to work or not.

defined as the difference between official exchange rate and black market rate. The index also ranges from 1 to 10, where 10 denotes a smallest black market exchange rate premium. All three indices can be obtained from Gwartnet, Lawson et al. (2002).

5 Results and Analysis

Table 5-1 is the estimation of the SPF and TE model. The elasticity of output to capital and labour are 0.6368 and 0.3427 respectively. The results are expected. It is because the number of industrialized economies dominates our sample (23 out of 80), and they usually have a bigger capital-labour ratio (see Appendix Table 8.3-2). The world production function, in other words, exhibits constant return to scale. Even though we incorporate time trend in the production function estimation, it has an insignificant positive effect. The production frontier seemingly shifted over time, but the magnitude was insignificant over the last 20 years.

γ is equal to $\dfrac{\sigma_u^2}{\sigma_u^2 + \sigma_v^2}$ and can be interpreted as the inefficiency indicator. It measures the the percentage of total variance comes from the technical inefficiency model variance. In our case, it is about 83% of total variance of our model can be explained by the TE model and it is significant at 1% level.

[TABLE ON THE NEXT PAGE]

[14] Citizens enjoy self-determination or an extremely high degree of autonomy (in the case of territories), and minority groups have reasonable self-government or can participate in the government through informal consensus are also justified as having high degree of political rights.

Table 5-1 : Estimation of Stochastic Production Frontier and Technical Efficiency

Dependent Variable: lnY
Panel I: Estimation of the Stochastic Production Frontier

ind. var.	*coefficient*	*(standard error)*
constant	3.6979***	(0.1799)
lnK	0.6368***	(0.0133)
lnL	0.3427***	(0.0152)
time	0.0010	(0.0098)
africa	0.0640	(0.0436)
latin	0.0807**	(0.0383)
easia	0.0047	(0.0519)
eca	-0.0216	(0.0550)
sas	-0.1127	(0.0593)
mideast	0.0360	(0.0507)

Dependent Variable: u_{it} **(technical inefficiency)**
Panel II: Estimation of the Technical Efficiency Model

ind. var.	coefficient	(standard error)
GOV	0.0231***	(0.0050)
TRS	-0.0456***	(0.0124)
COURT	-0.0411**	(0.0199)
PROPR	0.2386***	(0.0489)
COURT * PROPR	-0.0192***	(0.0062)
CREDIT	-0.0261**	(0.0121)
LABOR	-0.0171	(0.0146)
DURAB	-0.0068***	(0.0009)
XCONT	0.0492*	(0.0299)
REGIME	-0.0050	(0.0142)
PR	0.0517**	(0.0243)
FOREIGN	-0.0135	(0.0089)
TRADEB	-0.0680**	(0.0270)
BLACK	-0.0099	(0.0092)

σ^2	0.0756***	(0.0115)
γ	0.8260***	(0.0434)
log (likelihood)		106.9769

***, **, * denote 1%, 5% and 10% significance level respectively.

We first refer to the TE model (PANEL II) to discuss the explanatory factors of technical inefficiency. Government consumption (***GOV***) positively relates to technical inefficiency as expected. In other words, government consumption seems to be distortionary. On the other hand, the size of transfer and subsidies (***TRS***) significantly and negatively relates to technical inefficiency. Countries which are more redistributive are less technically inefficient.

An impartial court, proxied by the quality of legal system (***COURT***) , negatively relates to technical inefficiency. As expected, a weak legal system implies private property rights and contract rights are less secured. Inefficiency arised as a result of extra effort and cost have to be made to reduce information cost and settle disputes.

The result also shows a positive and significant relationship between intellectual property rights and technical inefficiency. It was expected that with better protected intellectual property rights, society tends to be more efficient because it encourages innovation. However, in our estimation, we do not control for the structure of the economy. Especially in developing countries, where they may heavily rely on the agricultural sector, innovation and R&D industry are not that important. On the contrary, too much emphasis of intellectual property rights would cause inefficiency since they may turn into another form of requirement to comply with.

Alternatively, a country may have intellectual property rights legislation and rules, but it lacks an efficient court system to enforce. If this is the case, then it implies intellectual property rights alone cannot guarantee technical efficiency. Therefore, in our estimation, we use an interactive term that captures the effect of both legal system effectiveness and intellectual property rights. The coefficient is significantly negative. It implies intellectual property rights only reduces inefficiency when there is a good enough legal system to enforce the legislation.

We consider two indices to capture the regulatory environment (***CREDIT*** and ***LABOR***). Both coefficients are negative, as expected, implying countries with less regulations are more efficient. However, only ***CREDIT*** is significant at 5% level; ***LABOR*** is not significant. Labour market regulation causes inefficiency because of the excessive practices to set up an employment contract. The adverse effect of labour market regulation is probably better reflected when unemployment rate is taken into account[15].

Our results show that the *type* of regime – either authoritative or democratic – is not statistically significant in explaining a country's technical efficiency, but its durability does. In our case, the coefficient of ***REGIME*** is negative but not statistically significant, i.e. a more democratic society is less inefficient, but the effect is insignificant. On the contrary, the durability of the regime type ***(DURAB)*** is significantly negative. Irrespective of the type of regime, the longer the regime can sustain, the country is less efficient. Political rights (***PR***) secures private property from government/military conscription and it is significant at 5% level. Executive constraint ***(XCONT)*** also positively relates to technical efficiency (at 10% significant level). In other words, countries which impose more constraints on the political executives, who in turn would be less likely to use conscription.

