Malaysian Journal of Economic Studies Vol. XXXXII Nos. 1 & 2, 2005 ISSN 1511-4554

Openness and Efficiency of Malaysia, India and China Relative to the World Economy: A Comparative Study

[1]Guy S. LIU, [2]Xiaming LIU[2] and [3]Yingqi WEI[3]

Abstract: This paper adopts a dynamic approach to investigate the impact of openness on efficiency improvement of the world economy and compares the linkages between openness and performance in Malaysia, India and China. Based on a panel of data covering 126 countries over the period 1970-98, a world production frontier was established using stochastic frontier techniques. The economic efficiency of an economy relative to the world production frontier was identified and its determinants examined. The results indicate that openness, as measured by international trade, foreign direct investment (FDI) and its interaction with human capital plays a positive role in improving efficiency, although the impact of trade is not as robust as that of FDI. Given its highest degree of openness, Malaysia enjoyed the highest relative economic performance among the three economies. Contrary to the conventional perception, India performed better than China in raising efficiency until the mid-1990s. However, China has experienced a higher degree of openness and therefore a faster rate of catching-up with the world's best efficiency practices than India.

1. Introduction

The relationship between openness and economic growth has long been a subject of controversy. Liberal analysts suggest that free trade would lead to better economic performance, but some economists argue that protectionism may promote faster growth. Grossman and Helpman (1991), Rivera-Batiz and Romer (1991) and Barro and Sala-I-Martin (1995) propose that openness can have a positive impact on growth, but openness may not automatically lead to growth. For instance, Grossman and Helpman (1991: Ch. 9) show that whether or not a country gains from openness to trade depends on a number of factors, including its comparative advantage *vis-à-vis* the rest of the world. Buffie (1992) contends that whether an export boom acts as an engine of growth depends on the structural characteristics of the economy.

Most empirical tests of the openness-growth relationship are based on the growth accounting approach. Total factor productivity (TFP), defined as a ratio of aggregate output to combined factors used, is estimated from the traditional production function, and then regressed on openness, normally proxied by international trade measures, as well as other relevant explanatory variables. The growth accounting approach implicitly assumes economic efficiency, and therefore may be applied validly only to equilibrium states and marginal changes over short periods of time (Nelson and Pack 1999). The notable examples of research on linkage between openness and TFP include cross-section analyses by Dollar (1992), Sachs and Warner (1995), Edwards (1998) and a panel data study by Miller and Upadhyay

1 Department of Economics and Finance, Brunel University, Uxbridge, UB8 3PH, UK.
Email: *guy.liu@brunel.ac.uk*

2 Aston Business School, Aston University, Birmingham, B4, 7ET, UK.
Email: *x.liu@aston.ac.uk*

3 Department of Economics, Lancaster University Management School, Lancaster University LA1 4YX, UK.
Email: *y.wei@lancaster.ac.uk*

(2000). If TFP is regressed on openness under the assumption of economic efficiency, the contribution of openness to technological progress may be biased–the growth of TFP can be due to gains in efficiency, as well as to technical progress (Groskopf 1993; Maudos *et al.* 2000).

An alternative method is the production frontier approach. This line of analysis focuses on efficiency, which can be defined as an economic unit's production relative to some predicted level of maximum output given the level of inputs available at a given point in time. This method has been applied in the past mainly at the micro level, but has gradually gained popularity in macroeconomic analyses in recent years. For example, Fare *et al.* (1994), Kruger *et al.* (2000), Maudos *et al.* (2000), Salinas-Jimenez (2003) and Henderson and Russell (2005) adopt a non-parametric production frontier function determined by the data envelopment analysis (DEA) to examine productivity differences and convergence. Moroney and Lovell (1997) use a stochastic production frontier model to compare the relative efficiency of market and planned economies.

One common feature of many existing studies is that they are static, ignoring adjustment costs in a dynamic process of labour and capital substitution. The impact of knowledge spillovers brought by opennness on re-organising production for efficiency improvement could be played down by high adjustment costs in an economy. The rigidity of the adjustment in production for Chinese state-owned enterprises was an example, since these enterprises were supplied with immobile labour forces. This suggests that without control of the adjustment process, it is hard to measure the true influence of openness on an economy for its productivity improvement. Another common feature in the existing openness literature is that foreign direct investment (FDI), an important variable which reflects both the stock of advanced technological knowledge and the intensity of market competition between domestic incumbents and new foreign entrants, is often excluded from the estimation of the effect of openness on productivity improvement.

To take these arguments into account in estimating the relationship between openness and productive efficiency, the current paper departs from many exisiting studies in two aspects: (1) dynamic panel data models are adopted to identify a world production frontier for analysing efficiency changes of individual countries and to estimate the impact of openness on the time-variant efficiency; and (2) FDI and its interaction with human capital are explicitly included as the important measures of openness in explaining efficiency improvement.

With the establishment of the world production frontier, comparison of economic efficiency can be made between any economy. In this study, Malaysia, India and China were chosen as they are three very important Asian developing countries which not only share some similarities but also have many differences. For instance, their degrees of openness are very different. A comparison of these economies can provide important policy implications for openness and growth in the developing world. Indeed, the efficiency comparison of Malaysia, India and China relative to the world production frontier shows that Malaysia performed best because of its highest degree of openness. India had outperformed China in the quality of growth until the mid-1990s.

The paper is organised as follows. The next section reviews the literature on openness and efficiency. Section 3 describes the data, methodology and estimation procedures used. Section 4 presents the empirical results on the impact of openness on efficiency. Section 5 compares the linkages between openess and efficiency in Malaysia, India and China relative to the world production frontier. A final section offers the overall conclusion of the paper.

2. Openness and Efficiency

The literature on the relationship between openness and economic performance mainly focuses on the impact of trade orientation on productivity. Neoclassical growth models assume that technical change is exogenous, and is not affected by a country's trade policy. As Edwards (1993) notes, in the 1950s, 1960s, and 1970s free trade policies were not widely supported.

In the last two decades, there have been hot debates on whether trade liberalisation packages have played an important role in the performance of the outward-oriented economies. Taylor (1991) argues that the trade liberalisation strategy is intellectually moribund, and that there are no great benefits (plus some losses) in following open trade and capital market strategies. Therefore, 'development strategies oriented internally may be a wise choice towards the century's end' (Taylor 1991).

Grossman and Helpman (1991) argue that protection could enhance long-run growth if government intervention in trade encourages domestic investment along the comparative advantage lines. Levine and Renelt (1992) note that increasing openness may raise long-run growth only when openness provides greater access to investment goods. Trade liberalisation may stimulate FDI inflows. However, if domestic investment is discouraged because of increased international competition, the output effect of the two driving forces is ambiguous. Batra (1992), Batra and Slottje (1993) and Leamer (1995) have gone further by suggesting that free trade can be a primary source of economic downturn. Trade liberalisation and openness imply lower tariffs. This may make imports more attractive than domestic production. Thus, the domestic economy may suffer a loss.

