Technology Transfer and National Efficiency in Developing Countries: The Role of International Trade

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Abstract:
Productivity differences are viewed as an important explanation of cross-country per-capita income differences. The recent literature has put forward two principal explanations for differences in productivity, technology transfer and absorptive capacity. This paper finds evidence that both are important for explaining productivity differences in developing countries and that international trade makes a contribution to both. Developing countries benefit from the R&D investments of developed countries by importing capital goods in which this technology is embedded, while openness to international trade, through greater competitive pressures, also reduces inefficiency.

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1. Introduction

Recent studies by Coe & Helpman (1995, henceforth CH), Coe, Helpman & Hoffmaister (1997, henceforth CHH), Keller (2001a) and Eaton and Kortum (1999) have demonstrated the importance of foreign R&D and international trade to domestic productivity growth. A theoretical motivation for this work can be found in Grossman and Helpman (1991) and Rivera-Batiz and Romer (1991). Technical progress embodied in new materials; intermediate manufactured products; capital equipment *etc.* are traded on international markets allowing countries to import the R&D investments made by others.

Technology transfer and therefore international trade takes on even greater importance for productivity growth in developing countries, who as a group undertake little domestic R&D and therefore have few domestic sources of new technology. According to CHH (1997) a 1 per cent increase in the R&D capital stock in the industrialised countries raises output in developing countries by 0.06 per cent. In 1990, this amounted to 22 billion US dollars. Clearly, the spillovers to developing countries through international trade are therefore substantial.

Yet, it is likely that this literature provides only a partial explanation of cross-country productivity differences. Countries are also likely to differ in the efficiency with which they use technologies (Fagerberg, 1994). Variables such as human capital, R&D, social institutional measures and international trade have been found to be important for efficiency by Fagerberg, (1994), Griffith et al. (2000) and Kneller & Stevens (2003). In the case of international trade, the competitive pressures associated with greater openness are likely to make firms more efficient in the use of a given technology thus, improving productivity.

In this paper we consider the effect of technology transfer and absorptive capacity on developing country productivity using Stochastic Frontier Analysis (SFA). We focus in particular on the dual effect of international trade. This is a novel aspect of this paper. Koop et al. (1998, 1999), Kumar and Russell (2002), Kneller & Stevens (2002) and Milner and Weyman-Jones (2003) have previously investigated cross-country efficiency differences using SFA and the related data envelopment analysis (DEA). We develop this literature in two regards. First, we recognise that the efficiency of a country can only be correctly measured against the technologies it has available (not those it does not). That is, the technical frontier faced by a country may differ from the global frontier due to time lags in the international transfer of technology. Secondly, we quantify the relative importance of international trade on these two sources of productivity growth. That is, we answer the question of whether international trade plays a greater role in determining the level of available frontier technology, or how close a country is to that frontier. This involves calculating trade efficiency scores, the contribution of trade to efficiency net of the other determinants of cross-country efficiency within each country and time period

We investigate these differences for a sample of 57 developing countries over the period 1970-1998. Using a translog production function we find evidence that physical capital, labour and foreign R&D all contribute significantly to output in developing countries, but that human capital has a positive effect only in some countries. The estimated elasticity of output with respect to human capital passes through zero, for example it is negative in many Sub-Saharan African countries. This result, combined with the significant effect of human capital on efficiency leads us to modify the Benhabib & Speigal conclusion to include that of Pritchett (1995). Human capital has a positive effect on productivity and a positive direct effect on production when the social institutional structure is such that additional education does not lead to rent seeking.

The level of efficiency also determines developing country output. Even when we control for the possibility that not all technologies will be known in all developing countries, through the trade weighted foreign R&D term, large differences in efficiency are still apparent. Over time we find evidence that efficiency levels in developing countries have converged. This period coincides with a period of improvements in the macroeconomic and policy environments for example trade liberalisation. By the end of the period differences in efficiency would appear less important that differences in factor inputs and technology transfer as an explanation of developing country productivity differences, although low efficiency is still evident in some countries. Of the determinants of efficiency we find a significant contribution from policy openness to international trade, the level of capital imports, the level of human capital and the tropical status of the country. This latter variable is intended to capture the effects of climate on public health, the quality of human resources and agricultural productivity.

Finally we calculate the contribution of international trade to developing country GDP, through technology transfer and efficiency. The average effect of technology transfer on GDP over a decade was about 7.5 per cent, against 0.82 per cent for the effect of trade on efficiency. The effect of international trade on technology transfer is therefore much more important than the effect of trade on efficiency, although both play a role. Combined we calculate that on average international trade contributed about one quarter of the increase in GDP in developing countries.

The rest of the paper is organised as follows, Section 2 outlines the methodology upon which this study is based; reviews the empirical literature that highlights international trade as one of the main channels of technology diffusion/transfer and; discusses the data used in our empirical analysis. We present the results of our empirical exercise in Section 3. We quantify the contribution of international trade to both technology transfer and efficiency in Section 4. Section 5 concludes the paper.

2. Methodology, Existing Literature and Data

Prescott (1998), Hall and Jones (1999) and Easter and Levine (2001) have suggested that the principal explanation for the large differences in per capita income levels that exist across countries is due more to differences in productivity and less to differences in capital (both physical and human). Statistical investigations have centred on absorptive capacity and technology transfer as the principal explanations of these productivity differences (Keller, 2000; 2001a; 2001b; Eaton and Kortum, 1999; Griffith *et al*, 2000a).[1] We review these literatures in the context of a discussion of the empirical methodology used in this paper.

[1] Kneller and Stevens (2002) identify two additional explanations in the literature, which they label resistance to new technologies because of institutional design (Prescott, 1998; Parente and Prescott, 2000) and appropriate technology (Acemoglu and Zilibotti, 1998).

Technical Frontier

This section outlines the stochastic frontier methodology on which this study is based. Since its development independently by Aigner, Lovell and Schmidt (1977), and Meeusen and van den Broeck (1977), a large empirical literature utilising SFA has developed. This literature straddles a diverse range of economic inquiry and incorporates both cross-section and panel data. Forsund, Lovell and Schmidt (1980); Bauer (1990); Green (1993) and Coelli (1995) provide comprehensive reviews of this literature.

In this study we assume that output, *Y*, is a function of the production technology set out in (1):

$$Y_{it} = f\left(K_{it}, L_{it}, H_{it}, LAND_{it}, RD_{it}^{m}\right)\eta_{it}\varepsilon_{it}, \qquad i=1,2,\ldots N;\ t=1,2,\ldots T \qquad \textbf{(1)}$$

where *Y* is output (GDP); $f(.)$ is a suitable functional form; *K* is the stock of physical capital; *H* is a measure of the stock of human capital; *L* is the labour supply; LAND is arable land; RD^m is the stock of foreign technical knowledge, η $(0 < \eta \leq 1)$ represents economic efficiency and ε reflects the random character of the frontier, due to measurement error or other effects not captured by the model. This last term is unique to the SFA approach. Finally, *i* indexes country and *t* indexes time.

In light of the questions raised over the suitability of the Cobb-Douglas functional forms (Duffy and Papageorgiou, 2000; Kneller and Stevens, 2002), we adopt a translog production function to characterise the production frontier facing developing countries.[2] Equation (1) can be expressed in log-linear form to give,

$$y_{it} = \beta_0 + \beta_1 k_{it} + \beta_2 l_{it} + \beta_3 h_{it} + \beta_4 land_{it} + \frac{1}{2}\beta_5 k_{it}^2 + \frac{1}{2}\beta_6 l_{it}^2 + \frac{1}{2}\beta_7 h_{it}^2 + \frac{1}{2}\beta_8 land_{it}^2$$

[2] Since our sample comprises only developing countries, then the technical frontier that we measure is not the global frontier. The latter is likely to be defined by the industrialised countries in general, which in 1990 accounted for 96% of total world R&D expenditures, and by the G-7 OECD countries (U.S.A., Japan, U.K., France, Germany, Italy and Canada) in particular which accounted for 92% of total OECD R&D expenditure in 1991 (See Coe, Helpman and Hoffmaister, 1997).

$$+\beta_9 k_{it} l_{it} + \beta_{10} k_{it} h_{it} + \beta_{11} k_{it} land_{it} + \beta_{12} l_{it} h_{it} + \beta_{13} l_{it} land_{it} + \beta_{14} h_{it} land_{it} + \beta_{15} rd^m_{it}$$

$$+\sum_{j=1}^{3} d_j D_j + \sum_{i=1}^{57} t_i + \nu_{it} - \upsilon_{it} \qquad \textbf{(2)}$$

where *k, l, h, rd^m* and *land* are the logarithms of the corresponding uppercase variables defined in Equation (1), and $\nu_{it} = \ln \varepsilon_{it}$, and $\upsilon_{it} = -\ln \eta_{it}$. Equation (2) also contains region specific dummy variables for Latin America and the Caribbean (LAC), Sub-Saharan Africa (SSA) and Asia (ASIA). These capture differences in the initial level of technology for these regions and are preferred to country specific fixed effects (Temple, 1999). Country specific time trends are included to measure elements of domestic technical progress not captured by imported foreign R&D.[3]

To account for possible complementarity between human capital and physical capital we follow Griliches (1969) and Mankiw, Romer & Weil (1992) and include human capital as a separate term in the production function.[4] Benhabib & Spiegel (1994) and Pritchett (1996) have previously argued that human capital affects only productivity and has no direct effect on production. We formally consider this modelling issue and test for the acceptance of this assumption below. To account for the importance of agricultural output to GDP in many developing countries, we include arable land as an input in the production function.[5]

Aside from the usual set of factor inputs Equation 1, output in is assumed to be a function of the total stock of knowledge in a country at time *t*. Following Griliches and Lichtenberg (1984) we assume this to depend on the stock of R&D.[6] Given that most developing countries undertake little domestic R&D, the stock of knowledge is

[3] Coe, Helpman and Hoffmaister (1997) also include country specific time trends in their estimating equation.