Last but not least, the three indicators ***(FOREIGN, TRADEB, BLACK)*** which proxy the country's openness, show the negative relationship as expected. Countries with fewer restrictions on foreign trade are more efficient. It may be due to technology and skills transfer. However, only the level of trade barriers ***(TRADEB)*** is significant at 5%. The freedom to own foreign currency bank accounts ***(FOREIGN)*** and black market premium exchange rate ***(BLACK)*** are not significant.

All in all, when we compare the magnitude of the estimated coefficients in the TE model, those measuring the size of government, legal system, regulatory environment and political institutions are much bigger than those measuring the openness to international trade. It may imply that domestic institutional quality helps improving efficiency more than openness per se.

[15] Using employed labour force, instead of total labour force as we did is more capable to reflect the adverse effect of labour regulation on employed labourforce. However, cross-country and annul data on unemployment rate is very patchy which significantly reduces our sample size.

5.1 Measures on Technical Efficiency (Complete Measures)

Table 5.1-1 : Measures of Technical Efficiency (1981-2000)

country	TE (81-85)		TE (86-90)		TE (91-95)		TE (96-00)		Change(%) (81-00)
Argentina	0.845	{46}	0.8364	{49}	0.8201	{54}	0.926	{32}	9.1523
Australia	0.9338	{18}	0.9435	{16}	0.961	{12}	0.9661	{7}	3.4
Austria	0.9204	{22}	0.9316	{20}	0.9461	{20}	0.9566	{17}	3.8575
Bangladesh	0.7252	{62}	0.7172	{64}	0.7402	{64}	0.7994	{58}	9.7465
Belgium	0.9542	{6}	0.9584	{4}	0.9643	{10}	0.9655	{9}	1.1855
Belize	0.9154	{24}	0.9086	{31}	0.926	{29}	0.9146	{36}	-0.0846
Bolivia	0.7624	{55}	0.7721	{57}	0.7827	{60}	0.8606	{51}	12.1133
Brazil	0.7974	{52}	0.775	{56}	0.79	{58}	0.7935	{60}	-0.4894
Cameroon	0.9164	{23}	0.8924	{36}	0.8416	{48}	0.7481	{65}	-20.2888
Canada	0.9614	{2}	0.9648	{3}	0.97	{4}	0.966	{8}	0.4785
Chile	0.9069	{28}	0.9218	{24}	0.929	{26}	0.9431	{21}	3.9192
China	0.6148	{71}	0.6171	{70}	0.5936	{75}	0.68	{69}	10.0758
Colombia	0.9241	{21}	0.9225	{23}	0.8937	{38}	0.9024	{40}	-2.368
Costa Rica	0.8655	{41}	0.8611	{44}	0.8825	{42}	0.8884	{44}	2.6157
Cote d'Ivoire	0.7562	{58}	0.7581	{59}	0.8147	{55}	0.8604	{52}	12.9074
Denmark	0.9016	{32}	0.919	{26}	0.957	{15}	0.9601	{14}	6.2855
Dominican Rep.	0.8496	{45}	0.8402	{48}	0.8392	{50}	0.884	{46}	3.9706
Ecuador	0.6871	{68}	0.6828	{68}	0.6713	{70}	0.6432	{73}	-6.6029
Egypt	0.9489	{12}	0.9434	{17}	0.9277	{28}	0.9616	{12}	1.3307
El Salvador	0.8918	{35}	0.9003	{34}	0.9301	{25}	0.9415	{23}	5.4282
Finland	0.8801	{38}	0.8987	{35}	0.9479	{19}	0.941	{26}	6.6967
France	0.95	{9}	0.9527	{10}	0.9515	{17}	0.9514	{19}	0.1469
Gabon	0.7158	{63}	0.7579	{60}	0.8002	{57}	0.9149	{35}	24.5358
Germany	0.9538	{7}	0.9477	{13}	0.9559	{16}	0.9573	{16}	0.3705
Ghana	0.5525	{73}	0.6059	{71}	0.6946	{67}	0.7804	{61}	34.5433
Greece	0.8121	{49}	0.8542	{46}	0.8702	{44}	0.883	{47}	8.3643
Guatemala	0.9253	{20}	0.9267	{22}	0.9398	{23}	0.9414	{24}	1.7206
Honduras	0.7596	{56}	0.7927	{52}	0.8207	{53}	0.7046	{67}	-7.5187
Hong Kong	0.9379	{17}	0.9403	{18}	0.9646	{9}	0.9637	{11}	2.7155
Hungary	0.9495	{10}	0.9487	{12}	0.951	{18}	0.918	{34}	-3.3794
Iceland	0.8525	{43}	0.8713	{41}	0.9156	{32}	0.9098	{38}	6.4974
India	0.8079	{51}	0.8503	{47}	0.8999	{36}	0.9335	{30}	14.4537
Indonesia	0.8757	{39}	0.8548	{45}	0.8115	{56}	0.8147	{56}	-7.2108
Iran	0.6704	{69}	0.6667	{69}	0.6514	{71}	0.7714	{63}	14.0442
Ireland	0.9545	{4}	0.9553	{8}	0.9692	{5}	0.9792	{2}	2.5493
Israel	0.8617	{42}	0.8805	{40}	0.892	{40}	0.9384	{27}	8.5251
Italy	0.9494	{11}	0.9575	{6}	0.9613	{11}	0.9582	{15}	0.924
Jamaica	0.5089	{77}	0.5502	{76}	0.6261	{73}	0.5921	{76}	15.1412
Japan	0.9046	{30}	0.9176	{27}	0.9093	{35}	0.8964	{42}	-0.9087
Jordan	0.9435	{14}	0.9282	{21}	0.8935	{39}	0.8086	{57}	-15.4273
Kenya	0.5494	{74}	0.5861	{74}	0.6356	{72}	0.6607	{71}	18.4451
Luxembourg	0.908	{27}	0.9662	{2}	0.9756	{2}	0.979	{3}	7.5227
Madagascar	0.8887	{37}	0.9136	{30}	0.9148	{33}	0.9079	{39}	2.1413
Malawi	0.3635	{79}	0.3736	{79}	0.3611	{80}	0.4317	{79}	17.1807
Malaysia	0.8505	{44}	0.8198	{51}	0.8408	{49}	0.8865	{45}	4.1527

