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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-Martín (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 point².

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.
\[ y_i = a_i f(x_i; \beta) \quad 0 < a_i \leq 1 \quad (2.2.1) \]

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

Rewrite (2.2.1) in log-form:

\[ \ln y_i = \ln f(x_i; \beta) - u_i \quad (2.2.2) \]

where \( u_i = -\ln a_i \geq 0 \) 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:

\[ y_i = f(x_i; \beta) \exp(v_i - u_i) \quad (2.2.3) \]

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 \( \leq 0^3 \).

In short, we can interpret the above as follows: if \( u_i = 0 \), then \( \varepsilon \) (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 \( \varepsilon = v - u \) 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 \( v \).

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

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

3) 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

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\(^5\) 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:

\[
Y_{it} = x_{it} \beta + E_{it}
\]  

\[(3.1)\]

where \(E_{it} = V_{it} - U_{it}\) and \(i = 1, ..., N\) and \(t = 1, ..., T\)

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

Technical efficiency model is specified as:

\[
U_{it} = z_{it} \delta + W_{it}
\]  

\[(3.2)\]

where \(W_{it}\) is random variable and is defined by truncation of the normal distribution with zero mean and variance \(\sigma^2\) 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 \(\sigma^2\). \(z_{it}\) is a \((1 \times m)\) vector of country specific institutional environment which may vary over time. \(\delta\) is an \((m \times 1)\) vector of unknown coefficients of the country-specific inefficiency variable.
Thus, technical efficiency of production can be defined as:

\[ TE_i = \exp(-U_i) = \exp(-z_i \delta - W_i) \]  \hspace{1cm} (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:

\[
\begin{align*}
\ln Y_i &= \beta_0 + \beta_1 \ln K_i + \beta_2 \ln L_i + \beta_{africa} + \beta_{easia} + \beta_{mideast}, \\
&+ \beta_{eca} + \beta_{sas} + \beta_{lati} + \beta_{time} + v_{it} - u_i \hspace{1cm} (3.4)
\end{align*}
\]

where \( v_{it} \sim iid N(0, \sigma^2_v) \) is a random disturbance. \( u_i \) is cross-country technical inefficiency. \( \beta_0 \) is the constant term in production function to capture technical progress. The specification of the SPF model also includes regional dummies: namely Africa (\( \text{africa} \)), East Asia (\( \text{easia} \)), Middle East (\( \text{mideast} \)), Europe and Central Asia (\( \text{eca} \)), South Asia (\( \text{sas} \)) and Latin American (\( \text{latin} \)) 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 (\( \text{time} \)) to capture the possibility that production frontier shifts over time.

We specify the technical inefficiency model as follows\(^7\):

\[ u_i = \delta_1 \text{gov} + \delta_2 \text{politic} + \delta_3 \text{openness} + w_{it} \hspace{1cm} (3.5) \]

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

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\(^6\) 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 \( \gamma (= \frac{\sigma^2_u}{\sigma^2_u + \sigma^2_e}) \) 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. $\delta_j$ 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 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, we take a 5-year average for $Y$, $K$ and $L$ 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

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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\textsuperscript{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 (\textit{GOV}) and the size of transfer and subsidies over GDP (\textit{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 (\textit{COURT}) to proxy for the quality of legal system. We also use the index of intellectual property rights (\textit{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).

\textsuperscript{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\(^{12}\) \((\text{CREDIT})\) and labour market regulation index\(^{13}\) \((\text{LABOR})\). 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 \text{REGIME}. It ranges from -10 to 10 which represents the regime from authoritative to democratic. We are also interested in the durability \((\text{DURABLE})\) of the regime type which is measured by the number of years since the last regime transition. We also measure the executive constraints \((\text{XCONST})\) – 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 \((\text{PR})\). 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 \((\text{FOREIGN})\) to proxy the free flow of capital. Second, we use the index of measuring the level of regulatory trade barriers \((\text{TRADEB})\), 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 \((\text{BLACK})\) which is

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\(^{12}\) 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.

\[ \gamma = \frac{\sigma_u^2}{\sigma_u^2 + \sigma_v^2} \]

\( \gamma \) is equal to \( \frac{\sigma_u^2}{\sigma_u^2 + \sigma_v^2} \) 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]

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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