[4] Koop (2001) does not include H in the production function or as a determinant of efficiency.

[5] Harrison (1996) and Milner & Weyman-Jones (2003) include a similar measure in an aggregate production function for developing countries.

[6] Nadiri and Kim (1996) model the stock of knowledge as a geometric mean of own and foreign R&D capital, with the latter being constructed like CH (1995) as an import- share weighted sum of the R&D capital stock in other countries. Similarly, Kneller & Stevens (2002) assume that knowledge depends on domestic and foreign R&D, but is global in nature. In contrast, Koop (2001) and Koop *et al.* (1999, 2000) use an alternative assumption that technology growth depends on a (quadratic) time trend.

assumed to depend on the stock of foreign R&D. The measure of technology transfer used in this paper builds on that found from earlier studies.

Within the literature on technology transfer we focus on those studies that propose international trade (specifically imports) as the principal channel for the diffusion of technological knowledge.[7] The general approach adopted can be described as a two-stage approach. Productivity estimates are generated as the residuals from a production function (where the parameters are either estimated or imposed) in a first stage. Then in the second stage these are regressed on domestic and/or foreign R&D stocks and measures of international trade. It is implicitly assumed that countries are efficient in the use of all technologies imported.

The level of imported R&D is calculated as the sum of R&D stocks of trade partners weighted by some appropriate variable. Differences across studies are concentrated largely on differences in the choice of weights. For example, CH (1995) estimate an equation of the following form,

$$\log TFP_{it} = \alpha_i + \alpha_t + \beta_r \log R_{it} + \beta_s \log S_{it} + \varepsilon_{it} \qquad \textbf{(3)}$$

where *TFP* is total factor productivity; *R* measures domestic R&D stock; *S* foreign R&D stock; α_i and α_t are country and time varying intercepts; ε is an error term; *i* indexes countries and *t* indexes time. CH (1995) measure foreign R&D spillovers (S) on the domestic economy as the bilateral-imports-share weighted sum of R&D capital stocks of trade partners. That is:

$$S_i = \sum_{h \neq i} \frac{M_{ih}}{M_i} S_h \qquad \textbf{(4)}$$

[7] Other channels identified in the literature are: FDI, Foreign Technology Payments and disembodied R&D spillovers (e.g. scientific literature, international patenting, international conferences etc.) [see Keller, 2001e; Cincera and Van Pottelsberghe de la Potterie, 2001].

where M_{ih} is the flow of imports of goods and services of country *i* from country *h;* and $M_i = \sum_{h \neq i} M_{ih}$. Thus CH's (1995) bilateral weight captures the relative importance of R&D in country *h* for productivity in country *i*.

Doubts over the conclusions reached by CH (1995) were however, raised by Keller (1998) and Lichtenberg and van Pottelsberghe de la Potterie (1998, henceforth LP). Keller (1998) repeated CH's (1995) regressions using counterfactual (or made up) 'import' shares and obtained similarly high coefficients and levels of explained variation. This led him to conclude that the import composition of a country does not have a strong influence on the regression results.

Subsequent work by Keller (1997b, 2000) based on industry level data for industrialised countries has given partial support to the import composition effect by CH (1995). The composition of a country's imports is important only when it receives a disproportionately high share of its imports from one country. Further support for the import composition effect, and by extension for trade as a significant channel for R&D spillovers, was provided by Xu and Wang (1999) and CHH (1997). The first of the two studies finds (for OECD countries) that the foreign R&D variable, when weighted by capital goods imports, explains more of the variation in productivity across countries compared to total manufacturing imports. Similarly, CHH (1997) find stronger and more robust evidence for spillovers from the North (industrialised countries) to the South (77 LDCs) when using machinery and equipment import data (SITC class 7) instead of either all-manufacturing or total import data as their weighting variable.

Finally, Mayer (2001) finds that the coefficient on the machinery imports variable is twice as large as the coefficient on the machinery and equipment imports variable for a corresponding regression.[8] Mayer argues that the entire class of SITC 7 imports

[8] The theoretical basis of Mayer's (2001) study is an augmented model of Nelson and Phelps (1966) which really addresses the issue of absorptive capacity. Specifically, the role of human capital in helping countries that are technological laggards to successfully close the gap with countries at the technological frontier. However, as Mayer also considers the direct impact of capital goods on productivity we review his study under technology diffusion studies.

includes many consumption and equipment goods, which are unlikely to lead to much technology diffusion.

Previous research has also concentrated on the choice of denominator in equation (4). In questioning CH's weighting methodology, LP (1998) demonstrated that the import-share weighting scheme of CH (1995) is highly sensitive to a potential merger between countries. They contended that what really matters is the real R&D intensity embodied in the import flows of the home country from the foreign country. As such, they propose that the denominator of the weighting variable be foreign country GDP rather than the total imports of the home country. This was shown to significantly reduce the 'aggregation bias' associated with CH's measure and also to empirically outperform it.

Given our sample consists only of developing countries, which as a group undertake little R&D (CHH, 1997), we measure the stock of frontier technology by the stock of machinery R&D in OECD countries.[9] Our measure of the stock of frontier technology available in each country follows LP (1998). Specifically we weight the foreign machinery R&D stock by the ratio of developing countries' machinery imports in the 15 OECD countries' GDP. That is we compute the stock of foreign machinery R&D as:

$$RD_i^m = \sum_{j \neq i} \frac{MM_{ij}}{Y_j} RD_j^m \qquad \textbf{(5)}$$

where MM_{ij} is capital goods imports of developing country *i* from developed country *j*, and Y is the GDP of the developed country. Our use of machinery imports rather than the broader class of capital goods imports - machinery and transport equipment imports- is influenced by the argument of Mayer (2001) over the amount of technology diffused by some of the goods contained in the latter group of imports.

[9] The 15 OECD countries used to generate this measure are: Australia, Canada, Denmark, Finland, France, Germany, Ireland, Italy, Japan, Netherlands, Norway, Spain, Sweden, United Kingdom and the United States.

Since our sample comprises only developing countries, then the technical frontier that we measure is not the global frontier. The latter is likely to be defined by the industrialised countries in general, which in 1990 accounted for 96% of total world R&D expenditures, and by the G-7 OECD countries (U.S.A., Japan, U.K., France, Germany, Italy and Canada) in particular which accounted for 92% of total OECD R&D expenditure in 1991 (See Coe, Helpman and Hoffmaister, 1997).

Inefficiency Effects

It is argued that a key determinant of a country's success in adopting foreign technology is the extent to which it invests in 'imitative' or 'adaptive' research activities (see Geroski, 1995). The higher the knowledge-absorptive capacity of a country, the more it should benefit from foreign R&D. Abramovitz (1986) and Nelson and Phelps (1966) model the idea of absorptive capacity as depending on the level of human capital, whereas Cohen and Levinthal (1989) emphasise the importance of a firm's own R&D efforts.

Equation (3) recognises that countries may differ in their level of productivity through the term η . If a country is 100% efficient ($\eta = 1$), it can utilise all frontier knowledge, otherwise impediments to absorption or internal inducements to slack will cause the country to produce below the frontier.

Prior to the studies of Kumbhakar, Ghosh and McGukin (1991, henceforth KGM) and Reifschneider and Stevenson (1991), several studies (e.g. Lee and Pitt, 1981; Kalirajan, 1981) employed a two-step procedure to determine variation in technical inefficiency among firms in an industry. The first stage involves an estimation of the stochastic frontier, while in the second step the predicted inefficiencies from the first stage are regressed upon a vector of firm specific factors. It is now widely acknowledged in the SFA literature (Coelli, 1995; Battese and Coelli, 1995; Coelli, 1996) that there is a logical inconsistency in the two-step approach: the inefficiency effects are assumed to be independent and identically distributed in the first stage, while in the second stage they are assumed to be a function of a number of firm specific factors, thus implying they are not identically distributed.

Noting this inconsistency, KGM (1991) and Reifschneider and Stevenson (1991) specify stochastic models in which the inefficiency effects are made an explicit function of the firm specific factors, and all parameters estimated in as single stage maximum likelihood (ML) procedure. Battese and Coelli (1995) extended the KGM (1991) model to accommodate the use of panel data. Following Battese and Coelli (1995), the inefficiency effects are obtained as truncations at zero of the normal distribution $N(\mu_{it}, \sigma_{\upsilon}^{2})$. Where $\upsilon = -\eta$. Inefficiency is thus specified as:

$$\mu_{it} = z_{it}\delta \qquad \textbf{(6)}$$

where μ_{it} are technical inefficiency effects in the SFA framework and are assumed to be independently, but not identically distributed; z_{it} is a vector of variables which may influence the technical efficiency of a country, and δ is a vector of parameters to be estimated.

In determining the set of variables to include in the technical efficiency vector we draw on the previous literature[10]. Within this literature the most commonly used measure of absorptive capacity has been some measure of human capital. Benhabib & Spiegel (1994), Keller (1996), Griffith et al. (2000) and Kneller & Stevens (2003) have all previously found robust evidence for this variable. Given this, we consider it important to include a measure of human capital amongst our determinants of efficiency.