country	TE (81-85)		TE (86-90)		TE (91-95)		TE (96-00)		Change(%) (81-00)
Mali	0.6198	{70}	0.5905	{73}	0.5506	{77}	0.5852	{78}	-5.7431
Mauritius	0.9129	{26}	0.9317	{19}	0.9572	{14}	0.9686	{6}	5.9194
Mexico	0.9044	{31}	0.8876	{39}	0.8576	{46}	0.8658	{49}	-4.3597
Morocco	0.7651	{54}	0.7869	{53}	0.835	{51}	0.8466	{53}	10.1263
Netherlands	0.9522	{8}	0.9562	{7}	0.9682	{7}	0.9706	{5}	1.9092
New Zealand	0.9543	{5}	0.9581	{5}	0.9654	{8}	0.9604	{13}	0.6314
Niger	0.4995	{78}	0.5012	{78}	0.5127	{78}	0.5904	{77}	16.7148
Nigeria	0.5589	{72}	0.6051	{72}	0.6798	{69}	0.6644	{70}	17.3018
Norway	0.843	{47}	0.863	{42}	0.9282	{27}	0.9411	{25}	11.0113
Pakistan	0.7919	{53}	0.83	{50}	0.8696	{45}	0.8652	{50}	8.8438
Panama	0.7558	{59}	0.7575	{61}	0.7765	{61}	0.7557	{64}	-0.015
Paraguay	0.9132	{25}	0.9065	{33}	0.8899	{41}	0.8906	{43}	-2.5126
Peru	0.7094	{65}	0.6889	{67}	0.6838	{68}	0.6856	{68}	-3.41
Philippines	0.7123	{64}	0.6906	{66}	0.7298	{65}	0.774	{62}	8.3067
Portugal	0.8889	{36}	0.9076	{32}	0.9339	{24}	0.9271	{31}	4.2014
Rwanda	0.928	{19}	0.9192	{25}	0.8718	{43}	0.7474	{66}	-21.6478
Senegal	0.7496	{60}	0.739	{62}	0.7866	{59}	0.7955	{59}	5.9444
Singapore	0.6977	{66}	0.6911	{65}	0.753	{63}	0.8725	{48}	22.3622
South Africa	0.901	{33}	0.9158	{28}	0.9219	{30}	0.9427	{22}	4.5175
South Korea	0.7395	{61}	0.7815	{54}	0.8307	{52}	0.8182	{54}	10.105
Spain	0.8677	{40}	0.8882	{38}	0.9205	{31}	0.9339	{29}	7.3532
Sri Lanka	0.9064	{29}	0.8891	{37}	0.8938	{37}	0.9138	{37}	0.8096
Sweden	0.9401	{16}	0.9449	{15}	0.9687	{6}	0.9644	{10}	2.547
Switzerland	0.9419	{15}	0.9472	{14}	0.9572	{13}	0.9549	{18}	1.3694
Thailand	0.546	{75}	0.5834	{75}	0.6012	{74}	0.6094	{75}	10.9839
Togo	0.695	{67}	0.7281	{63}	0.7103	{66}	0.6436	{72}	-7.6975
Trinidad & Tobago	0.9568	{3}	0.9506	{11}	0.9446	{21}	0.949	{20}	-0.8224
Tunisia	0.8086	{50}	0.7799	{55}	0.8503	{47}	0.8994	{41}	10.6468
Turkey	0.8965	{34}	0.9136	{29}	0.9434	{22}	0.9201	{33}	2.5958
United Kingdom	0.9453	{13}	0.955	{9}	0.9717	{3}	0.9722	{4}	2.8077
United States	0.9764	{1}	0.9779	{1}	0.982	{1}	0.9823	{1}	0.6001
Uruguay	0.8382	{48}	0.863	{43}	0.9104	{34}	0.9372	{28}	11.158
Venezuela	0.7571	{57}	0.7604	{58}	0.7599	{62}	0.8159	{55}	7.4745
Zambia	0.3541	{80}	0.3652	{80}	0.3623	{79}	0.4011	{80}	12.4569
Zimbabwe	0.5199	{76}	0.5215	{77}	0.5755	{76}	0.6164	{74}	17.0124
Mean TE[16]	***0.8144***		***0.8220***		***0.8374***		***0.8496***		***4.7795***

Ranking in { } parenthesis.