On the other hand, international trade was seen as the engine of growth by many economists such as Adam Smith and David Ricardo. Benefits from free trade have been widely documented since. For instance, Scitovsky (1954) suggests that exports produce positive externalities whose favourable impact is particularly significant in economic development. Keesing (1967), Bhagwati (1978), and Krueger (1978) argue that openness exposes countries to the most advanced new ideas and methods of production dictated by international competitive behaviour, and thus it enhances efficiency. Through openness countries manage to overcome the small size of their domestic market and reap in the process, the cost advantage of increasing returns to scale. Chenery and Strout (1966) and Voivodas (1973) contend that exports contribute to a relaxation of foreign exchange constraints that normally impinge on development efforts.

The importance of international trade to economic performance has been strongly emphasised in new or endogenous growth theory (Grossman and Helpman 1991). While neoclassical theory regards technical progress as an exogenous process, endogenous growth theory views commercially oriented innovation efforts that respond to economic incentives as a major engine of technological progress and productivity growth. Endogenous growth theory argues that international trade enables a country to use a large variety of technologically advanced physical capital, which may enhance the productivity of its own resources. International trade promotes across-the-board learning in product design, facilitates the diffusion and imitation of foreign technologies and helps the creation of innovations.

Although the term openness is widely used in international economics and in the economic growth literature, there is no consensus on how to measure it. In existing empirical studies, various measures have been tried. These include trade dependency ratios and the rate of export growth (Balassa 1982), the trade orientation indexes which are defined as the distance between actual trade and the trade predicted by the 'true' model in the absence of distortion (Leamer 1988; Wolf 1993), the World Bank's outward orientation index which classifies countries into four categories according to their perceived degree of openness (World Bank 1987), the 'subjective index' of trade liberalisation (Michaely *et al.* 1991), the black market premium for foreign exchange (Levine and Renelt 1992), the average import tariff on manufacturing and the average coverage of non-tariff barriers reported by UNCTAD and used in Barro and Lee (1994), the composite openness index which is based on trade-related indicators such as tariffs, quotas coverage, black market premium, social organisation and the existence of export marketing boards (Sachs and Warner 1995), and the Heritage Foundation index of trade policy which classifies countries into five categories according to the level of tariffs and other perceived distortions (Johnson and Sheehy 1996).

Significant efforts have been made to construct a satisfactory comparative openness index, but the vast majority of the existing openness measures continue to be subject to various limitations (Edwards 1998). As international trade is influenced by various factors such as tariff and non-tariff barriers and exchange controls, it is very difficult, if not impossible, to develop an ideal indicator for openness. Therefore, instead of using just one or at most two of these indexes to study the relationship between openness and economic performance, which is the case in most empirical studies, Edwards (1998) uses nine measures of openness in order to determine whether econometric results are robust to alternative indexes.

One fundamental problem with the above indexes is their ignorance of FDI. FDI is a composite bundle of capital stocks, know-how and technology. FDI transfers are not just capital and managerial skills, but also embodied and tacit technologies. The special role that FDI plays in tacit technology transfer and diffusion cannot be replaced by any other form of international integration (Balasubramanyam *et al.* 1996). Multinational enterprises (MNEs) are among the most technologically advanced firms, accounting for a substantial part of the world R&D investment. As a result, FDI is considered to be a major channel for the access to advanced technologies (Borensztein *et al.* 1998). Specifically, MNEs may develop new products and technologies earlier than indigenous firms, exert competitive pressure on them and force them to imitate or innovate. MNEs may generate spillover effects on the local economy via 'learning by doing' or 'learning by watching' by indigenous firms. Furthermore, advanced technologies or ideas may be diffused via the movement of labour from foreign subsidiaries to indigenous firms. All this indicates that FDI has an important effect on economic performance, and needs to be seen as a very important component of openness.

Another problem with many existing openness indexes is that they are available for just one or a few years due to lack of comparative data. Consequently empirical tests of openness on economic performance are mostly restricted to cross-section analyses (see Dollar 1992; Sachs and Warner 1995; Edwards 1998), although Edwards (1993) suggests that a more precise answer to the general question of how openness affects output growth would require more detailed analysis relying at least in part on time series data. One exception is Miller and Upadhyay (2000), where the available time series of the ratio of exports to GDP, the terms of trade and local price deviation from purchasing power parity were used to measure openness.

When examining the impact of openness on economic performance, most extant empirical studies relate trade orientation to TFP obtained from growth accounting. Recent examples include Sachs and Warner (1995), Edwards (1998) and Miller and Upadhyay (2000). As mentioned earlier, this type of research is based on the conventional measure of technological change, i.e. equating the Solow residual to TFP, and may lead to biased estimates of technical progress in the presence of inefficiency (Grosskopf 1993).

While there is a large literature on openness and productivity, how to define productivity is still a question worth noting. Fare *et al.* (1994) decompose TFP of an industry into two components: a shift in the production frontier that is the best possible output level obtained in the industry for the given inputs and technology, and a shift of firms towards the frontier. The first shift reflects technical progress in the industry, and the second measures a change in technical efficiency that is the ratio of the actual output to the best potential output. Based on this concept of productivity, we will measure the economic performance of each country relative to the world best possible achievement for the available resources and technology in a time period. This comparative measurement of economic performance is called economic efficiency, identical to the concept of technical efficiency of Fare *et al.* (1994). In this sense, a change in efficiency of an economy is different from a change in the productivity. For instance, if innovations increase production potential by 5 per cent for the same level of capital and labour input, and actual output rises by 3 per cent, a productivity index would indicate an increase of 3 per cent, while an efficiency measurement would show only 98 per cent efficiency, a 2 per cent reduction. So it is possible that the improvements in productivity and economic efficiency move in different directions. This suggests that one advantage of using economic efficiency measurement to analyse the role of openness is to enable us to identify how openness enables the catch-up effect to reduce the efficiency gap between the host economy and the world's best possible efficiency practice.

3. Data, Methodology and Estimation Procedures

Most of the data used in this paper are taken from the World Bank's World Development Indicators (WDI) CD-ROM. There are no capital stock data available directly. Capital stocks are estimated mainly from available gross domestic fixed investment (constant 1995 price) data from WDI CD-ROM based on the standard perpetual inventory method (See Appendix 2). When estimating the world production frontier, a panel data set covering 126 countries for the period 1970-98 was employed.

Either a non-parametric or a stochastic frontier approach can be used to relate openness to an economy's efficiency relative to the world best possible practice. A major advantage of the non-parametric frontier approach based on the data envelopment analysis (DEA) is that there is no need to impose any functional form arbitrarily on the dataset. However, the technical efficiency measures from this deterministic frontier production function computed from mathematical programming are susceptible to extreme observations and measurement errors (Forsund *et al.* 1980; Kalirajan and Shand 1999); they ignore stochastic shocks and are lacking in statistical properties (Martin-Marcos and Suarez-Galvez 2000). On the other hand, modelling a production function following the stochastic frontier approach is in conformity with production theory (Fried *et al.* 1993), and offers flexibility in testing various hypotheses. A major criticism against the stochastic frontier approach is that it requires the imposition of a specific distributional assumption on country-specific efficiency-related variables. However, this problem can be resolved by introducing country-specific dummy variables in the stochastic frontier estimation.