The international trade variables used previously come in two main forms, indicators of policy openness and measures of the volume of trade. Kneller & Stevens (2003) using SFA efficiency for a cross-country study of developing countries include the Sachs Warner (1995) measure of policy-openness to international trade amongst the efficiency determinants. They find that policy-open countries were more efficient than those that were closed to international trade. Mastromarco (2002), also using

[10] In this paper the term "technical efficiency" has a broad connotation. It includes anything that brings a country closer to the best practice frontier such as improvements in productive efficiency, as well reductions in allocative inefficiency and the elimination of incentives for X-inefficiency.

SFA, considers the effect of the volume of trade on efficiency, specifically capital good imports. Again evidence is found to suggest more open countries have greater efficiency.[11]

In light of these results, we also attempt to determine the importance of international trade in explaining deviations from the frontier. To do so, we use two measures of international trade. Firstly, the measure of capital goods imports already discussed and secondly, the Sachs & Warner (1995) indicator of openness to international trade. This has been updated by Wacziarg & Welch (2002) to cover the data period up until 1998 and uses additional data sources to correct some of the misclassifications of countries in the original study. The Sachs & Warner indicator is used to capture the effects of policy openness, while the capital import measure captures competition effects and spillovers from the use of capital imports.[12]

Our final efficiency determinant is a dummy variable (TROP) that takes the value of 1 if the developing country has a tropical climate and 0 if it does not. This variable is intended to capture the effects of climate on public health, the quality of human resources and agricultural productivity. Increasing empirical evidence have been adduced which shows physical geography and correlates like disease burden and life expectancy at birth, help explain variations in per capita income levels across countries (see Diamond, 1997; Gallup et al., 1998; Hall and Jones, 1999; Sachs, 2001). For example, for a cross-section of countries Hall and Jones found per capita income to be positively correlated with the absolute value of latitude. Additionally, Gallup et al. (1998) in stressing the lower levels of per capita GNP in the tropics, argue that human health and agricultural productivity are adversely impacted upon by tropical climate. In a later paper, Sachs (2000) argued that tropical climates are burdened by many infectious diseases (e.g. malaria) which have much lower incidence and prevalence in temperate ecozones and are much easier to control in the temperate zones. It is also argued that tropical climates face special problems of

[11] Both Kneller & Stevens (2003) and Mostromarco (2002) fail to consider the possible technology transfer effects of international trade. Indeed Kneller & Stevens (2003) assume that all knowledge is global.

[12] Following Rodriguez and Rodrik (2000) we recognise that the Sach and Warner openness variable may capture other elements of policy. We therefore avoid making strong conclusions regarding the relationship between trade policy and efficiency when using this variable.

agricultural management, and are characterised by lower average food output per unit input.

We thus specify the mean level of inefficiency as :

$$\mu_{ijt} = \delta_0 + \delta_1 h_{it} + \delta_2 SW_{it} + \delta_3 KM_{it} + \delta_4 TROP \qquad \textbf{(7)}$$

If human capital and international trade promote the absorption of technology, we would expect to find negative coefficients on δ_1, δ_2 and δ_3, respectively. That is, they reduce the distance from the frontier. In contrast, if having a tropical climate increases inefficiency (or the distance from the frontier) then δ_4 would be positive.

Data

Data on GDP, labour force and physical capital investment were taken from the World Bank's World Development Indicators (WDI) CD ROM 2000 for the period 1960 to 1998. This data is in constant 1995 US $ (see Appendix A for full data sources). The capital stock data were constructed using the perpetual inventory method. Initial capital stocks were constructed for 1960 (or the earliest available year) in order to avoid the problem of initial conditions (Appendix A provides greater detail of the construction of variables used in the empirical exercise). Human capital is measured by mean years of schooling in the population aged 25 and over from Barro and Lee (2000).

R&D investment on machinery for the 15 OECD countries was taken from the OECD's ANBERD Database. This data covers the period 1970-1995. Like the physical capital stock, the stock of R&D was computed using the perpetual inventory method. Data on machinery imports are from the United Nations COMTRADE database. This database contains data on Machinery and Transport Equipment (SITC Rev. 2, Sec 7) imports for 89 developing countries for the period 1970-2001. The machinery data is also disaggregated by type (e.g. Agricultural; Textile and Leather Making; Metalworking etc.).

Finally, the Sachs and Warner and the tropical indexes were obtained from Wacziarg & Welch (2002) and the World Bank, respectively.

3. Results

The parameters of the models defined by (4) and (6) were estimated simultaneously using FRONTIER Version 4.1 (Coelli, 1996) for 57 developing countries over the period 1970-1998. The log-likelihood function for this model is presented in Battese and Coelli (1993), as are the first partial derivatives of the log-likelihood function with respect to the different parameters of the model.[13]

The coefficients of the translog production function do not have any direct interpretation and so instead we calculate the elasticities of output with respect to each of the inputs, E_m, in the following manner.

$$\mathrm{E}_m = \frac{\partial y}{\partial x_m} = \beta_m + \sum_n \beta_{mn} x_{nit} \quad , m= k,\, l,\, h,\, land \qquad \textbf{(8)}$$

The full set of parameters used to determine these elasticities are reported in Table B1 of the Appendix. Returns to scale (elasticity of scale) is calculated from the sum of the input elasticities as:

$$RTS = \sum_m \mathrm{E}_m \qquad \textbf{(9)}$$

The input elasticities vary both over time and countries, we therefore present the input elasticities and returns to scale calculated for various groups of countries in Table 1. The first row of the table reports the elasticities evaluated at the mean of the data for the entire period and all countries; while rows 2-5 report them for various regional groups.[14] At first glance the results appear plausible and the estimated capital elasticity compares well with those from the previous literature. At the mean for the

[13] This parameterisation originates in Battese and Corra (1977).

entire period the elasticity of output with respect to physical capital is 0.47, for labour 0.43 and for human capital 0.04.[15] The estimated capital elasticity is within the range estimated for developing countries reported in Table 1 of Koop et al. (1998) using SFA and that found from a Cobb-Douglas production function in a two-stage approach by Miller and Upadhyay (2000).

The output elasticity of labour and human capital found by Miller and Upadhyay (2000) are somewhat different from those found here however (the estimated labour elasticity is somewhat higher at 0.28 and the human capital elasticity somewhat lower at 0.11). The estimated output elasticity of human capital in Table 1 also requires some careful interpretation, the estimated elasticity passes through zero (varying between –0.239 in Sub-Saharan Africa and 0.336 in Asia). The elasticity with respect to arable land is negative at –0.13. We infer from this that there is an over reliance on agriculture in some countries, where this sector tends to have lower value added for a given set of inputs.

Two arguments might be used to explain these differences between this and the Miller and Upadhyay (2000) results. Firstly, it might reasonably be explained by differences in the sample of countries and period covered by the respective studies; Miller & Upadhyay's sample include both developed and developing countries, and cover the period 1960-1989. Secondly, it might be explained by the choice of a two-stage approach in that paper. Part of the contribution of human capital to productivity in Miller & Upadhyay is captured by the human capital variable included in the first stage regression (the production function), which would tend to bias upwards the coefficient on this variable; while this in turn captures part of the effect of labour in the first stage, biasing down the coefficient on this variable.

While a negative human capital elasticity might appear unlikely it is in fact consistent with the explanation given by Pritchett (1999) for why human capital has consistently been found to be negative in growth regressions and forms our preferred explanation

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[14] Since the elasticity of each input is a linear function of the other factor inputs, the elasticities evaluated at the mean are the same as the mean elasticities (Kumbhakar et al., 1997).

[15] The elasticity with respect to arable land is negative at –0.13. We infer from this that there is an over reliance on agriculture in some countries, where this sector tends to have lower value added for a given set of inputs.

of this result. The effect of human capital on the economy depends in part upon the institutional and social environment. If the institutional and social structure is such that the returns to education are greater for 'rent-seeking' activities over 'entrepreneurial' activities, and rent-seeking activities do not contribute to GDP (they transfer wealth between individuals instead), then increases in human capital (as has occurred in developing countries over the post war period) will not translate into increased GDP. The weak institutional environment in many developing countries therefore explains the low value of the output elasticity of human capital in general and Sub-Saharan Africa in particular. Interestingly the elasticity estimated for the Asian group of countries is close to that suggested by national accounts data (Pritchett, 1999). These countries have on average a better institutional environment.

Table 1: Mean Estimates of Input (K, L, H, R&D, LAND) and Elasticity of Scale (RTS)

VARIABLE	K	L	H	R&D	LAND	RTS
All countries	0.477	0.431	0.034	0.089	-0.133	0.899
Latin America	0.484	0.513	0.072	0.089	-0.141	1.018
Sub-Saharan Africa	0.423	0.375	-0.239	0.089	-0.173	0.475
Asia	0.560	0.346	0.336	0.089	-0.097	1.235
Others	0.429	0.456	0.005	0.089	-0.080	0.900

As expected foreign R&D contributes positively to the level of output in developing countries. Technologies embodied in capital good imports are an important source of output growth in developing countries. We quantify the contribution of foreign R&D to domestic output in Section 4 below. The coefficient indicates that, ceteris paribus, a 1 per cent increase in the stock of foreign R&D will raise the level of output by 0.089 per cent.

The effect of foreign R&D on the domestic economy is close to that obtained by CH (1995) for OECD countries based on their first specification, reported as regression (i) in Table 3 of CH.[16] It is also close to that found, using the same measure of machinery imports from developed countries, by Mayer (2001) for a sample of developing countries; albeit it in a growth regression. However, it is considerably smaller than that found by CH for their preferred specification[17] as well as that obtained by Keller (2001a,b) and Kneller (2002), also for OECD countries.