Table 5.1-1 is the complete measurement of technical efficiency level for each cross-section during the period 1981-1985; 1986-1990; 1991-1995 and 1996-2000. The average TE levels across 80 countries are 81.44%, 82.2%, 83.74% and 84.96%. Over the four subsequent periods, the average growth rate is 4.78%. Most of the countries experience positive TE growth. Cameroon and Rwanda, on the contrary, have the greatest percentage decline of efficiency over the last 20 years.

[16] It denotes a simple average.

The TE level of each country is compared to the best-practice in the sample. As shown, the relative position of each cross-section did not change much in the measured period. Industrialized economies are among the best-practice in each sub-period. Sub-Saharan African countries are consistently among the least efficient.

It is interesting to compare the results of developing economies, particularly, China, India and Jamaica. The catching-up effect is rather dramatic in 20 years. South Korea and Singapore are two examples among developed economies that show substantial percentage change of TE in the same period.

5.2 Descriptive Statistics of Technical Efficiency

Table 5.2-1 : Descriptive Statistics of Technical Efficiency Across Regions

		TE (81-85)	TE (86-90)	TE (91-95)	TE (96-00)
Industrial Economies					
	Mean	0.9194	0.9320	0.9500	0.9512
	Std Dev	0.0438	0.0355	0.0263	0.0260
	Min	0.8121	0.8542	0.8702	0.8830
	Max	0.9764	0.9779	0.9820	0.9823
	Count	23	23	23	23
East Asia and Pacific					
	Mean	0.7468	0.7473	0.7657	0.8024
	Std Dev	0.1338	0.1227	0.1252	0.1143
	Min	0.5460	0.5834	0.5936	0.6094
	Max	0.9379	0.9403	0.9646	0.9637
	Count	8	8	8	8
Europe and Central Asia					
	Mean	0.9230	0.9312	0.9472	0.9191
	Std Dev	0.0375	0.0248	0.0054	0.0015
	Min	0.8965	0.9136	0.9434	0.9180
	Max	0.9495	0.9487	0.9510	0.9201
	Count	2	2	2	2
Middle East and North Africa					
	Mean	0.8330	0.8309	0.8417	0.8710
	Std Dev	0.1078	0.1059	0.0989	0.0748
	Min	0.6704	0.6667	0.6514	0.7714
	Max	0.9489	0.9434	0.9277	0.9616
	Count	6	6	6	6
Latin America and Caribbean					
	Mean	0.8237	0.8252	0.8337	0.8418

		TE (81-85)	TE (86-90)	TE (91-95)	TE (96-00)
	Std Dev	0.1086	0.1028	0.0950	0.1099
	Min	0.5089	0.5502	0.6261	0.5921
	Max	0.9568	0.9506	0.9446	0.9490
	Count	20	20	20	20
Sub-Saharan Africa					
	Mean	0.6754	0.6885	0.7054	0.7211
	Std Dev	0.1924	0.1888	0.1850	0.1692
	Min	0.3541	0.3652	0.3611	0.4011
	Max	0.9280	0.9317	0.9572	0.9686
	Count	17	17	17	17
All					
	Mean	0.8144	0.8220	0.8374	0.8496
	Std Dev	0.1470	0.1435	0.1407	0.1324
	Min	0.3541	0.3652	0.3611	0.4011
	Max	0.9764	0.9779	0.9820	0.9823
	Count	80	80	80	80

Regional comparison confirms that industrial economies are most efficient on average, whereas the Sub-Saharan Africa countries are the least efficient. In the third period and the fourth period (1990-1995 to 1996-2000), East Asian and Sub-Saharan Africa countries experienced the largest percentage of average TE growth. Industrial economies, Latin American countries and Sub-Saharan African countries have a similar sample size to facilitate our comparison. We find that the standard deviation of TE in the latter two groups is significantly bigger. In other words, there are substantial regional TE gap within the regions. Among the industrial economies, TE levels are similar with smaller standard deviation.

5.3 Sources of Growth Across Regions

In this section, we further elaborate our results into a standard growth accounting framework. We further decompose output growth into input growth and total factor productivity (TFP) growth. TFP is defined as the residual of output growth from input growth.

$$\frac{T\dot{F}P}{TFP} = \frac{\dot{Y}}{Y} - \beta_1 \frac{\dot{K}}{K} - \beta_2 \frac{\dot{L}}{L} \qquad (5.3.1)$$

where $\frac{\dot{X}}{X} \approx \ln(X_{t+1}) - \ln(X_t)$. Thus, we can compare the result of TE growth versus TFP growth across regions. The major difference between TE measurement and TFP measurement is the following. First, TFP is regarded as the "residual" measurement. It is not a good measure for cross-country comparison since it does not consider a particular country as best-practice whereas TE does. In the latter case, we can hence identify the best possible output level (but not growth rate), taking into account of all technology parameter and inputs available. Secondly, TFP does not take into account of stochastic events, whereas, in our case we do.