<table>
<thead>
<tr>
<th>ind. var.</th>
<th>coefficient</th>
<th>(standard error)</th>
</tr>
</thead>
<tbody>
<tr>
<td>constant</td>
<td>3.6979***</td>
<td>(0.1799)</td>
</tr>
<tr>
<td>lnK</td>
<td>0.6368***</td>
<td>(0.0133)</td>
</tr>
<tr>
<td>lnL</td>
<td>0.3427***</td>
<td>(0.0152)</td>
</tr>
<tr>
<td>time</td>
<td>0.0010</td>
<td>(0.0098)</td>
</tr>
<tr>
<td>africa</td>
<td>0.0640</td>
<td>(0.0436)</td>
</tr>
<tr>
<td>latin</td>
<td>0.0807**</td>
<td>(0.0383)</td>
</tr>
<tr>
<td>easia</td>
<td>0.0047</td>
<td>(0.0519)</td>
</tr>
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<td>eca</td>
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<td>(0.0550)</td>
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<td>sas</td>
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<td>(0.0593)</td>
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<td>mideast</td>
<td>0.0360</td>
<td>(0.0507)</td>
</tr>
</tbody>
</table>

Dependent Variable: $u_i$ (technical inefficiency)

Panel II: Estimation of the Technical Efficiency Model

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

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
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<tbody>
<tr>
<td>$\sigma^2$</td>
<td>0.0756***</td>
<td>(0.0115)</td>
</tr>
<tr>
<td>$\gamma$</td>
<td>0.8260***</td>
<td>(0.0434)</td>
</tr>
<tr>
<td>log (likelihood)</td>
<td>106.9769</td>
<td></td>
</tr>
</tbody>
</table>

***, **, * 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 arises 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.\footnote{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 labour force. However, cross-country and annual data on unemployment rate is very patchy which significantly reduces our sample size.}

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 \textit{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 (\textit{DURAB}) is significantly negative. Irrespective of the type of regime, the longer the regime can sustain, the country is less efficient. Political rights (\textit{PR}) secures private property from government/military conscription and it is significant at 5\% level. Executive constraint (\textit{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 (\textit{FOREIGN}, \textit{TRADEB}, \textit{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 (\textit{TRADEB}) is significant at 5\%. The freedom to own foreign currency bank accounts (\textit{FOREIGN}) and black market premium exchange rate (\textit{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.
### 5.1 Measures on Technical Efficiency (Complete Measures)

<table>
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<tr>
<th>country</th>
<th>TE (81-85)</th>
<th>TE (86-90)</th>
<th>TE (91-95)</th>
<th>TE (96-00)</th>
<th>Change (%) (81-00)</th>
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</table>
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.

<table>
<thead>
<tr>
<th>country</th>
<th>TE (81-85)</th>
<th>TE (86-90)</th>
<th>TE (91-95)</th>
<th>TE (96-00)</th>
<th>Change(%)</th>
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<td>0.9506</td>
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<td>0.9717</td>
<td>0.9722</td>
<td>2.8077</td>
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<tr>
<td>United States</td>
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<td>0.9779</td>
<td>0.982</td>
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<tr>
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<tr>
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<td>0.7604</td>
<td>0.7599</td>
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<td>17.0124</td>
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</tbody>
</table>

Mean TE\textsuperscript{16} 0.8144  0.8220  0.8374  0.8496  4.7795

\textsuperscript{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>
<thead>
<tr>
<th></th>
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<th></th>
</tr>
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<tr>
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<tr>
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<td>0.0355</td>
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</tr>
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<tr>
<td>Max</td>
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<tr>
<td><strong>Europe and Central Asia</strong></td>
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</tr>
<tr>
<td>Mean</td>
<td>0.9230</td>
<td>0.9312</td>
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<tr>
<td>Std Dev</td>
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<td></td>
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<td>0.8417</td>
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<td>Std Dev</td>
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<td>Count</td>
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<td><strong>Latin America and Caribbean</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>0.8237</td>
<td>0.8252</td>
<td>0.8337</td>
<td>0.8418</td>
</tr>
</tbody>
</table>

22
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.

\[
\frac{TFP}{TFP} = \frac{\dot{Y}}{Y} - \beta_1 \frac{\dot{K}}{K} - \beta_2 \frac{\dot{L}}{L}
\]  