In this study, the world production frontier is estimated based on the following stochastic production frontier model:

$$y_{it} = a_i + b_t + \alpha(1 - \theta)k_{it} + \beta(1 - \theta)l_{it} + \theta y_{it-1} + v_{it} - u_{it} \quad (1)$$

where i and t denote the cross-section and time series observations respectively, and y_{it} is the natural log of output level, i.e. GDP in the i[th] country at the t[th] period of observation. The coefficient a_i is the country-specific time invariant efficiency, capturing the fixed effects on the differences of efficiency between the countries/regions in the long run, which could be a result of the quality of macroeconomic management system and natural resources available to the country. The coefficient b_t is the time-specific effect, picking up shifts in the world production frontier over time, while k_{it} and l_{it} are the natural log of capital and labour respectively. The null hypothesis implied in equation (1) is that there are constant returns to scale in production in the long run (i.e. $\alpha + \beta = 1$), but the directly estimated elasticity of capital or labour is for the short run. The coefficient θ reflects the pace of dynamic adjustment process of input substitution for output changes. The error terms v_{it} and u_{it} are assumed to be independently distributed, v_{it} is a random disturbance term with $N(0, \sigma_v^2)$, and is associated with the random factors which are beyond the country's control and u_{it} is a non-negative random variable. Economic efficiency is estimated as $exp(-u_{it})$, which is the short-run efficiency, arising from the improvement of management in employing the given natural resources and production factors for producing outputs.

The dynamic model of equation (1) departs from the static production frontier equation where lagged adjustment of output is not included as an explanatory variable. This type of dynamic model has been applied in Nickell (1996) and Hay and Liu (1997) at the firm and industry level respectively. The introduction of dynamics is not just to capture the dynamic adjustment process, but also to alleviate any bias caused by the possible exclusion of explanatory variables other than capital and labour. With the presence of the autocorrelation in estimating equation (1), the lagged dependent variable is instrumented using orthogonal pre-determined variables, such as y_{it-3} backwards.

Given that u_{it} is allowed to vary over time, there is a need to impose a specific distributional assumption. u_{it} can be assumed to follow the exponential, truncated normal, or half normal distributions, and the estimated results from the different assumptions are subject to hypothesis testing. The truncated normal model has been compared with that of the half normal. Given that is statistically insignificant, the assumption that u_{it} follows a truncated distribution with $N(\mu, \sigma_u^2)$ is invalid. Having controlled for the country-specific fixed effects, the time effects and the dynamic adjustment process, the frontier models based on the half-normal and the exponential distribution assumptions provide similar estimation results, therefore only results assuming exponential distribution are reported.

Our panel estimation is based on a two-way fixed-effects model since (1) the Hausman test rejects the random effects model, and (2) the likelihood ratio test rejects the insignificance of both year and country fixed effects. Moreover, the estimation has taken into account the possible endogenous effect of explanatory variables, such as capital (k), labour (l), the trade ratio (tr) and foreign direct investment (fd), by applying the Wu-Hausman test to identify the effect. As can be seen in Tables 1 and 2, the Wu-Hausman statistics strongly reject the exogeneity claim for the variables in our large-sample estimation, and therefore, GMM techniques are applied to the estimation.

We are interested in examining the relationship between openness and the time-variant efficiency of countries. More specifically, we would like to estimate the following general equation:

$$m_{it} = \lambda_i + \xi_i + \Phi' Openness_{it} + \Gamma' HumanCapital_{it} + \Pi DomesticFixedInvestment_{it} + m_{it-1} + \varepsilon_{it} \quad (2)$$

where $m_{it} = \log[\exp(-u_{it})]$ is the time-varying efficiency estimated from equation (1). There can be several different measures in the vector of $Openness_{it}$. Based on the availability of time series data, FDI, international trade, and the black market premium for foreign exchange are used to measure openness. The other variables on the right hand side of equation (2) are the control variables. The vector $HumanCapital_{it}$ contains secondary and tertiary school enrolment. Human capital is seen to be very important in economic development in new growth theory and is expected to have a positive impact on efficiency changes. The interaction between FDI and human capital is introduced in the regressions to examine if there is a minimum threshold of human capital for FDI to have a positive impact. The introduction of a similar interaction term can be found in Borensztain *et al.* (1998). Domestic fixed investment relative to GDP is a country's own investment in fixed assets such as machinery and equipment. This upgrades embodied technologies or improves the infrastructure, and is expected to have a positive impact on economic performance. Moreover, placing domestic fixed investment and FDI in the estimation enables us to directly test whether there is any crowding-out effect of FDI on domestic investment. λ_i are the country fixed effects, whereas ξ_t are the year dummies.

Equation (2) is estimated in a dynamic form in order to capture the costs of the adjustment process in changing efficiency. The higher the adjustment costs, the slower the process of efficiency change will be in response to greater openness. With the presence of first and second order autocorrelation, the lagged efficiency variable is instrumented using its third and higher order lagged dependent variables as the instruments Z in order to ensure Cov $(Z,\varepsilon) = 0$.

Having pursued a general investigation of the role of openness in promoting efficiency improvement, efficiency changes over time are plotted against the growth of FDI and trade for Malaysia, China and India in order to learn their comparative experiences.

4. Empirical Results

Table 1 represents our estimation of equation (1) for efficiency measurement. The estimation starts with a full estimation of the Cobb-Douglas function with two extensions: (1) a dynamic

Table 1: Estimation of the world production frontier

Dep. variable y_{it}=log(GDP)$_{it}$	Dynamic panel data estimation (GMM)		Panel stochastic frontier estimation	
Indep. Variables	Dynamic	Static	Half-normal	Exponential
Intercept	1.877 (1.1)	-0.961 (0.3)	2.083 (2.6)	4.157 (4.8)
k_{it}	0.288 (4.4)	0.893 (11.6)	0.218 (6.6)	0.162 (4.8)
l_{it}	0.062 (2.4)	0.095 (2.9)	0.067 (2.5)	0.048 (2.1)
tr_{it}	0.032 (3.0)	0.031 (2.7)		
fd_{it}	0.023 (7.5)	0.028 (7.4)		
y_{it-1}	0.541 (35.1)	-	0.593 (45.9)	0.577 (43.6)
Statistics of estimations				
Country-fixed effect (χ^2)	9668.24	8634.49		
[countries: Σa_i=0, df = 125]	[0.000]	[0.000]	Included	Included
Year-time effect (χ^2)	357.20	149.96	Included	Included
[years: Σb_t=0, df = 20]	[0.000]	[0.000]		
Hausman (F-Statastic)	1219.2	773.68		
[H_0: Random Effect]	[0.000]	[0.000]		
Wu-Hausman (χ^2)	42.52	36.65		
[H_0: Exogeneity, df=4]	[0.000]	[0.001]		
$\hat{\sigma}_\varepsilon$	0.102	0.491		
AR [1]	0.789 (34.6)	1.048 (47.1)		
AR [2]	-0.001 (0.05)	-0.184 (8.1)		
$\lambda = \sigma_u / \sigma_v$			0.745 (2.9)	
$\sigma = (\sigma_u^2 + \sigma_v^2)^{0.5}$			0.114 (5.7)	
θ				10.678
(26.2)				
σ_v				0.053 (22.5)
U^2			0.0046	0.0028
V^2			0.0083	0.0028
N	2247	2247	2241	2241
Instrument Set	$k_{it-2} \sim k_{it-24}$	$k_{it-2} \sim k_{it-24}$	$k_{it-2} \sim k_{it-24}$	$k_{it-2} \sim k_{it-24}$
$\Delta l_{it-2} \sim \Delta l_{it-8}$	$\Delta l_{it-2} \sim \Delta l_{it-8}$	$\Delta l_{it-2} \sim \Delta l_{it-8}$	$\Delta l_{it-2} \sim \Delta l_{it-8}$	
	$l_{it-2} \sim l_{it-24}$	$l_{it-2} \sim l_{it-24}$	$l_{it-2} \sim l_{it-24}$	$l_{it-2} \sim l_{it-24}$
$\Delta tr_{it-2} \sim \Delta tr_{it-24}$	$\Delta tr_{it-2} \sim \Delta tr_{it-24}$	$q_{it-3} \sim q_{it-24}$	$q_{it-3} \sim q_{it-24}$	
	$tr_{it-2} \sim tr_{it-24}$	$tr_{it-2} \sim tr_{it-24}$		
	$fd_{it-2} \sim fd_{it-24}$	$fd_{it-2} \sim fd_{it-24}$		
	$q_{it-3} \sim q_{it-24}$			