Of the other parameters in the production function we note that summing across the elasticities suggests that the elasticity of scale (RTS) in developing countries is below 1, i.e. there are decreasing returns to scale. Of the country specific time trends, the majority are negative and significant, suggesting technical regression over the period.[18] Duffy and Papageorgiou (2000) find similar negative trends for a sample of developed and developing countries over the period 1960-87. Given that the contribution of foreign R&D has tended to be positive over the period, this result seems somewhat surprising. To explain this, we turn to similar a result in Koop et al. (1999). They interpret this result as suggesting that large negative shocks to the economies close to the frontier will tend to move the frontier inwards over time, in the SFA methodology this will be interpreted as inward shifts of the frontier (or technical regress) [see Koop et al., 1999]. We note as above that the estimated production function does not measure the position of the global frontier, only the frontier for developing countries. It is likely that the global frontier moved outward over this period. Given the increase in efficiency identified below this result is also consistent with the bunching of developing country GDP found by Quah (1996).

Finally, the coefficients on the regional country dummies are positive for both the Latin American and Caribbean (LAC) and Asia (ASIA) group of countries and negative for the Sub-Saharan Africa (SSA) group.

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[16] Coe and Helpman's (1995) initially specified the level of TFP as a function of domestic and foreign R&D capital stocks, where the latter is defined as the import-share-weighted average of the domestic R&D capital stocks of trade partners. As indicated our foreign R&D stock is constructed in a similar manner but with different weights.

[17] According to Coe and Helpman (1995) because the weights that they use to construct the foreign stock of knowledge are fractions that sum to one, they do not properly reflect the level of imports. In order to adequately the role of international trade, they argue that the variable capturing the stock of foreign knowledge should be interacted with the share of imports in GDP. They thus modified their base specification to reflect this argument.

[18] Only Cameroon, Mauritius, Rwanda, Singapore, Tunisia, Uganda and Uruguay have been found to have a positive and significant time trend coefficient. Hong Kong, Jordan and Senegal while also having a positive time trend, it is not significantly different from zero.

Efficiency Levels

Table 2 presents efficiency scores across all countries and for the respective regions at four points in time (1970, 1980, 1990 and 1998) as well as the average (and standard deviation) for the entire time period. Similar information on the 57 developing countries that make up the sample are presented in Table B2 of the Appendix.

The Table shows a marked increased in the average level of efficiency for the entire group of countries for the period 1970-98, with the improvements higher in the post-1980 period. The average efficiency level increased from 0.71 in 1970, to 0.75 in 1980 through to 0.90 in 1998. This pattern of convergence in efficiency scores is demonstrated clearly in Figure 1. For, instance in 1980 only 37% of the sample had an efficiency score between 0.90 and 1. This increased to 52% in 1990 and by 1998 approximately three-quarters of the sample of countries had an efficiency score of between 0.90 and 1.

The findings for the entire group of countries mask some country and region specific trends, however. As a regional group the largest average efficiency gain has been in LAC countries. The average efficiency level in Latin America & Caribbean was below the average for all countries (0.69 against 0.71), but the highest (with Asia) in 1998 at 0.95. Of the countries that make up this group three distinct trends are evident. In the first group there were large increases in efficiency over the period, albeit from initially low levels. Honduras, Jamaica, Dominican Republic, Costa Rica and Ecuador are included in this group. In the second group, a large increase in efficiency occurred between 1970 and 1980, and then small increases thereafter. Brazil, Colombia, Chile and Paraguay are included in this group. Finally, there is a group of Latin American countries in which average efficiency levels are high on average but there was no increase and in some cases a decline in efficiency levels over the remainder of the period. Argentina, Peru, Uruguay, Venezuela and Mexico form this group (efficiency declined in Mexico and Uruguay).

In contrast to Latin American & Caribbean countries much of the increase in efficiency levels in the Sub-Saharan African group occurred between 1990 and 1998. Indeed, at the average there was a decline in efficiency levels between 1970 and 1980.

Again there is large variation in the performance across groups however. For example there were large increases in efficiency in Ghana, Zambia, Mozambique and Niger but falls in efficiency in Cameroon, Rwanda and Senegal. Unlike the Latin American countries in which efficiency fell, these latter countries did not have high initial levels of efficiency. Indeed as a group, even accounting for the general improvement in efficiency, the Sub-Saharan African countries are much less efficient than the average developing country. For example, Gambia; Malawi; Mali; Niger and Mozambique all have a mean efficiency score less than 50 per cent, amongst the lowest of all developing countries in the sample.[19]

Table 2: Average Efficiency Scores

	1970	***1980***	***1990***	***1998***	***mean***	***s.d.***
All countries	0.71	0.75	0.83	0.90	0.80	0.19
Latin America & Caribbean	0.69	0.81	0.88	0.95	0.84	0.14
Sub-Saharan Africa	0.60	0.56	0.67	0.81	0.66	0.21
Asia	0.82	0.86	0.94	0.95	0.89	0.10
Others	0.68	0.85	0.87	0.91	0.86	0.16

Finally, across all regions the countries that consistently recorded the highest efficiency scores are concentrated in Asia. The standard deviation of efficiency levels is also the lowest for this region. The average efficiency score in Korea, Singapore, Malaysia, Hong Kong, Indonesia and China was over 90 per cent. As such while there were notable increases in average efficiency for this group over the period these changes are less marked than the other regions.[20]

The most efficient and inefficient countries in our sample are shown in Table 3 at the four distinct time periods used in Table 2. In 1970 and 1980 respectively, Latin

[19] Two exceptions within SSA are the Democratic Republic of Congo and Mauritius

American (e.g. Uruguay, Mexico, Venezuela) and Asian (e.g. Korea, India, Singapore) countries dominated the list of the most efficient countries. Middle East and North African countries (Algeria, Tunisia and Jordan) were also represented particularly in 1980, Jordan was shown to be the most efficient country.

By 1990, Asian countries dominated the list of most efficient developing countries. Chile and Paraguay were the only two Latin American countries listed. The picture changed once again in 1998. Over the 1990s, there was a general rise in the average efficiency scores of developing countries. This convergence in efficiency levels led to a broader regional mix of countries among the most efficient group, with Argentina now the most efficient. Moreover, it was the South Asian (Sri Lanka, Bangladesh and Pakistan) rather than East Asian countries, as well as countries from the Middle East and North Africa (Syria, Egypt and Iran) that occupied the other top spots. 1998 also represented the first and only time that a Sub-Saharan African country (Ghana) was represented among the most efficient countries.

With respect to the group of countries listed as the most inefficient (in descending order) in Table 3, SSA countries (e.g. Niger, Mali, Rwanda, Mozambique, Togo) dominate this group in all time periods bar one- 1970 - when countries from the LAC region (Honduras, Jamaica, Ecuador, Nicaragua, Bolivia and Guatemala) made up the majority. In fact, since 1970, SSA countries account for at least eight of the ten countries listed as the most inefficient in Table 3. This is despite the fact that by 1998 most countries within this regional grouping – Rwanda being the notable exception- had increased their efficiency levels significantly relative to the earlier periods. Apart from the SSA and LAC countries, among the list of most inefficient countries were Papua New Guinea (all periods except 1998) and Jordan (1998).

Turning to the factors used to explain technical inefficiency in Table B1. All four variables have the expected signs and are statistically significant at a level below 1%. This result is consistent with those of Griffith et al. (2000), Kneller (2002) and Kneller & Stevens (2002) for OECD countries; CHH (1997) and Mayer (2001) for

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[20] The exceptions to this are Sri Lanka and Bangladesh which had efficiency levels of 60 per cent or less in 1980 (60.5 and 55.9 respectively) but efficiency scores above 97 per cent in 1998 (97.4 and 97.1 respectively).

developing countries; and Fagerberg (1994), Keller (1996), and Barro & Lee (2000) about the importance of human capital technology in facilitating technology absorption.

Given the negative output elasticity of human capital in the production function it is noteworthy that human capital is shown to significantly reduce inefficiency in LDCs. To calculate the contribution of human capital to efficiency over time we follow Coelli et al. (1999) in calculating the difference between gross human capital efficiency and efficiency net of the contribution of human capital, where gross efficiency is found using the conditional expectation of $\exp(-\upsilon_{it})$, given the random variable $\varepsilon_{it,}$[21]

$$\begin{aligned} EE_{it} &= E\left[\exp(-\upsilon_{it})\middle|\varepsilon_{it}\right] \\ &= \left[\exp\left(-\theta_{it} + \tfrac{1}{2}\tilde{\sigma}^2\right)\right] \times \left[\Phi\left(\frac{\theta_{it}}{\tilde{\sigma}} - \tilde{\sigma}\right) \Big/ \Phi\left(\frac{\theta_{it}}{\tilde{\sigma}}\right)\right] \end{aligned} \qquad \textbf{(10)}$$

where $\Phi(.)$ denotes the distribution function of the standard normal variable,

$$\theta_{it} = (1-\gamma)\left[\delta_0 + \sum_{m=1}^{M}\delta_m z_{it}\right] - \gamma\varepsilon_{it}, \qquad \tilde{\sigma}^2 = \gamma(1-\gamma)\sigma^2, \quad \text{and} \quad \gamma = \frac{\sigma_\upsilon^2}{\sigma_\nu^2 + \sigma_\upsilon^2}$$

The operational predictor for the efficiency of country *i* at time *t* is calculated by replacing the unknown parameters in equation (9) with the maximum likelihood predictors. Net efficiency is calculated by replacing $\left[\sum_{m=1}^{M}\delta_m z_{it}\right]$ with $\min\left[\sum_{m=1}^{M}\delta_m z_{it} - \delta_H HUM\right]$ and then re-calculating the efficiency predictions. From this exercise we find that human capital contributes positively to reductions inefficiency for all countries in the sample, including those in Sub-Saharan Africa. The average effect is 11 per cent across all countries and time periods and ranges from 0.015 per cent (Gambia in 1976) to 14.68 per cent (Hong Kong in 1998). We therefore modify the conclusion reached by Benhabib & Spiegel (1994) to one where human capital has a positive effect on productivity (in agreement with Benhabib & Spiegel) but also a direct effect on production function in some countries, where these countries may be defined by high institutional quality.