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

<table>
<thead>
<tr>
<th>Period</th>
<th>Output Growth</th>
<th>Capital Growth</th>
<th>Labour Growth</th>
<th>TFP Growth</th>
<th>Technical Efficiency Change</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Industrial Economies</strong></td>
<td></td>
<td></td>
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<td></td>
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</tr>
<tr>
<td>81-85</td>
<td>1.97%</td>
<td>3.24%</td>
<td>1.08%</td>
<td>-0.46%</td>
<td>..</td>
</tr>
<tr>
<td>86-90</td>
<td>3.33%</td>
<td>3.31%</td>
<td>1.10%</td>
<td>0.85%</td>
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<td>-0.13%</td>
<td>1.92%</td>
</tr>
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<td>3.50%</td>
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<td>0.72%</td>
<td>1.22%</td>
<td>0.12%</td>
</tr>
<tr>
<td>81-00</td>
<td>2.69%</td>
<td>3.12%</td>
<td>0.97%</td>
<td>0.37%</td>
<td>3.42%</td>
</tr>
<tr>
<td><strong>East Asia and Pacific</strong></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>81-85</td>
<td>5.19%</td>
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<td>2.67%</td>
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<tr>
<td>86-90</td>
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<td>2.06%</td>
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<tr>
<td>91-95</td>
<td>7.00%</td>
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<td>0.82%</td>
<td>2.42%</td>
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<td>96-00</td>
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<tr>
<td>81-00</td>
<td>5.80%</td>
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<td>2.39%</td>
<td>0.11%</td>
<td>7.18%</td>
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<td><strong>Europe and Central Asia</strong></td>
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<td>81-85</td>
<td>3.57%</td>
<td>3.48%</td>
<td>1.02%</td>
<td>1.01%</td>
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<td>2.91%</td>
<td>4.68%</td>
<td>0.80%</td>
<td>-0.34%</td>
<td>0.88%</td>
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<tr>
<td>91-95</td>
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<td>3.91%</td>
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<tr>
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<td>81-85</td>
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<td>86-90</td>
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<td>-0.17%</td>
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<td>3.64%</td>
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<td>3.39%</td>
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<tr>
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<td>4.18%</td>
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<td>0.12%</td>
<td>5.18%</td>
</tr>
<tr>
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</tr>
<tr>
<td>81-85</td>
<td>0.94%</td>
<td>3.84%</td>
<td>2.88%</td>
<td>-2.49%</td>
<td>..</td>
</tr>
</tbody>
</table>

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.
<table>
<thead>
<tr>
<th>Period</th>
<th>Output Growth</th>
<th>Capital Growth</th>
<th>Labour Growth</th>
<th>TFP Growth</th>
<th>Technical Efficiency Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>86-90</td>
<td>2.52%</td>
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<td>2.68%</td>
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<td>91-95</td>
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</tr>
<tr>
<td>96-00</td>
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<td>-0.61%</td>
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</tr>
<tr>
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<td>3.34%</td>
<td>2.71%</td>
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</table>

**Sub-Saharan Africa**

<table>
<thead>
<tr>
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<th>Output Growth</th>
<th>Capital Growth</th>
<th>Labour Growth</th>
<th>TFP Growth</th>
<th>Technical Efficiency Change</th>
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</table>

**All**

<table>
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<th>TFP Growth</th>
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<td>2.15%</td>
<td>0.15%</td>
<td>4.23%</td>
</tr>
</tbody>
</table>

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.
7 Bibliography


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\(^\text{18}\). 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 \(\delta\) 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:

\[
\kappa_i = i_i / (\delta + \lambda g_i + (1 - \lambda) g_w)
\]

(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. \(\lambda\) 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:

\[
K_{i,60} = \kappa_i \cdot Y_{i,60}
\]

(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.
\[ K_{t+1} = I_t + (1 - \delta)K_t \]  \hspace{1cm} (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

<table>
<thead>
<tr>
<th>Economy</th>
<th>Code</th>
<th>Income group</th>
</tr>
</thead>
<tbody>
<tr>
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<td></td>
<td></td>
</tr>
<tr>
<td>1 Australia</td>
<td>AUS</td>
<td>High income</td>
</tr>
<tr>
<td>2 Austria</td>
<td>AUT</td>
<td>High income</td>
</tr>
<tr>
<td>3 Belgium</td>
<td>BEL</td>
<td>High income</td>
</tr>
<tr>
<td>4 Canada</td>
<td>CAN</td>
<td>High income</td>
</tr>
<tr>
<td>5 Denmark</td>
<td>DNK</td>
<td>High income</td>
</tr>
<tr>
<td>6 Finland</td>
<td>FIN</td>
<td>High income</td>
</tr>
<tr>
<td>7 France</td>
<td>FRA</td>
<td>High income</td>
</tr>
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**South Asia**

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**Sub-Saharan Africa**

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### 8.3 Data Analysis and Descriptive Statistics

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

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Table 8.3-2: Average Capital Labour Ratio Across Regions

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Sub-Saharan Africa

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Table 8.3-2: Average Capital Labour Ratio Across Regions

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**Latin America & Caribbean**

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**All**

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**Table 8.3-3 : Descriptive Statistics of Production Function**

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### 8.4 Descriptive Statistics of Institutional Variables

**Table 8.4-1: Descriptive Statistics of Institutional Variables**

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