Table 5.3-1 : Comparison of TFP Growth and TE Growth By Regions[17]

	Period	*Output Growth*	*Capital Growth*	*Labour Growth*	*TFP Growth*	*Technical Efficiency Change*
Industrial Economies						
	81-85	1.97%	3.24%	1.08%	-0.46%	..
	86-90	3.33%	3.31%	1.10%	0.85%	1.38%
	91-95	1.94%	2.73%	0.97%	-0.13%	1.92%
	96-00	3.50%	3.18%	0.72%	1.22%	0.12%
	81-00	2.69%	3.12%	0.97%	0.37%	3.42%
East Asia and Pacific						
	81-85	5.19%	9.05%	2.67%	-1.49%	..
	86-90	7.02%	6.45%	2.49%	2.06%	0.07%
	91-95	7.00%	8.46%	2.30%	0.82%	2.42%
	96-00	4.00%	6.67%	2.11%	-0.97%	4.69%
	81-00	5.80%	7.66%	2.39%	0.11%	7.18%
Europe and Central Asia						
	81-85	3.57%	3.48%	1.02%	1.01%	..
	86-90	2.91%	4.68%	0.80%	-0.34%	0.88%
	91-95	0.37%	3.91%	1.48%	-2.63%	1.71%
	96-00	3.62%	5.18%	1.19%	-0.08%	-3.02%
	81-00	2.62%	4.31%	1.12%	-0.51%	-0.43%
Middle East and North Africa						
	81-85	4.46%	6.19%	3.21%	-0.59%	..
	86-90	2.14%	2.23%	2.94%	-0.28%	-0.17%
	91-95	5.20%	4.66%	3.83%	0.92%	1.96%
	96-00	3.64%	3.65%	2.59%	0.42%	3.39%
	81-00	3.86%	4.18%	3.14%	0.12%	5.18%
Latin America and Caribbean						
	81-85	0.94%	3.84%	2.88%	-2.49%	..

[17] All growth rates are calculated on individual country basis. The measurement is then stacked and simple average is taken for presentation and comparison purpose.

	Period	Output Growth	Capital Growth	Labour Growth	TFP Growth	Technical Efficiency Change
	86-90	2.52%	1.99%	2.68%	0.33%	0.15%
	91-95	3.93%	3.37%	2.64%	0.88%	0.87%
	96-00	2.96%	4.17%	2.66%	-0.61%	1.10%
	81-00	2.59%	3.34%	2.71%	-0.47%	2.12%
Sub-Saharan Africa						
	81-85	2.03%	2.16%	2.74%	-0.28%	..
	86-90	3.14%	1.31%	2.67%	1.39%	1.86%
	91-95	0.81%	0.80%	2.22%	-0.46%	2.37%
	96-00	3.41%	1.70%	2.64%	1.43%	2.05%
	81-00	2.35%	1.49%	2.57%	0.52%	6.28%
All						
	81-85	2.45%	4.08%	2.28%	-0.94%	..
	86-90	3.45%	2.88%	2.17%	0.87%	0.93%
	91-95	3.02%	3.27%	2.10%	0.22%	1.85%
	96-00	3.47%	3.64%	2.04%	0.45%	1.45%
	81-00	3.10%	3.47%	2.15%	0.15%	4.23%

We have to reiterate that TFP growth measures the percentage change from period to another without any comparison to other countries' performance. Its change only denotes the performance change within one country, whereas only technical efficiency measurement allows comparison.

The table above shows that TFP growth is consistently smaller than TE growth in each sub-period. In some of the cases, there is a negative growth of TFP but a positive growth of TE. The negative TFP growth rate is possibly a result of faster growth of input rather than output (Young (1992)).

In almost all regions (in particular, East Asia and Pacific, Middle East and North Africa and Sub-Saharan Africa), there are significant increases in TE from 1980 to 2000, but TFP growth is much smaller. Since our results show that the shifting out of the world frontier took place but not in a significant manner, the positive TE growth demonstrates the "catching-up" effect. It possibly explains the improving living standard in all these regions, as what we have observed in the development process.

For TFP growth rate, the magnitude is overall small, if not negative. It appears that capital growth rate significantly outweighed output growth rate in all regions, especially in the East Asian and Pacific region. Hence, TE and TFP derived from different context present substantial different estimates.

6 Conclusion

In this paper, we argue that conventional growth empirics are not sufficient to understand diverse economic performance. Measuring technical efficiency using stochastic production frontier (SPF) would be a better approach. This approach also allows us to incorporate explanatory factors of technical inefficiency.

We applied the Battese and Coelli (1993) model to estimate technical efficiency and incorporated the institutional factors we are interested in. The results suggest that a sizeable government, a non-redistributive government, a weak legal system and heavy credit market regulation all significantly contribute to inefficiency. In terms of political institution, regime type *per se* is not significantly relevant, but its durability and the political rights enshrined matter for efficiency. Last but not least, openness to trade may reduce inefficiency, but not as much as building-up better domestic governance. It may suggest that improving domestic governance may be more essential in promoting economic development for developing economies than simply adopting an open economy strategy without local governance reform.

Finally, we compare the results of TE to standard TFP growth measurement. The measures are drastically different. Certainly, the SPF approach is far from perfect. Nevertheless, growth accounting would bring more insights if we are able to decompose the sources of growth and incorporate different factors therein.