Before turning to the effect of international trade on efficiency we briefly discuss the effect of the geographic indicator TROP. In terms of the impact of climate and associated factors on inefficiency, our estimation shows that tropical countries are 0.62% more technically inefficient relative to non-tropical countries. This finding thus lends support to those researchers that argue that aspects of geography and their correlates negatively affect output growth in particular groups of countries. These mirror earlier findings by Bloom et al. (2002) and Hall and Jones (1999) of the importance of geography in determining the level of productivity.

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[21] See Battese and Coelli (1993) and Coelli, Perelman and Romano (1999).

Table 3: The Ten Most Efficient & Inefficient Countries 1970-98

1970				1980				1990				1998			
Efficient	**Score**	**Inefficient**	**Score**	**Efficient**	**Score**	**Inefficient**	**Score**	**Efficient**	**Score**	**Inefficient**	**Score**	**Efficient**	**Score**	**Inefficient**	**Score**
Korea	0.99	Papua New Guinea	0.326	Jordan	0.98	Niger	0.19	Korea	0.97	Niger	0.34	Argentina	0.98	Rwanda	0.40
Uruguay	0.98	Honduras	0.327	Mexico	0.97	Gambia	0.21	Malaysia/ Hong Kong	0.964	Mali	0.42	Sri Lanka/ Syria	0.974	Mali	0.65
Mexico	0.97	Jamaica	0.39	Uruguay	0.966	Mali	0.27	Chile	0.962	Mozambique	0.44	Egypt	0.972	Senegal	0.67
India	0.96	Zambia	0.40	Korea	0.964	Malawi	0.32	India	0.961	Gambia	0.456	Bangladesh	0.971	Togo	0.70
Venezuela	0.956	Rwanda	0.47	Singapore	0.961	Mozambique	0.38	Paraguay	0.96	Rwanda	0.46	Iran	0.97	Mozambique	0.71
Argentina	0.95	Ecuador	0.48	Tunisia	0.95	Papua New Guinea	0.46	Thailand	0.959	Benin	0.55	Chile	0.969	Niger	0.72
Algeria	0.94	Sri Lanka	0.49	Chile/ Algeria	0.947	Togo	0.47	Singapore/ China	0.954	Papua New Guinea	0.57	Pakistan/ Philippines	0.968	Cameroon	0.77
Peru	0.93	Nicaragua	0.50	India	0.946	Jamaica	0.50	Indonesia	0.953	Togo	0.59	China	0.967	Jordan	0.79
Singapore	0.92	Bolivia	0.52	Paraguay	0.944	Zambia	0.55	Tunisia	0.952	Senegal	0.67	Dominican Republic	0.966	Uganda	0.795
Malaysia	0.87	Guatemala	0.53	Peru	0.942	Rwanda/ Bangladesh	0.56	Philippines	0.95	Nicaragua	0.71	Ghana/ Ecuador	0.962	Gambia	0.80

4. Contribution of International Trade to the Change in Developing Country GDP

We next turn to our two measures aimed at gauging the importance of international trade in helping countries close the productivity gap with the frontier. First, the modified Sachs and Warner index (see Warcziarg and Welch, 2002) which is intended to capture policy oriented trade openness shows that greater openness to international trade leads to increases in the efficiency (reductions in inefficiency) with which resources are utilised. The second measure, machinery imports from developed countries, intended to capture possible spillovers resulting from the use of capital goods which embody foreign knowledge, is also inversely related to technical inefficiency in developing countries. At the mean a one percentage point increase in machinery imports reduces inefficiency by approximately 0.2%.

In this section of the paper we quantify the effect of international trade on developing countries output through technology transfer and efficiency. International trade in this context is broadly defined to include the influences of trade (e.g. changes in the volumes of machinery imports) and trade policy (e.g. trade liberalisation) on efficiency. Regional summary tables for the contribution of international trade to efficiency, changes in the stock of trade weighted R&D and the contribution of each of these factors to the change in GDP growth can be found as Tables 4 and 5 below. The same information for each of the individual countries can be found in Tables B3 to B4 in Appendix B. The contribution of international trade to efficiency is calculated in the same manner as that for human capital, except

$\min\left[\sum_{m=1}^{M}\delta_m z_{it} - \delta_{KM} MACHIMP - \delta_{SW} SWOPEN\right]$ now replaces $\left[\sum_{m=1}^{M}\delta_m z_{it}\right]$ in equation (10).

The average contribution of trade to efficiency is about 6 per cent over the entire sample between 1970-98 (see Table B3). As shown in Table 4, over time the contribution of international trade to the average level of efficiency increased up until

1990 and then fell between 1990 and 1998. However, international trade was still more important in 1998 for cross-country efficiency than in 1970.

At the regional level this decline in the importance of trade is not universal. It would appear to be true for the average in Latin America and Caribbean, and Other countries but not in Sub-Saharan Africa and Asia where the contribution of trade rose during this time period. Indeed this does not appear to be a regional phenomenon. As is evident from Table B3, for the countries that make up these regional groupings there are a number that display sizeable falls in the contribution of trade to efficiency. For example, Bangladesh, Sri Lanka and Pakistan in Asia; Argentina, Ecuador and Venezuela in Latin America; Ghana and Mauritius in Sub-Saharan Africa and Syria and Egypt in Others. This decline in the contribution of international trade occurred despite the fact that there was an increase in the average level of capital-imports in these countries, the trade policy liberalisation that occurred between 1990 and 1998[22], and the increase in average non-trade efficiency. Unfortunately from closer inspection there does not appear to be a single consistent explanation for this change. It instead comes from a number of factors that include, the stagnation of trade levels; changes in the error term on which these the efficiency scores are conditioned; and changes in the non-trade parts of efficiency.

Table 4: Contribution of International Trade to Efficiency (%)

	1970	*1980*	*1990*	*1998*
All countries	3.9	5.7	6.7	6.4
Latin America	4.0	6.0	7.8	7.0
Sub-Saharan Africa	2.4	3.7	4.4	4.6
Asia	5.5	8.2	7.4	8.0
Others	2.1	6.0	9.2	7.2

In contrast to the effect of international trade on efficiency, its contribution to technology transfer increased in all time periods and across all of the regions. The

[22] For example just over half of the Latin American countries in the sample were considered policy open to international trade in 1990, whereas all were in 1998.

greatest contribution is within the Asian countries of the sample and the least the Sub-Saharan African countries. Similarly, the biggest increase in absolute terms was in the Asian countries, followed closely by the Latin American and Caribbean countries. The smallest average absolute gain was in Sub-Saharan Africa countries.

Table 5: Change in the Log of Machinery Imports Weighted R&D (1970-98)

	1970	***1980***	***1990***	***1998***
All countries	14.70	15.80	16.36	17.00
Latin America	14.67	15.85	16.31	17.49
Sub-Saharan Africa	13.59	14.78	15.04	15.20
Asia	15.55	16.95	18.25	18.84
Others	14.92	16.63	16.94	17.41

Finally in Table 6 we quantify the contribution of technology transfer and trade efficiency to changes in GDP, by decade for each country. So for example, in Argentina the percentage increase in GDP between 1970 and 1980 was 29 per cent. Of this increase in GDP from its 1970 level, technology transfer accounted for 13.7 per cent, while international trade through improvements in efficiency accounted for 3.7 per cent. The total contribution of trade was therefore 17.4 per cent or about 60 per cent of the total increase in GDP that occurred over the period.

Across all countries the average effect of technology transfer on GDP across each decade was 7.5 per cent, against 0.82 per cent for the effect of trade on efficiency. The effect of international trade on technology transfer is therefore much more important than the effect of trade on efficiency, although both play a role. The average increase in GDP over each decade was 33.5 per cent (an average annual growth rate of about 2.8 per cent). According to the estimates from this paper, international trade therefore contributed about one quarter of the increase in GDP on average.

Table 6: Percentage increase in GDP_{t-1} caused by increases technology transfer and efficiency.