Notes:

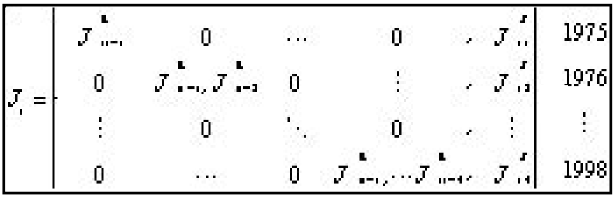
1. All variables in small letter means that they are in logarithm.
2. t-statistics are in parentheses, and p-values are in square brackets.
3. The likelihood ratio statistic is applied to test the country fixed effects and the year specific effects.
4. The presence of higher-order autocorrelation is detected on the basis of

$$y_{it} = \Sigma a_i D_i + \Sigma b_t T_t + f(\hat{X}, \hat{\beta}) + \theta y_{it-1} + \hat{\varepsilon}_{it}$$

where $\hat{\varepsilon}_{it} = \rho_{t-1}\hat{\varepsilon}_{it-1} + \rho_{t-2}\hat{\varepsilon}_{it-2} + \varepsilon_{it}$ $\qquad \varepsilon_{it} \sim N(0, \sigma_\varepsilon^2)$.

Notes (Cont'd):

5. The basic instrument set used is of the form:



where $\mathbf{J}^{L}_{k}$ is the vector of pre-determined variables, and $\mathbf{J}^{X}_{k}$ is the vector of exogenous variables including dummies (Sargan 1988 ; Arellano and Bond 1991).

6. Since the Wu-Hausman statistic rejects the exogeneity of k, l, tr and fd, instrumental variables (**Z**) are applied, which include the corresponding pre-determined variables from lag 2 onwards in order to ensure Cov $(\mathbf{Z}, e_{it-2}) = 0$.

adjustment process and (2) the openness effect. The estimation is compared with the static estimation, and we find that the latter is mis-specified, evidenced by the strong presence of first and second order autocorrelation and the negative constant coefficient as well as the unusually large estimated capital elasticity. In estimating our dynamic panel stochastic frontier equation, the FDI and trade variables are excluded in order to create the residual variable of the efficiency, $exp(-u_{it})$, for our second-stage estimation. It is expected that efficiency will be related to openness if the increase in output as a result of openness is not captured in the production function.

Having obtained the economic inefficiency indexes relative to the world production frontier given the resources available for production, u_{it}, we are in a position to assess the impact of openness on efficiency. Table 2 shows the results. In the estimation, the Wu-Hausman statistic rejects the exogeneity of the FDI variable. As a result, an instrumental-variable estimation is carried out. The dynamic variable and the endogenous variables are instrumented by the pre-determined variables from lag 3 backwards in order to ensure the orthogonality between the instruments and the disturbance term that have first and second order autocorrelation. Another technical issue is the multicollinearity between trade and FDI. Therefore, the trade ratio is differenced once to mitigate the problem.

Since similar results are obtained from the half-normal and the exponential distribution frontier models in the first-stage estimation, the information from the exponential model is used in the regressions of efficiency on openness. As indicated in Table 2, the results suggest that both FDI stock and the growth in the trade-GDP ratio have positive and significant impacts on efficiency. This lends strong support to the hypothesis that openness promotes efficiency improvement. Openness introduces advanced technologies and managerial skills and promotes competition. All this helps move the production of an open economy towards the worlds' best possible practice.

As mentioned earlier, this study also introduces the black market premium for foreign exchange as an alternative measure of openness. In addition, human capital and domestic investment in fixed assets are also important in determining economic performance. These two types of variables should be controlled for when the relationship between efficiency

Table 2: Openness and efficiency of the world economy: a dynamic panel data GMM estimation

Dep. variable $m_{it} = \log[\exp(-u_{it})]$	Total sample			
Indep. variables	Endogenous		Exogenous	
Intercept	-0.108	(2.5)	- 0.149	(5.9)
Δtr_{it}	0.065	(3.2)	0.061	(3.1)
fd_{it}	0.022	(3.1)	0.036	(8.5)
m_{it-1}	0.605	(12.2)	0.554	(11.3)
Country-fixed effect (χ^2)	235.36		263.18	
[countries: $\Sigma a_i = 0$, $df = 79$]	[0.000]		[0.000]	
Year-time effect (χ^2)	31.57		91.17	
[year: $\Sigma b_t = 0$, $df = 20$]	[0.004]		[0.001]	
Hausman (F-Statistic)	3.13		2.83	
[H_0: Random Effect]	[0.005]		[0.005]	
Wu-Hausman (χ^2)	6.034		----	
[H_0: Exogeneity]	[0.025]			
AR [1]	0.671	(19.0)	0.663	(18.9)
AR [2]	-0.199	(4.6)	-0.182	(4.3)
AR[3]	-0.039	(0.7)	0.011	(0.2)
$\bar{\sigma}_\varepsilon$	0.060		0.059	
$\bar{R}^2$	0.26		0.29	
N	1280		1280	
Instrument Set	$\Delta tr_{it-3} \sim \Delta tr_{it-18}$		$m_{it-3} \sim m_{it-18}$	
	$tr_{it-3} \sim tr_{it-18}$			
	$d_{it-3} \sim fd_{it-18}$			
	$m_{it-3} \sim m_{it-18}$			

Notes:

(1)-(3) and (5) are the same as in Table 1.

(4) The presence of higher-order autocorrelation is detected on the basis of

$$m_{it} = \Sigma a_i D_i + \Sigma b_t T_t + f(\hat{X}, \hat{\beta}) + \theta\, m_{it-1} + \hat{\varepsilon}_{it}$$

where

$$\hat{\varepsilon}_{it} = \rho_{t-1}\hat{\varepsilon}_{it-1} + \rho_{t-2}\hat{\varepsilon}_{it-2} + \rho_{t-3}\hat{\varepsilon}_{it-3} + \varepsilon_{it} \qquad \varepsilon_{it} \sim N(0,\sigma_\varepsilon^2),$$

(6) Δtr is the first difference of the trade ratio.