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8 Appendix

8.1 Capital Stock Calculation

Capital stock estimates are based on Limam and Miller (2004). Similar to the perpetual inventory method with the steady-state initial capital stock as in King and Levine (1994), we first estimate the initial capital stock (1960) for each country[18]. We use the 1960 capital stock as initial steady-state value and incorporate with investment data to derive the capital stock for subsequent periods (till 2000).

King and Levine (1994) assume that capital-output ratio is constant in the steady-state. Therefore, physical capital and real output grow at same rate. We assume δ is the depreciation rate and equals to 7% across countries and over time as King and Levine (1994), Benhabib and Spiegel (1997) and Limam and Miller (2004). Hence, the steady-state capital-output ratio for country i is derived as:

$$\kappa_i = i_i / (\delta + \lambda g_i + (1-\lambda) g_w) \qquad (8.1.1)$$

where i_i is the steady-state investment rate for country i. It is the average investment rate for country i from 1960 to 2000. $\lambda g_i + (1-\lambda) g_w$ is the steady-state growth rate which is the weighted average of the country's growth rate and the world growth rate. λ is a measure of mean reversion of growth rates and equals to 0.25 as Easterly, Kremer et al. (1993). g_i is the country's average growth rate over the period 1960 to 2000. g_w is the world growth rate and is approximated to be 4%.

Initial capital stock in year 1960 (or earliest possible year in our sample) can be expressed as:

$$K_{i,60} = \kappa_i \cdot Y_{i,60} \qquad (8.1.2)$$

where Y is defined as above as real GDP.

The calculation of capital stock for the remaining years, as calculated using perpetual inventory method, is as the following:

[18] Alternatively, the earliest possible date if data are not available in 1960.

$$K_{it+1} = I_{it} + (1-\delta)K_{it} \quad (8.1.3)$$

Hence, we obtain the series of capital stock from 1980 to 2000, and ultimately we take a 5-year average in our estimation.

8.2 List of Cross-sections

Table 8.2-1 : List of Panel Units[19]

	Economy	*Code*	*Income group*
	Industrial Economies		
1	Australia	AUS	High income
2	Austria	AUT	High income
3	Belgium	BEL	High income
4	Canada	CAN	High income
5	Denmark	DNK	High income
6	Finland	FIN	High income
7	France	FRA	High income
8	Germany	DEU	High income
9	Greece	GRC	High income
10	Iceland	ISL	High income
11	Ireland	IRL	High income
12	Italy	ITA	High income
13	Japan	JPN	High income
14	Luxembourg	LUX	High income
15	Netherlands	NLD	High income
16	New Zealand	NZL	High income
17	Norway	NOR	High income
18	Portugal	PRT	High income
19	Spain	ESP	High income
20	Sweden	SWE	High income
21	Switzerland	CHE	High income
22	United Kingdom	GBR	High income
23	United States	USA	High income
	East Asia and Pacific		
1	China	CHN	Lower middle income
2	Hong Kong, China	HKG	High income: nonOECD
3	Indonesia	IDN	Lower middle income
4	Korea, Rep.	KOR	High income: OECD
5	Malaysia	MYS	Upper middle income
6	Philippines	PHL	Lower middle income
7	Singapore	SGP	High income: nonOECD
8	Thailand	THA	Lower middle income
	Europe and Central Asia		
1	Hungary	HUN	Upper middle income
2	Turkey	TUR	Lower middle income
	Middle East and North Africa		
1	Egypt, Arab Rep.	EGY	Lower middle income
2	Iran, Islamic Rep.	IRN	Lower middle income
3	Israel	ISR	High income: nonOECD
4	Jordan	JOR	Lower middle income
5	Morocco	MAR	Lower middle income

[19] Classification is based on World Bank Economies Classification.

	Economy	*Code*	*Income group*
6	Tunisia	TUN	Lower middle income

	Latin America & Caribbean		
1	Argentina	ARG	Upper middle income
2	Belize	BLZ	Upper middle income
3	Bolivia	BOL	Lower middle income
4	Brazil	BRA	Lower middle income
5	Chile	CHL	Upper middle income
6	Colombia	COL	Lower middle income
7	Costa Rica	CRI	Upper middle income
8	Dominican Republic	DOM	Lower middle income
9	Ecuador	ECU	Lower middle income
10	El Salvador	SLV	Lower middle income
11	Guatemala	GTM	Lower middle income
12	Honduras	HND	Lower middle income
13	Jamaica	JAM	Lower middle income
14	Mexico	MEX	Upper middle income
15	Panama	PAN	Upper middle income
16	Paraguay	PRY	Lower middle income
17	Peru	PER	Lower middle income
18	Trinidad and Tobago	TTO	Upper middle income
19	Uruguay	URY	Upper middle income
20	Venezuela, RB	VEN	Upper middle income

	South Asia		
1	Bangladesh	BGD	Low income
2	India	IND	Low income
3	Pakistan	PAK	Low income
4	Sri Lanka	LKA	Lower middle income

	Sub-Saharan Africa		
1	Cameroon	CMR	Low income
2	Côte d'Ivoire	CIV	Low income
3	Gabon	GAB	Upper middle income
4	Ghana	GHA	Low income
5	Kenya	KEN	Low income
6	Madagascar	MDG	Low income
7	Malawi	MWI	Low income
8	Mali	MLI	Low income
9	Mauritius	MUS	Upper middle income
10	Niger	NER	Low income
11	Nigeria	NGA	Low income
12	Rwanda	RWA	Low income
13	Senegal	SEN	Low income
14	South Africa	ZAF	Lower middle income
15	Togo	TGO	Low income
16	Zambia	ZMB	Low income
17	Zimbabwe	ZWE	Low income