	Period	*GDP*	*R&D*KM*	*EFF*	*TOTAL*
Algeria	1970-80	58.092	15.90028	2.64857	18.54885
	1980-90	26.011	2.36026	4.28884	6.6491
	1990-98	10.508	0.362024	1.55799	1.920014
Argentina	1970-80	29.106	13.6612	3.71911	17.38031
	1980-90	-15.204	-5.15448	-0.48031	-5.63479
	1990-98	48.737	16.99359	-6.57593	10.41766
Bangladesh	1980-90	46.416	7.511705	3.83085	11.34256
	1990-98	36.667	2.219508	-6.2908	-4.07129
Benin	1990-98	36.155	8.002685	2.60506	10.60775
Bolivia	1970-80	40.694	9.970805	1.49035	11.46115
	1980-90	0.953	2.33631	2.36156	4.69787
	1990-98	33.339	11.79889	-2.50989	9.288997
Brazil	1970-80	81.191	10.86402	1.952	12.81602
	1980-90	15.348	5.778352	0.40719	6.185542
	1990-98	21.482	12.19156	-1.29829	10.89327
Cameroon	1980-90	32.722	-0.3236	-0.02984	-0.35344
	1990-98	5.2	2.710666	2.2314	4.942066
Chile	1970-80	28.192	8.252554	-0.61442	7.638134
	1980-90	36.979	10.02049	-2.22511	7.795383
	1990-98	59.46	7.312954	-1.24452	6.068434
China	1980-90	87.95	11.60943	-3.09067	8.51876
	1990-98	82.006	12.06895	-2.13086	9.938093
Colombia	1970-80	53.645	11.60603	0.70626	12.31229
	1980-90	33.277	4.263589	0.41486	4.678449
	1990-98	27.525	8.802337	2.45433	11.25667
Congo, Dem. Rep.	1970-80	4.191	6.375052	0.62479	6.999842
	1980-90	8.776	5.471199	2.33729	7.808489
Congo, Rep.	1990-98	9.82	2.285996	-1.16222	1.123776
Costa Rica	1970-80	54.87	11.00174	2.80117	13.80291
	1980-90	23.829	6.899455	1.86784	8.767295
	1990-98	31.658	10.03944	-2.21935	7.820088
Dominican Republic	1970-80	67.041	8.481064	2.37597	10.85703
	1980-90	25.217	8.345674	1.92474	10.27041
	1990-98	42.446	10.01218	-3.66539	6.346791
Ecuador	1970-80	85.292	17.32344	5.20996	22.5334
	1980-90	20.677	-0.48392	-1.49437	-1.97829
	1990-98	22.792	10.83024	-2.7084	8.121843
Egypt, Arab Rep.	1980-90	53.244	4.583432	-0.10288	4.480552
	1990-98	32.347	6.400522	-3.9369	2.463622
El Salvador	1970-80	22.428	6.864513	2.20048	9.064993
	1980-90	-3.877	10.06214	2.67175	12.73389
	1990-98	38.952	8.949345	-1.14157	7.807775
Gambia, The	1980-90	35.529	2.002079	1.34125	3.343329
	1990-98	21.959	0.437449	1.94957	2.387019
Ghana	1970-80	3.476	5.495775	0.9638	6.459575
	1980-90	21.311	8.270517	4.2095	12.48002
	1990-98	34.03	7.051289	-4.33705	2.714239
Guatemala	1970-80	55.004	11.8097	3.14946	14.95916
	1980-90	8.695	3.246151	2.25622	5.502371
	1990-98	33.162	12.06851	-0.32156	11.74695
Honduras	1970-80	52.545	11.82275	2.20733	14.03008

	1980-90	23.993	1.053542	2.5299	3.583442
	1990-98	28.942	11.22194	-0.17103	11.05091
Hong Kong, China	1970-80	88.656	15.69053	-0.05861	15.63192
	1980-90	63.472	13.1695	-2.82926	10.34024
	1990-98	30.289	9.491711	6.82003	16.31174
India	1970-80	29.405	12.61445	4.08867	16.70312
	1980-90	56.888	10.87484	-1.08979	9.785047
	1990-98	43.638	6.449584	3.92268	10.37226
Indonesia	1980-90	61.823	11.54938	-1.93549	9.613885
	1990-98	35.658	0.54737	4.78161	5.32898
Iran, Islamic Rep.	1980-90	26.33	9.933628	0.39751	10.33114
	1990-98	31.828	0.01546	-6.43282	-6.41736
Jamaica	1970-80	-7.978	-3.70442	0.09826	-3.60616
	1980-90	24.334	13.03492	5.36248	18.3974
	1990-98	1.185	2.62693	-4.96539	-2.33846
Jordan	1980-90	19.667	-1.79225	9.15316	7.360914
	1990-98	40.172	6.26808	1.88946	8.15754
Kenya	1980-90	39.859	6.590783	2.13848	8.729263
	1990-98	15.791	-0.75845	0.05773	-0.70072
Korea, Rep.	1970-80	73.169	16.5884	7.4694	24.0578
	1980-90	86.671	16.24496	0.9131	17.15806
	1990-98	41.345	0.866677	3.78575	4.652427
Malawi	1980-90	21.776	4.362964	1.28981	5.652774
	1990-98	30.003	-0.13307	-1.09662	-1.22969
Malaysia	1970-80	75.39	16.81244	0.69014	17.50258
	1980-90	57.785	12.22186	-2.81744	9.404419
	1990-98	49.311	7.221979	6.16228	13.38426
Mali	1980-90	5.949	4.530884	1.42509	5.955974
	1990-98	29.345	5.794616	1.40274	7.197356
Mauritius	1980-90	58.459	11.5988	1.08614	12.68494
	1990-98	40.411	3.711572	-1.75676	1.954812
Mexico	1970-80	64.693	16.04344	1.07989	17.12333
	1980-90	17.906	8.466587	6.82102	15.28761
	1990-98	23.837	9.854003	2.60599	12.45999
Mozambique	1980-90	1.486	8.215646	1.00123	9.216876
	1990-98	45.015	-2.80843	2.22596	-0.58247
Nicaragua	1970-80	3.486	3.055979	0.88696	3.942939
	1980-90	-13.664	2.584302	1.18156	3.765862
	1990-98	20.864	9.681346	-0.0139	9.667446
Niger	1980-90	-1.086	-3.93928	-0.02221	-3.96149
	1990-98	18.377	-0.6118	1.86512	1.253317
Pakistan	1980-90	60.932	9.353103	-1.2552	8.097903
	1990-98	32.919	-0.51189	-4.35462	-4.86651
Panama	1980-90	13.574	4.510062	0.01079	4.520852
	1990-98	37.948	10.48422	1.08931	11.57353
Papua New Guinea	1970-80	24.687	9.43675	1.43387	10.87062
	1980-90	12.523	3.211566	1.42178	4.633346
	1990-98	38.169	3.968322	2.19936	6.167682
Paraguay	1970-80	85.02	18.81943	0.6287	19.44813
	1980-90	27.346	8.233876	-0.22245	8.011426
	1990-98	19.326	11.31604	2.481	13.79704
Peru	1970-80	35.645	12.90659	1.10995	14.01654
	1980-90	-10.341	-0.36319	2.78532	2.422134
	1990-98	40.052	11.24866	1.492	12.74066
Philippines	1970-80	57.487	10.19217	1.62809	11.82026

	1980-90	16.713	6.214371	-0.73324	5.481131
	1990-98	20.958	10.45133	-3.06562	7.385709
Rwanda	1970-80	52.446	21.63555	2.39926	24.03481
	1980-90	20.11	3.885389	0.30466	4.190049
	1990-98	-9.828	-2.10181	-0.04495	-2.14676
Senegal	1970-80	16.874	13.58961	2.39619	15.9858
	1980-90	30.584	6.45155	0.33839	6.78994
	1990-98	22.566	2.769291	0.29171	3.061001
Singapore	1970-80	86.233	18.83463	-2.12573	16.7089
	1980-90	70.376	13.43876	3.08915	16.52791
	1990-98	60.092	5.949936	0.60403	6.553966
Sri Lanka	1970-80	43.07	13.57505	3.48064	17.05569
	1980-90	40.86	2.77215	0.63146	3.40361
	1990-98	40.709	9.309045	-4.82083	4.488215
Syrian Arab Republic	1980-90	21.632	-1.66034	-0.11115	-1.77149
	1990-98	46.738	8.180971	-7.35811	0.822861
Thailand	1970-80	66.317	9.910304	2.36161	12.27191
	1980-90	75.567	18.79209	-3.05974	15.73235
Togo	1980-90	10.477	1.361767	0.99508	2.356847
	1990-98	11.926	3.601025	1.0907	4.691725
Trinidad and Tobago	1990-98	17.639	12.66905	2.42303	15.09208
Tunisia	1970-80	71.088	19.23392	0.18565	19.41957
	1980-90	35.015	7.368808	2.78365	10.15246
	1990-98	36.023	6.016782	1.26241	7.279192
Uganda	1990-98	52.648	4.127573	0.80899	4.936563
Uruguay	1970-80	29.7	14.38873	2.97094	17.35967
	1980-90	-0.962	-1.7388	5.20339	3.464585
	1990-98	32.549	14.61268	1.94811	16.56079
Venezuela, RB	1970-80	26.6	13.75441	6.85668	20.61109
	1980-90	8.119	1.00877	-0.59706	0.41171
	1990-98	21.81	8.382136	-3.09144	5.290696
Zambia	1970-80	13.526	7.228145	2.16528	9.393425
	1980-90	10.353	3.853486	2.47053	6.324016
	1990-98	6.652	-6.30418	-2.06787	-8.37205
Zimbabwe	1980-90	43.089	18.42935	2.01983	20.44918
	1990-98	17.729	1.173562	2.363	3.536562

5. Conclusions

We use stochastic frontier analysis, to examine the role played by international trade both in determining the position of the technical frontier (through technology transfer), and in explaining deviations from the frontier since countries differ in the efficiency with which they use the available technology. We next quantify its (international trade) contribution to these two sources of productivity change. This analysis is undertaken for a sample of 57 developing countries over the period 1970-98.

Trade is shown to contribute positively to both technology transfer and efficiency. Over time however, its relative contribution to technology transfer is larger than its contribution to efficiency. Technology transfer is thus an important source of productivity growth for developing countries. Having said this however, the efficiency effects are large enough that they cannot be ignored.

There is also evidence that differences in efficiency between the developing countries in our sample have narrowed considerably over time; the narrowing of the efficiency gap coinciding with improvements in the policy environment and trade liberalisation. As a result of this convergence, by the end of the period differences in per capita GDP across developing countries are likely to be explained by differences in technology transfer rather than efficiency.