(7) The lagged variable in each column is instrumented using lagged m_{it} from lag 3 onwards since the third-order autocorrelation is not presented.

changes and openness is examined. Because of missing values for these additional variables, the number of observations has to be reduced in order to incorporate these variables into the estimation.

Table 3 presents the empirical results of the impacts of trade, FDI and black market premium individually as well as those of trade and black market premium alongside the product of FDI and human capital. When the FDI-human capital interaction terms are excluded (see the columns using the partial estimation approach in the table), the dynamic

Table 3: Impact of openness and interaction between FDI and human capital on efficiency improvement

Dep. variable m_{it}=log[exp($-u_{it}$)]	Partial est. approach [$s=ss_{it}$, $t=st_{it}$]				Integrative est. approach [$s*fd=ss_{it}\times fd_{it}$, $t*fd=st_{it}\times fd_{it}$]			
Indep. variables	Static		Dynamic		Static		Dynamic	
Intercept	-1.103		(9.4)	- 1.054	(8.8)	-0.711	(11.0)	-0.678
(10.2)								
Δtr_{it}	0.019	(0.5)	0.025	(0.6)	0.015	(0.4)	0.021	(0.5)
fd_{it}	0.022	(4.0)	0.021	(3.8)	-0.006	(0.4)	-0.005	(0.4)
S	0.101	(3.5)	0.096	(3.4)				
T	0.012	(0.7)	0.011	(0.7)				
$S*fd$					0.009	(2.7)	0.008	(2.6)
$T*fd$					-0.002	(0.8)	-0.002	(0.4)
bm_{it}	-0.004		(1.2)	0.004	(1.1)	-0.005	(1.3)	-0.004
(1.2)								
fx_{it}	0.179	(9.8)	0.176	(9.5)	0.179	(9.4)	0.176	(9.2)
m_{it-1}	-----		0.151	(1.8)	-----		0.167	(1.9)
Statistics of estimations								
Country-fixed effect (χ^2)	328.11		302.73		320.73			206.65
[H_0: Σa_i=0, df = 73]	[0.000]		[0.000]		[0.000]			[0.000]
Year-time effect (χ^2)	61.41		57.83		49.55		36.67	
[H_0: Σb_t = 0, df = 9]	[0.001]		[0.001]		[0.001]		[0.001]	
Lagged effect (χ^2)	4.746		-----		4.000		-----	
(H_0:m_{it-1} = 0, df = 1)	[0.030]				[0.035]			
Wu-Hausman (χ^2)	3.02		-----		3.08		-----	
[H_0: Exogeneity]	[0.167]		[0.182]					
AR [1]	0.143	(1.9)	-0.053	(0.5)	0.152	(2.1)	0.056	(0.5)
AR [2]	-0.194	(3.8)	-0.366	(3.5)	-0.176	(3.0)	-0.308	(2.9)
AR[3]	-0.079	(1.5)	-0.095	(1.3)	-0.092	(1.3)	0.05	(0.8)
$\bar{\sigma}_\varepsilon$	0.0463		0.0460		0.0472		0.0470	
$\bar{R}^2$	0.47		0.48		0.46		0.47	
N		412		412		412		412
Instrument Set			$fx_{it-3} \sim fx_{it-18}$				$fx_{it-3} \sim fx_{it-18}$	
			$m_{it-3} \sim m_{it-18}$				$m_{it-3} \sim m_{it-18}$	

Notes:
(1)-(6) are the same as in Table 2.
(7) The likelihood ratio statistic is used to test the lag effect of the dependent variable.
(8) The lagged variable in dynamic estimation was instrumented using lagged m_{it-3} onwards and fx_{it-3} onwards since the third-order autocorrelations are not presented.
(9) Wu-Hausman Statistic tests the exogeneity of both fd_{it} and fx_{it}, and the statistic does not reject H_0, so that

model indicates that the coefficient on the trade ratio is still positive, but no longer significant as compared with Table 2. The addition of the black market premium (*bm*), domestic fixed investment (*fx*) and human capital (measured by secondary school enrolment (*S*) and tertiary enducation enrolment (*T*)) to the estimation may weaken the significance of such variables as the trade ratio which are not very powerful in explaining efficiency.

In contrast, FDI is highly significant in different estimations, and the same is true for secondary school enrolment. This confirms the importance of FDI and human capital in enhancing a country's performance. Tertiary education enrolment has the expected positive sign, but is not statistically significant. This may suggest that seeking relatively low-cost labour is still a more important motivation for most FDI than strengthening R&D or relocating highly sophisticated production. Thus, a sufficient supply of labour with reasonable quality and low cost seems to be more desirable for the current configuration of FDI. The host country's ability to match this desirability is essential for FDI to have a positive impact on economic performance.

Moreover, the black market premium variable has the expected negative sign with reasonable significance. Domestic fixed investment has the expected positive sign and is highly significant. In terms of both the magnitude and the significance level, domestic fixed investment plays the most important role in efficiency improvement. But this is not made at the expense of the significant role of FDI in improving efficiency, as we can see in Table 3. This evidence clearly rejects the hypothesis of the crowding-out effect of FDI on domestic investment, as mentioned in Levine & Renelt (1992).

Another interesting point in Table 3 is that once the interaction terms are included, the coefficient on FDI becomes negative, but insignificant. Instead, the interaction term measured by the product of FDI and secondary school enrolment becomes positive and significant. This suggests that FDI has a significant positive impact on efficiency only when the host country has a minimum threshold of human capital as proxied by secondary school enrolment. The coefficient on the product of FDI and tertiary education enrolment has the wrong sign, but is statistically insignificant.

5. Openness and Efficiency of Malaysia, India and China

This section compares openness and performance, i.e. the relationship between the combined time-varying and time-invariant efficiency on one hand, and openness on the other, in Malaysia, India and China using a diagrammatic approach. The efficiency comparison is made relative to common criterion–the world best possible practice. One advantage of this comparison is that the three countries have many similarities but their degrees of openness are very different, which will enable us to learn some policy implications for opening an economy for higher growth in developing countries.

As shown in Figure 1, during the period 1980-1998, the relative efficiency of Malaysia to the world best possible practice was substantially higher than those of India and China. For instance, in 1980, Malaysia's relative efficiency was about 0.73, while India and China were only about 0.5 and 0.37 respectively. Malaysia opened its economy far earlier than India and China, and is the most open economy among the three. This explains its best efficiency performance in this group of economies.

Figure 1 also shows that the economic efficiency of both India and China followed a general rising trend over the whole sample period. Although it was lower than India at the start of the sample period, China's efficiency index rose faster than India from 1992 when China decided to develop a fully market-oriented economy with a higher degree of openness. Therefore, from 1995, China surpassed India. This result may not be a surprise

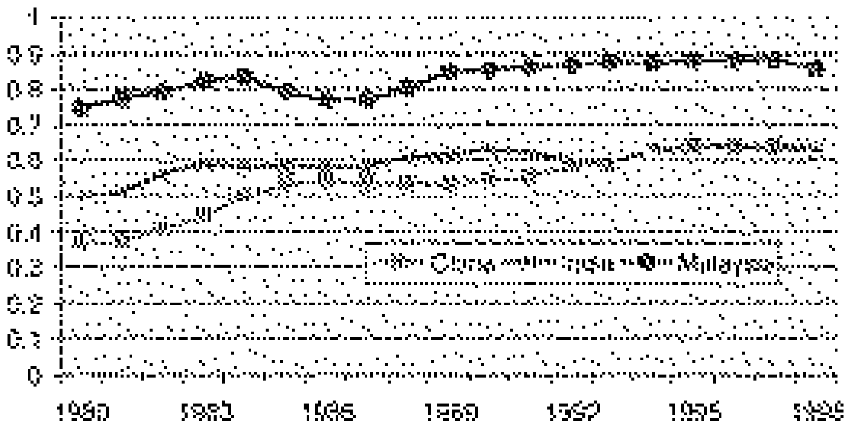


Figure 1: *Efficiency of China, India and Malaysia relative to the world total production frontier*

as India pursued relatively restrictive trade policies. Inevitably, this created unfavourable conditions in attracting FDI and for trade.