8.3 Data Analysis and Descriptive Statistics

Table 8.3-1 : Average Capital Stock Across Regions (in billion)

Period	81-85	86-90	91-95	96-00	80's	90's	80-00
Industrial Economies							
Mean	1110	1350	1630	1920	1200	1740	1500
Median	306	349	407	446	323	432	383
Maximum	8710	10900	13100	16100	9600	14400	12200
Minimum	9.87	11.2	10.7	10.6	10.5	10.7	10.6
Std. Dev.	2000	2510	3070	3730	2200	3340	2830
Observations	483	483	483	483	483	483	483
East Asia and Pacific							
Mean	383	573	881	1380	457	1090	778
Median	260	346	505	750	297	596	462
Maximum	1460	2270	3430	5600	1780	4350	3190
Minimum	101	146	197	292	119	237	12
Std. Dev.	423	666	1020	1680	518	1300	965
Observations	168	168	168	168	168	168	168
Europe and Central Asia							
Mean	204	248	334	445	220	380	308
Median	204	248	334	445	220	380	308
Maximum	259	324	486	686	282	567	439
Minimum	149	173	183	203	159	192	177
Std. Dev.	55.9	76.1	153	244	62.3	190	132
Observations	42	42	42	42	42	42	42
Middle East and North Africa							
Mean	278	319	376	433	294	399	352
Median	95.9	110	136	174	102	151	129
Maximum	1040	1180	1410	1600	1090	1480	1310
Minimum	10.1	13.4	17.9	24.5	11.5	20.6	16.5
Std. Dev.	363	411	490	552	381	514	454
Observations	126	126	126	126	126	126	126
Latin America & Caribbean							
Mean	191	212	236	274	200	252	228
Median	26.8	27	28.7	33.9	26.9	30.9	29.1
Maximum	1500	1720	1890	2090	1580	1980	1800
Minimum	0.646	0.861	1.38	1.78	0.723	1.53	1.17
Std. Dev.	365	412	459	518	383	483	438
Observations	420	420	420	420	420	420	420
South Asia							
Mean	290	370	478	639	321	545	444
Median	106	135	169	212	117	187	155
Maximum	917	1170	1520	2070	1010	1750	1420

Period	81-85	86-90	91-95	96-00	80's	90's	80-00
Minimum	29.7	42.6	52	64.9	35	57.4	47.3
Std. Dev.	366	464	609	833	404	702	568
Observations	84	84	84	84	84	84	84
Sub-Saharan Africa							
Mean	124	138	156	175	129	164	148
Median	13.2	12.6	12.5	14.6	12.9	12.7	13.7
Maximum	1520	1750	2050	2350	1600	2180	1920
Minimum	1.97	2.87	3.01	3.29	2.39	3.27	2.91
Std. Dev.	358	411	481	550	377	509	450
Observations	357	357	357	357	357	357	357
All							
Mean	471	575	709	870	511	775	654
Median	102	124	149	204	114	172	130
Maximum	8710	10900	13100	16100	9600	14400	12200
Minimum	0.646	0.861	1.38	1.78	0.723	1.53	1.17
Std. Dev.	1190	1490	1820	2240	1310	1990	1680
Observations	1680	1680	1680	1680	1680	1680	1680

Table 8.3-2 : Average Capital Labour Ratio Across Regions

Period	81-85	86-90	91-95	96-00	80's	90's	80-00
Industrial Economies							
Mean	2.2	2.191	2.29	2.24	2.194	2.256	2.23
Median	2.296	2.253	2.363	2.327	2.261	2.341	2.312
Maximum	2.999	3.117	3.01	3.253	3.042	3.065	2.958
Minimum	1.113	1.168	1.179	1.038	1.127	1.125	1.126
Std. Dev.	0.423	0.425	0.491	0.521	0.419	0.495	0.457
Observations	483	483	483	483	483	483	483
East Asia and Pacific							
Mean	1.657	1.753	1.802	2.078	1.71	1.939	1.675
Median	1.557	1.61	1.636	2.007	1.575	1.826	1.656
Maximum	2.901	3.188	2.906	2.869	3.085	2.887	2.942
Minimum	0.849	1.021	1.138	1.369	0.931	1.296	0.09
Std. Dev.	0.598	0.622	0.562	0.592	0.62	0.563	0.825
Observations	168	168	168	168	168	168	168
Europe and Central Asia							
Mean	1.366	1.407	1.728	1.847	1.372	1.768	1.605
Median	1.366	1.407	1.728	1.847	1.372	1.768	1.605
Maximum	1.577	1.714	2.088	2.108	1.627	2.072	1.866
Minimum	1.155	1.1	1.369	1.585	1.117	1.464	1.343
Std. Dev.	0.213	0.31	0.364	0.265	0.258	0.308	0.265
Observations	42	42	42	42	42	42	42
Middle East and North Africa							
Mean	1.748	1.731	1.695	1.677	1.742	1.686	1.703