While there is evidence of an absorptive capacity role for human capital, this variable does not impact output positively for all countries (notably the SSA countries). Consequently, this possibility should be recognised rather than omitting it from the production function. In light of our findings with respect to human capital, we thus modify the conclusion of Benhabib and Spiegel (1994) to include the interpretation of Pritchett (1999).

Finally, our findings clearly demonstrate that studies which consider only technology transfer or efficiency in explaining productivity differences are misspecified.

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APPENDIX A

Data Construction

Gaps in the data were evident for six countries, Chad, Guyana, Madagascar, Mauritania, Pakistan and Syria. We chose to exclude Chad completely from the sample because of this missing data and excluded observations for Guyana (data period now 1976-1983), Madagascar (time period now 1984-1998) and Syria (time period now 1975-1998). Missing observations for Pakistan in 1982 and Mauritania in 1994 were interpolated using surrounding years as a guide.

Physical Capital and R&D Stocks

Estimates of the physical capital stock are generated using the perpetual inventory method using the following pair of equations. K refers to the physical capital stock, Δ the depreciation rate, I is investment and g^K the average annual growth rate of investment over the sample period. To overcome problems of the assumptions about initial capital stocks this value was estimated for the first available observation. For most countries this was 1960. This also informed our choice about the depreciation rate which set equal to 10 per cent.

$$K_{it} = (1-\Delta)K_{it-1} + I_{it-1}$$
$$K_{i0} = \frac{I_0}{(g^K + \Delta)}$$

Estimates of the stock of machinery R&D (R_{it}) in OECD countries necessary to measure technology transfer were calculated in a similar manner. Individual country R&D stocks in US $ PPP were calculated and then aggregated across the 15 available OECD countries. Machinery R&D investments were taken from the OECD ANBERD database for Australia, Canada, Denmark, Finland, France, Germany, Italy, Ireland, Japan, Netherlands, Norway, Spain, Sweden, UK and US. The German data were adjusted to take account of German reunification. For most countries this was available for the period 1970/3 to 1995. The R&D investment data were extrapolated forward (and in some cases backwards) for missing years by assuming that the rate of growth of R&D was the same in these missing years as the average over the sample period. The rate of depreciation (Δ) was again set to equal 10 per cent while the initial stock of R&D is estimated in the usual way (where the term g^{RD} is the average annual growth rate of R&D over the period).

$$R_{it} = (1-\Delta)R_{it-1} + RD_{it-1}$$
$$R_{i0} = \frac{RD_1}{(g^{RD} + \Delta)}$$

Appendix B

Additional Tables of Results

Table B1: Maximum-Likelihood Estimates for Stochastic Translog Production Function with Inefficiency Component[a]

	Coeff.	*std. error*	*t-stat.*
	Production Function		
Constant	23.030		11.650
k	-0.903		-4.933
l	1.421		5.569
h	-2.438		-6.865
k^2	-0.009		-0.613
l^2	-0.115		-3.670
h^2	0.210		4.256
$k*l$	0.040		2.366
$k*h$	0.084		4.055
$l*h$	0.087		3.307
LAND	-1.131		-5.346
$(LAND)^2$	-0.005		-0.510
*K*LAND*	0.061		4.707
l LAND*	-0.019		-0.938
*h*LAND*	-0.077		-5.448
RD^m	0.089		9.721
LAC	0.804		20.482
SSA	-0.073		-1.647
ASIA	0.512		8.847
	Inefficiency Effects		
Constant	1.996		11.505
h	-0.393		-7.039
SWOPEN	-0.250		-8.156
Logmachimp.	-0.164		-12.290
TROPIC	0.624		8.384
σ^2	0.075		22.278
γ	0.919		87.101
Log-likelihood	706.285		
Countries	57		
Years	29		
Observations	1467		

[a] The dependent variable is the log of GDP. Country specific time trends not reported.

Table B2: Average efficiency scores and Standard Deviation by Country and Year

	1970	1980	1990	1998	mean	Std. Dev.	obs
Algeria	0.942	0.947	0.914	0.883	**0.927**	**0.030**	29
Argentina	0.945	0.930	0.929	0.975	**0.947**	**0.021**	29
Bangladesh		0.559	0.861	0.971	**0.814**	**0.137**	19
Bolivia	0.516	0.722	0.885	0.952	**0.771**	**0.130**	29
Brazil	0.703	0.903	0.915	0.957	**0.887**	**0.067**	29
Cameroon		0.839	0.749	0.775	**0.814**	**0.074**	24
Sri Lanka	0.492	0.605	0.809	0.974	**0.716**	**0.152**	29
Chile	0.844	0.947	0.962	0.969	**0.925**	**0.052**	29
China		0.888	0.954	0.967	**0.944**	**0.028**	24
Colombia	0.818	0.928	0.944	0.930	**0.915**	**0.031**	29
Congo, Rep.			0.719	0.938	**0.772**	**0.112**	14
Congo, Dem. Rep.	0.877	0.925	0.909		**0.917**	**0.024**	28
Costa Rica	0.698	0.830	0.902	0.948	**0.853**	**0.071**	29
Benin			0.554	0.833	**0.557**	**0.179**	17
Dominican Republic	0.534	0.713	0.822	0.966	**0.771**	**0.124**	29
Ecuador	0.476	0.751	0.906	0.962	**0.793**	**0.138**	29
El Salvador	0.698	0.788	0.823	0.937	**0.801**	**0.086**	29
Gambia, The		0.209	0.456	0.797	**0.395**	**0.192**	24
Ghana	0.598	0.606	0.836	0.962	**0.718**	**0.150**	29
Guatemala	0.529	0.751	0.845	0.928	**0.754**	**0.119**	29
Honduras	0.327	0.538	0.855	0.943	**0.669**	**0.209**	29
Hong Kong, China	0.859	0.939	0.964	0.927	**0.938**	**0.028**	29
India	0.960	0.946	0.961	0.945	**0.952**	**0.006**	29
Indonesia		0.925	0.953	0.901	**0.932**	**0.024**	20
Iran, Islamic Rep.		0.826	0.930	0.970	**0.917**	**0.052**	23
Jamaica	0.392	0.497	0.846	0.961	**0.655**	**0.204**	29
Jordan		0.979	0.928	0.789	**0.928**	**0.061**	23
Kenya		0.625	0.874	0.929	**0.801**	**0.119**	20
Korea, Rep.	0.986	0.964	0.967	0.956	**0.971**	**0.010**	29
Malawi		0.316	0.560	0.950	**0.481**	**0.222**	26
Malaysia	0.869	0.936	0.964	0.933	**0.930**	**0.027**	29
Mali		0.271	0.417	0.655	**0.412**	**0.120**	20
Mauritius		0.796	0.897	0.938	**0.890**	**0.035**	23
Mexico	0.970	0.970	0.944	0.931	**0.953**	**0.018**	29
Mozambique		0.381	0.444	0.706	**0.452**	**0.117**	19
Nicaragua	0.497	0.566	0.707	0.949	**0.679**	**0.129**	29
Niger		0.189	0.345	0.718	**0.359**	**0.161**	19
Pakistan		0.796	0.941	0.968	**0.853**	**0.105**	27
Panama		0.863	0.905	0.934	**0.907**	**0.035**	19
Papua New Guinea	0.326	0.456	0.568	0.831	**0.556**	**0.160**	29
Paraguay	0.696	0.944	0.960	0.953	**0.899**	**0.082**	29
Peru	0.926	0.942	0.842	0.926	**0.925**	**0.028**	29
Philippines	0.770	0.910	0.947	0.968	**0.905**	**0.049**	29
Rwanda	0.467	0.559	0.460	0.402	**0.468**	**0.073**	29
Senegal	0.704	0.675	0.669	0.670	**0.690**	**0.035**	29
Singapore	0.923	0.961	0.954	0.958	**0.945**	**0.015**	29
Zimbabwe		0.843	0.904	0.882	**0.864**	**0.039**	24

Syrian Arab Republic		0.875	0.906	0.974	**0.883**	**0.072**	24
Thailand	0.727	0.882	0.959		**0.884**	**0.082**	28
Togo		0.469	0.591	0.705	**0.574**	**0.084**	19
Trinidad &Tobago			0.911	0.924	**0.917**	**0.020**	14
Tunisia	0.782	0.952	0.952	0.952	**0.932**	**0.036**	29
Uganda			0.750	0.795	**0.758**	**0.041**	17
Egypt, Arab Rep.		0.932	0.945	0.972	**0.936**	**0.024**	24
Uruguay	0.979	0.966	0.943	0.940	**0.948**	**0.030**	29
Venezuela	0.956	0.845	0.929	0.960	**0.908**	**0.059**	29
Zambia	0.397	0.549	0.807	0.949	**0.669**	**0.193**	29
	0.711	**0.753**	**0.826**	**0.898**	**0.803**	**0.188**	**1436**

Table B3 : Contribution of International Trade (SW OPEN and KM) to Efficiency by Country and Year