The above relative efficiency development patterns are consistent with the opening-up patterns of these economies. As shown in Figures 2 and 3, the inward FDI stock and flows as a percentage of GDP were much higher in Malaysia than in the other two countries. Ramasamy (2003) argues that Malaysia's impressive economic growth since the 1960s can be traced back to policies of FDI promotion. Furthermore, Athucorala and Menon (1995) even suggest that FDI is the most important contributing factor to Malaysia's impressive economic performance.

The inward FDI stock and flow as a percentage of GDP were very small in both China and India up to the mid-1980s. The gap between the two countries began to rise in the second half of the 1980s, and became substantially larger in the 1990s. Between the mid-1980s and 1991 the ratio of net FDI flows to GDP increased from about 0.5 per cent to around 1.1 per cent in China, while it remained marginal in India. In 1998, the FDI stock to GDP ratio in China was more than 6 times higher then that in India. Given that FDI is a very important means for efficiency improvement as indicated in the preceding sections, the higher FDI may explain the better economic performance in China as compared to India.

From 1991, India began to encourage inward FDI. India's switch towards globalisation in 1991 was a consequence of domestic resource deficits and balance of payments problems. It was suggested that if only India could attract enough foreign capital it could move on to a higher growth path. (Alamgir 1999). It allowed up to 51 per cent foreign equity in 34 "high-priority" sectors. Parallel to China's Special Economic Zones (SEZs), it emphasised export promotion through Export Processing Zones (EPZs), where 100 per cent foreign ownership was allowed. Like China, India signed the Multilateral Investment Guaranty Agency's (MIGA) convention, protecting foreign investors from political risk.

However, despite the encouragement, FDI in India remained relatively small in relation to its economy even in the 1990s. The annual inflow of FDI in India was about two to three

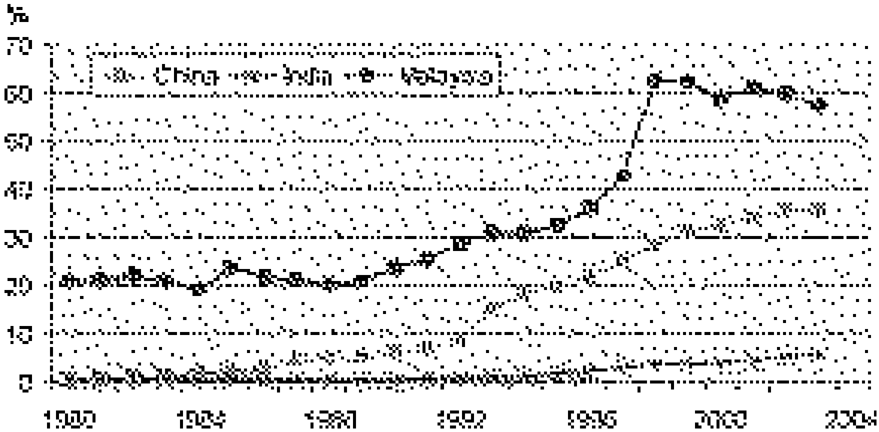


Figure 2: *FDI stock as per cent of GDP*

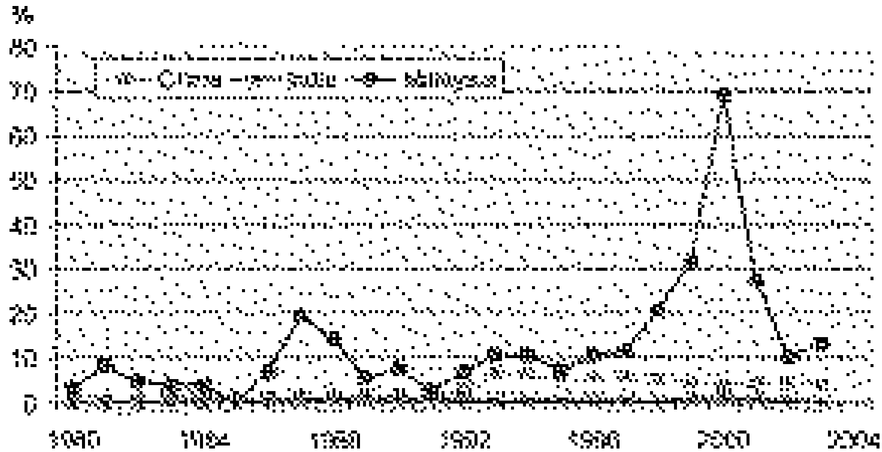


Figure 3: *FDI Inflows as per cent of GDP*

billion US dollars in the second half of the 1990s. This amount of inflows was much higher than that before 1991, but it was less than 5 per cent of domestic capital formation (Athreye and Kapur 2001), and less than 1 per cent of GDP. During the same period, the annual net FDI inflow to China was about 5 per cent of GDP, and China became the largest host of FDI in the developing world.

Figures 4 and 5 show the trade openness of the three economies. It is very clear that Malaysia had the highest trade-GDP and export-GDP ratios among the three countries. Min (2003) observes that Malaysia's economic growth began in the late 1960s with the development of abundant natural resources such as tin, rubber, palm oil and petroleum.