Period	81-85	86-90	91-95	96-00	80's	90's	80-00
Median	1.798	1.781	1.605	1.491	1.821	1.548	1.619
Maximum	2.357	2.276	2.407	2.407	2.321	2.394	2.366
Minimum	0.958	1.102	1.232	1.191	1.006	1.208	1.215
Std. Dev.	0.54	0.507	0.44	0.489	0.53	0.457	0.47
Observations	126	126	126	126	126	126	126
Latin America & Caribbean							
Mean	1.373	1.356	1.306	1.377	1.364	1.344	1.353
Median	1.301	1.276	1.192	1.403	1.281	1.275	1.3
Maximum	2.158	2.143	1.964	2.043	2.077	1.946	1.898
Minimum	0.704	0.738	0.624	0.536	0.727	0.585	0.631
Std. Dev.	0.476	0.437	0.408	0.426	0.45	0.412	0.419
Observations	420	420	420	420	420	420	420
South Asia							
Mean	0.947	0.954	0.944	0.962	0.95	0.953	0.952
Median	0.941	0.915	0.933	0.944	0.938	0.936	0.935
Maximum	0.971	1.083	1.042	1.095	1.006	1.072	1.049
Minimum	0.933	0.902	0.867	0.866	0.92	0.869	0.89
Std. Dev.	0.015	0.075	0.063	0.086	0.033	0.075	0.059
Observations	84	84	84	84	84	84	84
Sub-Saharan Africa							
Mean	1.123	1.011	0.983	0.909	1.074	0.944	0.994
Median	1.035	0.893	0.876	0.831	0.975	0.812	0.822
Maximum	2.378	1.92	1.898	1.873	2.197	1.878	1.833
Minimum	0.31	0.334	0.356	0.327	0.35	0.341	0.345
Std. Dev.	0.539	0.435	0.398	0.38	0.494	0.384	0.42
Observations	357	357	357	357	357	357	357
All							
Mean	1.593	1.572	1.591	1.609	1.584	1.598	1.573
Median	1.585	1.588	1.519	1.508	1.594	1.534	1.521
Maximum	2.999	3.188	3.01	3.253	3.085	3.065	2.958
Minimum	0.31	0.334	0.356	0.327	0.35	0.341	0.09
Std. Dev.	0.646	0.643	0.678	0.697	0.643	0.677	0.676
Observations	1680	1680	1680	1680	1680	1680	1680

Table 8.3-3 : Descriptive Statistics of Production Function

	ln (Y)	ln (K)	ln (L)
Mean	24.96	25.33	15.50
Median	25.16	25.50	15.30
Maximum	29.66	30.30	20.39
Minimum	20.40	20.29	10.77
Std. Dev.	1.77	2.01	1.63
Observations	320	320	320

8.4 Descriptive Statistics of Institutional Variables

Table 8.4-1 : Descriptive Statistics of Institutional Variables

Variable	Obs	Mean	Std. Dev.	Min	Max
GOV	320	18.52	6.37	5.89	40.81
TRS	298	9.46	8.54	.5	33.30
COURT	160	6.04	1.85	2.9	9.52
PROPR	112	5.59	1.76	1.65	8.80
COURT x PROPR	112	39.30	20.93	6.83	77.06
CREDIT	320	6.67	2.19	0	9.68
LABOR	197	5.09	1.14	3.20	8.53
DURAB	304	29.23	34.04	.17	189
XCONT	304	5.01	2.11	1	7
REGIME	304	3.79	6.70	-9.67	10
PR	315	2.88	1.97	1	7
FOREIGN	320	5.02	4.40	0	10
TRADEB	107	6.82	1.72	2.43	9.53
BLACK	320	8.15	2.79	0	10

Table 8.4-2 : Correlation Matrix of Institutional Variables

	GOV	TRS	COURT	PROPR	COURT x PROPR	CREDIT	LABOR	DURAB	XCONT	REGIME	PR	FOREIGN	TRADEB	BLACK
GOV	1													
TRS	0.5575	1												
COURT	0.6721	0.656	1											
PROPR	0.668	0.7054	0.8169	1										
COURT x PROPR	0.7023	0.6857	0.9391	0.9506	1									
CREDIT	0.0915	0.1281	0.5654	0.5271	0.5954	1								
LABOR	-0.1843	-0.252	0.1379	0.0082	0.0582	0.1313	1							
DURAB	0.386	0.4177	0.6227	0.6091	0.6564	0.1533	0.2173	1						
XCONT	0.2948	0.5246	0.5299	0.3942	0.4761	0.1817	-0.0388	0.4047	1					
REGIME	0.2382	0.5123	0.4629	0.3789	0.4366	0.1705	0.0007	0.3658	0.9625	1				
PR	-0.3108	-0.569	-0.5647	-0.5206	-0.5607	-0.1606	0.0195	-0.3745	-0.8483	-0.8834	1			
FOREIGN	0.1298	0.2983	0.3994	0.4749	0.4488	0.2566	0.1032	0.3298	0.4176	0.427	-0.4105	1		
TRADEB	0.519	0.6327	0.7448	0.7673	0.7843	0.5888	-0.0394	0.4038	0.4701	0.4847	-0.5461	0.4735	1	
BLACK	0.2414	0.2657	0.3545	0.3925	0.4179	0.1819	0.0582	0.2717	0.3411	0.3442	-0.32	0.2978	0.4683	1