	1970	**1980**	**1990**	**1998**	**mean**	**s.d**	**obs**
Algeria	0.042	0.068	0.111	0.127	**0.081**	**0.030**	29
Argentina	0.086	0.123	0.118	0.052	**0.089**	**0.027**	29
Bangladesh		0.056	0.094	0.031	**0.067**	**0.018**	19
Bolivia	0.037	0.052	0.075	0.050	**0.058**	**0.012**	29
Brazil	0.060	0.079	0.083	0.070	**0.075**	**0.009**	29
Cameroon		0.049	0.048	0.071	**0.048**	**0.011**	24
Sri Lanka	0.029	0.063	0.070	0.022	**0.054**	**0.018**	29
Chile	0.108	0.102	0.080	0.067	**0.094**	**0.027**	29
China		0.125	0.094	0.073	**0.088**	**0.019**	24
Colombia	0.056	0.063	0.067	0.091	**0.070**	**0.010**	29
Congo, Rep.		0.064	0.053	0.042	**0.052**	**0.008**	14
Congo, Dem. Rep.	0.057	0.067	0.087		**0.065**	**0.014**	28
Costa Rica	0.039	0.053	0.085	0.063	**0.065**	**0.012**	29
Benin		0.088	0.026	0.052	**0.023**	**0.019**	17
Dominican Republic	0.029	0.047	0.072	0.036	**0.056**	**0.017**	29
Ecuador	0.036	-0.002	0.073	0.046	**0.067**	**0.016**	29
El Salvador	0.025	0.035	0.074	0.063	**0.052**	**0.014**	29
Gambia, The		0.046	0.012	0.031	**0.008**	**0.012**	24
Ghana	0.025	0.032	0.077	0.034	**0.047**	**0.019**	29
Guatemala	0.015	0.089	0.069	0.066	**0.047**	**0.019**	29
Honduras	0.010	0.077	0.057	0.055	**0.041**	**0.021**	29
Hong Kong, China	0.090	0.080	0.061	0.129	**0.082**	**0.017**	29
India	0.036	0.104	0.066	0.106	**0.073**	**0.018**	29
Indonesia			0.061	0.108	**0.078**	**0.015**	20
Iran, Islamic Rep.			0.108	0.043	**0.083**	**0.033**	23
Jamaica	0.031	0.032	0.086	0.036	**0.045**	**0.016**	29
Jordan		0.019	0.111	0.130	**0.075**	**0.049**	23
Kenya		0.044	0.065	0.066	**0.056**	**0.011**	20
Korea, Rep.	0.008	0.083	0.092	0.130	**0.071**	**0.042**	29
Malawi		0.014	0.027	0.016	**0.019**	**0.009**	26
Malaysia	0.070	0.077	0.049	0.111	**0.078**	**0.014**	29
Mali		-0.003	0.011	0.025	**0.007**	**0.010**	20
Mauritius		0.067	0.077	0.060	**0.067**	**0.007**	23
Mexico	0.018	0.028	0.097	0.123	**0.063**	**0.042**	29
Mozambique		0.002	0.012	0.034	**0.011**	**0.010**	19

Nicaragua	0.021	0.030	0.042	0.041	**0.040**	**0.015**	29
Niger		0.000	-0.001	0.018	**0.003**	**0.007**	19
Pakistan		0.091	0.078	0.034	**0.076**	**0.017**	27
Panama		0.076	0.076	0.087	**0.072**	**0.009**	19
Papua New Guinea	0.000	0.014	0.028	0.050	**0.023**	**0.017**	29
Paraguay	0.060	0.066	0.064	0.089	**0.075**	**0.011**	29
Peru	0.044	0.055	0.083	0.098	**0.065**	**0.022**	29
Philippines	0.069	0.086	0.078	0.048	**0.079**	**0.011**	29
Rwanda	-0.016	0.008	0.011	0.011	**0.004**	**0.009**	29
Senegal	0.011	0.035	0.038	0.041	**0.033**	**0.007**	29
Singapore	0.067	0.046	0.077	0.083	**0.075**	**0.020**	29
Zimbabwe		0.040	0.060	0.084	**0.052**	**0.030**	24
Syrian Arab Republic		0.106	0.104	0.031	**0.085**	**0.026**	24
Thailand	0.071	0.094	0.064		**0.079**	**0.012**	28
Togo		0.018	0.028	0.039	**0.024**	**0.008**	19
Trinidad and Tobago			0.067	0.091	**0.072**	**0.014**	14
Tunisia	0.051	0.053	0.081	0.093	**0.072**	**0.014**	29
Uganda			0.054	0.062	**0.045**	**0.016**	17
Egypt, Arab Rep.		0.091	0.090	0.051	**0.086**	**0.022**	24
Uruguay	0.013	0.043	0.095	0.114	**0.066**	**0.040**	29
Venezuela, RB	0.027	0.095	0.089	0.058	**0.070**	**0.024**	29
Zambia	0.018	0.039	0.064	0.043	**0.043**	**0.016**	29
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					0.059	**0.030**	**1467**

Table B4: Mean Level and Standard Deviation (s.d.) of R&D weighted by Machinery Imports by Country and Year

	1970	**1980**	**1990**	**1998**	**mean**	**s.d**	**obs**
Algeria	15.926	17.705	17.969	18.009	**17.461**	**0.593**	29
Argentina	16.262	17.791	17.214	19.116	**17.384**	**0.898**	29
Bangladesh		15.305	16.146	16.394	**15.808**	**0.370**	19
Bolivia	13.554	14.670	14.931	16.251	**14.801**	**0.716**	29
Brazil	16.763	17.979	18.625	19.989	**18.278**	**0.792**	29
Cameroon		15.702	15.666	15.969	**15.479**	**0.400**	24
Sri Lanka	13.765	15.285	15.595	16.636	**15.108**	**1.095**	29
Chile	15.612	16.536	17.657	18.475	**16.776**	**1.052**	29
China		17.805	19.104	20.455	**18.640**	**1.414**	24
Colombia	15.604	16.903	17.380	18.365	**16.960**	**0.899**	29
Congo, Rep.		15.461	15.274	15.530	**15.169**	**0.235**	14
Congo, Dem. Rep.	14.748	15.108	16.073		**15.266**	**0.435**	28
Costa Rica	13.876	15.310	15.880	17.003	**15.296**	**0.806**	29
Benin		16.253	13.770	14.665	**13.948**	**0.393**	17
Dominican Republic	14.361	14.219	16.244	17.365	**15.614**	**0.864**	29
Ecuador	14.315	12.903	16.199	17.411	**16.052**	**0.820**	29
El Salvador	13.450	14.797	15.345	16.346	**14.954**	**0.779**	29
Gambia, The		15.154	13.127	13.176	**12.721**	**0.513**	24
Ghana	14.182	14.940	15.723	16.512	**15.229**	**0.751**	29
Guatemala	13.833	17.609	15.518	16.868	**15.270**	**0.820**	29
Honduras	13.617		15.058	16.314	**14.810**	**0.834**	29
Hong Kong, China	15.853		19.082	20.145	**18.132**	**1.449**	29
India	15.775	17.186	18.403	19.125	**17.682**	**1.073**	29

Indonesia		17.412	18.704	18.766	**18.416**	**0.753**	20
Iran, Islamic Rep.		17.206	18.317	18.319	**17.943**	**0.439**	23
Jamaica	14.819	14.404	15.863	16.157	**15.125**	**0.623**	29
Jordan		16.015	15.815	16.516	**16.082**	**0.440**	23
Kenya		15.740	16.477	16.392	**15.987**	**0.363**	20
Korea, Rep.	16.096	17.952	19.770	19.867	**18.590**	**1.406**	29
Malawi		13.666	14.154	14.139	**13.620**	**0.552**	26
Malaysia	15.240	17.122	18.489	19.298	**17.569**	**1.386**	29
Mali		13.966	14.473	15.122	**14.291**	**0.485**	20
Mauritius		13.871	15.169	15.584	**14.506**	**0.843**	23
Mexico	16.860	18.656	19.603	20.706	**18.790**	**1.162**	29
Mozambique		14.237	15.156	14.842	**14.631**	**0.290**	19
Nicaragua	13.603	13.945	14.234	15.317	**14.343**	**0.517**	29
Niger		14.439	13.998	13.930	**14.068**	**0.207**	19
Pakistan		16.387	17.433	17.376	**16.822**	**0.896**	27
Panama		15.460	15.965	17.138	**16.182**	**0.496**	19
Papua New Guinea	13.916	14.972	15.331	15.775	**14.952**	**0.730**	29
Paraguay	12.449	14.555	15.477	16.743	**14.649**	**1.351**	29
Peru	15.059	16.503	16.463	17.721	**16.429**	**0.660**	29
Philippines	16.007	17.147	17.843	19.012	**17.303**	**1.008**	29
Rwanda	10.780	13.201	13.635	13.400	**12.858**	**1.022**	29
Senegal	13.279	14.799	15.521	15.831	**14.861**	**0.718**	29
Singapore	15.842	17.949	19.453	20.119	**18.349**	**1.381**	29
Zimbabwe		13.737	15.799	15.930	**14.493**	**2.154**	24
Syrian Arab Republic		16.315	16.129	17.045	**16.406**	**0.432**	24
Thailand	15.797	16.906	19.008		**17.610**	**1.397**	28
Togo		14.246	14.398	14.801	**14.055**	**0.447**	19
Trinidad and Tobago			15.452	16.870	**15.808**	**0.517**	14
Tunisia	14.155	16.307	17.132	17.805	**16.392**	**0.981**	29
Uganda			14.613	15.075	**14.414**	**0.379**	17
Egypt, Arab Rep.		17.563	18.076	18.792	**17.872**	**0.590**	24
Uruguay	13.717	15.327	15.132	16.767	**14.894**	**1.012**	29
Venezuela, RB	16.230	17.769	17.882	18.820	**17.746**	**0.672**	29
Zambia	14.398	15.207	15.638	14.933	**15.061**	**0.324**	29
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					15.994	**1.784**	**1467**

Figure 1: Percentage of Countries Within Each Efficiency Decile, 1970-1998