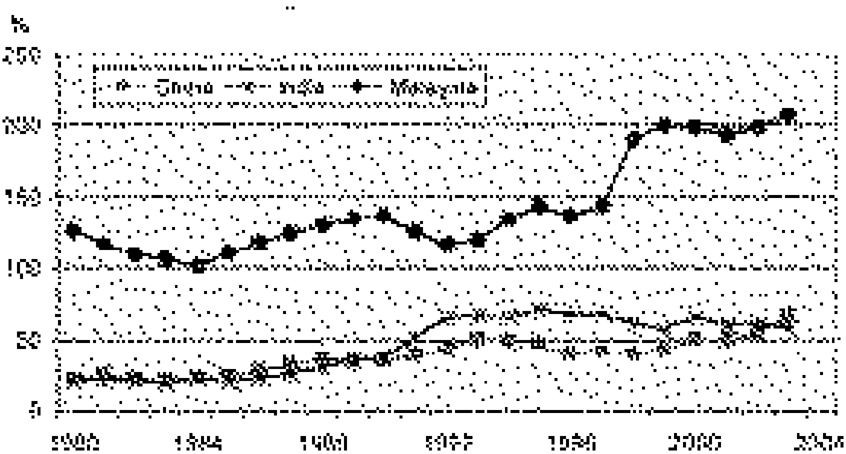


Figure 4: *Trade as per cent of GDP*

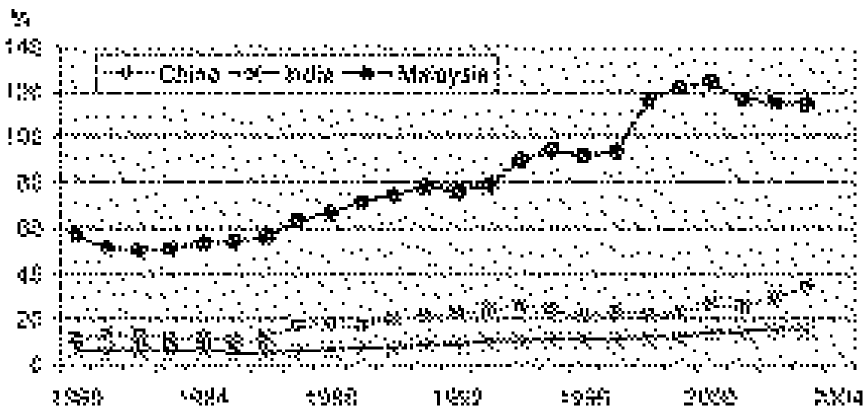


Figure 5: *Exports as per cent of GDP*

However, the share of the manufacturing sector in the national economy has grown continuously and its share in total value-added has overtaken the share of the primary sector since 1987. By the end of 1995, the share of manufactured exports in total exports was about 79 per cent. Trade has led to economic growth in Malaysia.

India's trade liberalisation started in 1991 when the government lowered peak tariff from 300 to 150 per cent, to match that of China. Then both countries experienced a number of incremental policy moves, and by the end of 1997, China and India had competitively lowered their average tariffs to 20.1 and 20.3 per cent, respectively (Alamgir 1999). During the same period, non-tariff barriers were also reduced in both countries. While a similar pattern in changes in trade policy was observed in both countries, Figure 5 shows that the export to GDP ratio in China was much higher than that in India since 1984. From 1991, although India's export to GDP ratio rose continuously, it never exceeded 16 per cent. That ratio in China was around 25 per cent for the same time period.

In sum, a more open economy gains more access to new knowledge and is exposed to stiffer competition from the world. In terms of the relative volumes of inward FDI and international trade, Malaysia is more open than China and India. This may explain why Malaysia enjoyed a higher relative economic performance over the period. Given the higher degree of openness, China experienced a more rapid improvement in efficiency than India in the second half of the 1990s.

6. Conclusions

The main features of this study include (1) the application of stochastic production frontier techniques in establishing the world production frontier, and (2) the adoption of dynamic models, both in setting up the frontier and examining the impact of openness on efficiency changes. The world production frontier was constructed using the full sample covering 126 countries for the period 1970-98. By controlling the country-specific fixed effects and time-period effects, the economic efficiency of a country relative to the world's best possible practice has been estimated. The role of openness on time-varying efficiency is then examined, and FDI and trade are found to have significant impacts over the sample period.

The effect of openness on efficiency improvement in Malaysia, India and China is examined against the common criterion–the world production frontier. It reveals that Malaysia enjoyed the highest relative economic efficiency among the three economies because of its earliest adoption of the opening-up policy and the highest degree of openness. China's efficiency index was lower than that of India in the period from 1980 to the mid-1990s. This result is contrary to the conventional wisdom that China performed better than India on almost all macroeconomic front since China started economic reform and opened up to the world. However, China experienced a higher degree of openness in terms of FDI inflows, FDI inward stock and international trade as a percentage of GDP than India. The higher degree of openness to the outside world aided China in accelerating its pace to catch up with the world best practice in reducing inefficiency, given the available resources for the economy. As a result, China has overtaken India slightly in raising productivity since 1995.

One policy implication from the study is clear. An economy needs to promote openness, and in particular, to create more favourable conditions for inward FDI growth. This will lead to the improved efficiency in employing scarce resources for output growth. Since the late-1960s, Malaysia has significantly benefited from inward FDI and international trade. In the 1990s, India paid a price for its failure in opening more of its economy, while China benefited from its liberalised policies. Developing countries can thus learn from the lessons of these three economies. The growth of a developing economy in future will largely depend on its ability to implement openness policies more effectively.

References

Alamgir, J. 1999. India's trade and investment policy: the influence of strategic rivalry with China. *Issues and Studies* **35(3)**: 105-133.

Arellano, M. and S. Bond. 1991. Some tests of specification for panel data: Monte Carlo evidence and an application to employment equations. *Review of Economic Studies* **58**: 277-297.

Athreye, S. and S. Kapur. 2001. Private investment in India: pain or panacea? *World Economy* 399-424.

Athucorala, P. and J. Menon. 1995. Developing with foreign investment: Malaysia. *Australian Economic Review* **109**: 9-22.

Balassa, B. 1982. *Development Strategies in Semi-Industrial Countries*. Oxford: Oxford University Press.

Balasubramanyam, V. N., M. Salisu and D. Sapsford. 1996. Foreign direct investment and growth in EP and IS countries. *Economic Journal* **106**: 92-105.

Barro, R. J. and J. W. Lee. 1994. Sources of Economic Growth. *Carnegie-Rochester Conference Series on Public Policy*.

Barro, R. J. and X. Sala-I-Martin. 1995. *Economic Growth*. New York: McGraw-Hill.

Batra, R. 1992. The fallacy of free trade. *Review of International Economics* **1**: 19-31.

Batra, R. and D. J. Slottje. 1993. Trade policy and poverty in the United States: theory and evidence, 1974-1990. *Review of International Economics* **1**: 189-208.

Bhagwati, J. 1978. *Foreign Trade Regimess and Economic Development: Anatomy and Consequences of Exchange Control Regimes*. Cambrige, MA: Ballinger.

Borensztein, E., J. De Gregorio and J. W. Lee. 1998. How does foreign direct investment affect economic growth? *Journal of International Economics* **45**: 115-35.

Borensztein, E., J. De Gregorio and J. W. Lee. 1998. How does foreign direct investment affect economic growth? *Journal of International Economics* **45**: 115-35.

Buffie, E. 1992. On the condition for export-led growth. *Canadian Journal of Economics* **25**: 211–25

Chenery, H. and A. Strout. 1966. Foreign assistance and economic development. *American Economic Review* **56**: 679-733.

Dollar, D. 1992. Outward-oriented developing economies really do grow more rapidly: evidence from 95 LDCs, 1976-1985. *Economic Development and Cultural Change* **40**: 523-544.

Easterly, W., M. Kremer, L. Pritchett and L. Summers. 1993. Good policy or good luck? Country growth performance and temporary shocks. *Journal of Monetary Economics* **32**: 459-483.

Edwards, S. 1993. Openness, Trade liberalisation, and growth in developing countries. *Journal of Economic Literature* **31**: 1358-93.

Edwards, S. 1998. Openness, productivity and growth: What do we really know? *Economic Journal* **108**: 33-398.

Fare, R., S. Grosskopf, M. Norris and Z. Zhang. 1994. Productivity growth, technical progress, and efficiency change in industrialied countries. *American Economic Review* **84(1)**: 66-83.

Forsund, F. R., C.A. K. Lovell and P. Schmidt. 1980. A survey of frontier production functions and their relationships to efficiency. *Journal of Econometrics* **13**: 5-25.

Fried, Harold, Lovell, C. A. Knox and Schmidt, Shelton. 1993. *The Measurement of Productive Efficiency: Techniques and Applications*. New York: Oxford University Press.

Grosskopf, S. 1993. Efficiency and productivity. In *The Measurement of Productive Efficiency: Techniques and Applications*, ed. H.O. Fried, C.A.K. Lovell and S. S. Schmidt. Oxford: Oxford University Press, pp. 160-94.

Grossman, G. and E. Helpman. 1991. *Innovation and Growth in the Global Economy*. Cambridge: MIT Press.

Hay, D. A. and G.S. Liu. 1997. The efficiency of firms: what difference does competition make? *Economic Journal* **107**: 597-617.

Henderson, D.J. and R.R. Russell. 2005. Huamn capital and convergence: A production-frontier approach. *International Economic Review* **46(4)**: 1167-1205.

Johnson, B. and T. Sheehy, T. (eds.) 1996. *1996 Index of Economic Freedom, Washington*: The Heritage Foundation.

Kalirajan, K. P. and R. T. Shand. 1999. Frontier production functions and technical efficiency measures. *Journal of Economic Surveys* **13(2)**: 149-72.

Keesing, D. B. 1967. Outward-looking policies and economic development. *Economic Journal* **77**: 303-20.

Krueger, A. O. 1978. *Foreign Trade Regimes and Economic Development: Liberalisation Attempts and Consequences*. Cambrige, MA: Ballinger.

Kruger, J. J., U. Cantner and H. Hanusch. 2000. Total factor productivity, the East Asian miracle, and the world production frontier. *Weltwirtschaftliches Archiv* **136(1)**: 111-36.

Leamer, E. 1988. Measures of Openness. In *Trade Policy and Empirical Analysis*, ed. Baldwin, R. Chicago: University of Chicago Press.

Leamer, E. 1995. A Trade Economicst's View of U.S. Wages and Globalisation, ed. Baldwin, R. Brookings Conference Proceedings.

Levine, R. and D. Renelt. 1992. A sensitivity analysis of cross-country growth regression. *American Economic Review* **82**: 942-63.

Martin-Marcos, A. and C. Suarez-Galvez. 2000. Technical efficiency of Spanish manufacturing firms: A panel data approach. *Applied Economics* **32**: 1249-1258.

Maudos, J., J.M. Pastor and L. Serrano. 2000. Convergence in OECD Countries: technical change, efficiency and productivity. *Applied Economics* **32**: 757-65.

Michaely, M., D. Papageorgiou and A. Choksiu (eds). 1991. *Liberalising Foreign Trade*. Oxford: Blackwell.

Miller, S. M. and M.P. Upadhyay. 2000. The effects of openness, trade orientation, and human capital on total factor productivity. *Journal of Development Economics* **63**: 399-423.

Min, Byung S. 2003. FDI and trade links in the case of Malaysia. *Journal of the Asia Pacific Economy* **8(2)**: 229–250

Moroney, John R. and C. A. K. Lovell. 1997. The relative efficiency of market and planned economies. *Southern Economic Journal* **63(4)**: 1084-93.

Nehru, V. and A. Dhareshwar. 1993. A new database on physical capital stock: sources, methodology and results. *Rivista de Analisis Economico* **8**: 37-59.

Nelson, R. R. and H. Pack, H. 1999. The Asian miracle and modern growth theory. *Economic Journal* **109(3)**: 416-436.

Nickell, S. J. 1996. Competition and corporate performance. *Journal of Political Economy* **104(4)**: 724-45.

Ramasamy, Bala. 2003. FDI and uncertainty: The Malaysian case. *Journal of the Asia Pacific Economy* **8(1)**: 85-101.

Rivera-Batiz, L.A. and P.M. Romer. 1991. Economic integration and endogenous growth. *Quarterly*

Journal of Economics **106**: 531-55.

Sachs, J. and A. Warner. 1995. Economic reform and the process of global integration. *Brookings Papers on Economic Activity* 1-118.

Salinas-Jimenez, M. M. 2003. Technological change, efficnecy gains and capital accumulation in labour productivity growth and convergence: An application to the spanish regions. *Applied Economics* **35(17)**: 1839-1851.

Sargan, J.D. 1988. Testing for mis-specification after estimating using instrumental variables. In *Contribution to Econometrics*, ed. J. D. Sargan. Cambridge: Cambridge University Press.

Scitovsky, T. 1954. Two concepts of external economies. *Journal of Political Economy* **62**: 143-51.

Taylor, L. 1991. Economic openness: problems to the century's end. In *Economic Liberalisation: No Panacea*, ed. T. Banuri. Oxford and New York: Oxford University Press, Clarendon Press, pp. 99-147.

Voivodas, C. 1973. Exports, foreign capital inflow and economic growth. *Journal of Internaitional Economics* **3**: 337-49.

Wolf, H. 1993. Trade orientation: measurement and consequences. *Estudios de Economia* **20**(2): 52-72.

World Bank. 1987. *World Development Report 1987*. Oxford: Oxford University Press.

Appendix 1
Variable Measurement and Data Sources

All data except FDI stock are taken from World Development Indicator CD-ROM, while FDI stock data are obtained from various sources, including *The World Investment Report*, *The International Direct Investment Statistics Yearbook* and *The World Investment Directory*.

Variable	Measurement
y	The natural log of GDP. GDP is measured at constant 1995 USD price.
k	The natural log of domestic capital stock. See appendix 2 for discussion on the construction of this variable.
fx	The natural log of gross domestic fixed investment (GDFI). GDFI is measured at constant 1995 USD price.
l	Total labour force.
fd	The natural log of FDI stock. GDP deflator is used here to convert FDI stock. measured at current price to that at constant price.
tr	Trade ratio, defined as the sum of exports and imports divided by GDP; IM: Imports of goods and services (constant 1995 USD); EX: Exports of goods and services (constant 1995 USD).
bm	Black market premium.
S	Secondary school enrolment (per cent gross).
T	Tertiary school enrolment (per cent gross).

Appendix 2
Estimation of Capital Stocks

Capital stocks were estimated mainly from available gross domestic fixed investment (constant 1995 price) data from WDI CD-ROM by the standard perpetual inventory calculation method. Data for some countries in some years were missing from WDI CD-ROM which were then calculated from gross domestic fixed investment (constant 1987 price) from Nehru and Dhareshwar (1993). As in Miller and Upadhyay (2000), the following procedure was taken to estimate the capital stock series:

Step 1: Initialise the capital stock by setting

$$K_0 = I_0/(\lambda g_d + (1-\lambda)g_w+\delta) \quad (1)$$

where the initial year is 1960;
g_d is the average growth rate of the GDP series for the country in question;
g_w is the world growth rate estimated at 4% per year;
$\lambda = 0.25$, is a measure of mean reversion in the growth rates, following Easterly *et al.* (1993); and
$\delta = 0.5$, is the assumed rate of depreciation.

Step2: Estimate the capital stock using the standard perpetual inventory method:

$$K_t = I_t + (1-\delta)K_{t-1} \quad (2)$$