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International R&D Transfer and Technical Efficiency: Evidence from Panel Study Using Stochastic Frontier Analysis

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Summary. – We study the effect of foreign R&D transferred through imports and FDI on domestic technical efficiency using stochastic frontier analysis. Unbalanced panel results from a 77-country sample over 1986-2007 show that FDI- and imports-transferred foreign R&D have a significant impact on domestic country's technical efficiency. Furthermore, we observe a complementarity between FDI-transferred R&D and domestic human capital. In other words, the domestic country needs to obtain a threshold level of human capital to benefit from FDI-transferred R&D. Other macro conditions such as infrastructure, political stability, and urbanization also help to improve the technical efficiency of a country.

Keywords – R&D, FDI, Trade, Technical Efficiency

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1. Introduction

The development of endogenous growth theory has put international technology diffusion in a central position in the recent literature on economic growth. Endogenous growth theories emphasize that technology improvement and human capital accumulation are the main engines of economic growth (Aghion & Howitt, 1992; Barro & Sala-i-Martin, 1997; Romer, 1990). Macro-level studies show that world research and development (R&D) activities tend to be concentrated in developed OECD countries. For instance, the U.S., Japan, the U.K., France, Germany, Italy, and Canada took up 92% of OECD R&D expenditure in 1991 (Coe, Helpman, & Hoffmaister, 1997). In 2007, the U.S., Japan, Germany, France, and the U.K. accounted for approximately 60% of world total R&D expenditure (UNESCO, 2009). Knowledge creation and technological innovations in these developed countries tend to promote their productivity growth. Yet, with increasing globalization, open economies constantly interact with each other in both product and capital markets. Knowledge created in a particular country generally transcends its national boundary and R&D spillovers will not be confined within one country. In other words, technological innovations in certain countries can be transferred to foreign economies through various channels such as foreign direct investment (FDI) and international trade, and the international diffusion of knowledge and innovations may be a major reason of total factor productivity (TFP) *growth* in many economies.

A large body of theoretical and empirical research has examined the impact of foreign R&D on domestic productivity and its importance has been recognized by many. Seminal studies include Grossman and Helpman (1991), Coe and Helpman (1995), Coe, *et al.* (1997), and van Pottelsberghe de la Potterie and Lichtenberg (2001).[1] For instance, Coe and Helpman (1995) find a significant contribution of international

R&D spillovers to the TFP growth of 22 developed countries. Focusing on imports as a channel of R&D spillovers, Coe, *et al.* (1997) estimate that a one-percent increase in foreign R&D raises the productivity growth in less developed countries (LDCs) by 0.06%, other things held constant.

However, as argued by Henry, Kneller, and Milner (2009), by mainly focusing on technology transfer and productivity, the literature might be providing only a partial explanation of the cross-country productivity differences since countries are likely to differ in the efficiency with which they use technologies. It is well acknowledged that a country's productivity as well as its economic growth performance depends on "the extent of technology transfers from the leading countries and the efficiency with which they are absorbed and diffused" (Blomstrom, Lipsey & Zejan, 1994, p.10) (see also Eaton & Kortum, 1996; Kneller & Stevens, 2006). Consequently, having access to technology transfer from foreign countries is *not necessarily* equivalent to productivity growth. It is also critical to understand whether the technology transfer can be utilized *efficiently* in a domestic country.

In this study, we employ a stochastic frontier model to explore the extent to which foreign R&D transfer contribute to domestic technical efficiency. Our study contributes to the literature in two respects. First, productivity growth in general consists of two components: (i) technical efficiency improvement, and (ii) technical change. Technical efficiency is defined as a country's ability to obtain maximum output from a given vector of inputs, so technical efficiency improvement refers to the *movements toward* the production frontier. On the other hand, a technical change leads to an outward *shift* of the production frontier. Growth-accounting methodology provides an empirical framework to study sources of economic growth (Solow,1957). It breaks down the growth rate of total output in an economy into two sources: an increase in the amount of factors of production used, and an increase in productivity -- "technical change", measured as a residual often referred to as the "Solow residual" (Kendrick, 1961; Jorgenson & Griliches, 1967). A potential caveat is that previous analyses of TFP based on the Solow residual calculation generally do not distinguish between technical efficiency change and technical change. Typically, all countries are assumed to be *perfectly efficient* and *operate on* their production frontier as Mastromarco and Ghosh (2009) note, "the use of the residual as technical change is reasonable only if all countries are producing on their Frontier" (p491) (see also Kumbhakar & Lovell, 2000).

As production efficiency varies across countries, we revisit studies of international R&D spillovers (Coe & Helpman, 1995; Coe, *et al.*, 1997) to investigate the impact of international R&D on the domestic country's technical efficiency. We take the approach of stochastic frontier analysis suggested by Battese and Coelli (1995), which estimates the production frontier and describes the deviation of a country's production from its best practice for panel data.[2] The major advantage of using the stochastic frontier model is that we can relax the assumption that individual countries always operate on their production frontier. By applying the stochastic frontier model, we can understand technical efficiency variation across countries and also analyze factors that affect technical efficiency change.

Second, previous research adopting the stochastic frontier framework primarily focuses on the role of trade or FDI *itself* as a determinant of technical efficiency (Kneller & Stevens, 2006; Mastromarco, 2008; Nourzad, 2008; Wijeweera, Villano, & Dollery, 2010). Few have focused on the role of trade and FDI as *conduits* for international R&D transfer with exceptions of Henry, *et al.* (2009) and Mastromarco and Ghosh (2009). Henry, *et al.* (2009) study imports as a channel of transferring international R&D into 57 less developed countries (LDCs) over the time period of 1970-1998. The authors find that trade is an important channel for international technology diffusion, which increases the individual country's ability to move toward its production frontier. The results are echoed in Mastromarco and Ghosh (2009). Based on panel data from 57 LDCs from 1960-2000, Mastromarco and Ghosh find that inward FDI, imports, and foreign R&D transferred through imports all have a positive effect on a domestic country's technical efficiency.

In our paper, we consider *both* FDI and trade as conduits for R&D transfer and estimate their effects on domestic technical efficiency. While Henry, *et al.* (2009) and Mastromarco and Ghosh

(2009) investigate imports as the only channel of international R&D spillovers, such spillovers can occur through inward FDI as well. World imports indeed have a larger value than world FDI inflows. But compared to imports, capital flows by many measures have grown much faster. The annual average growth of world FDI inflows, more than doubling the growth rate of world imports, was 23.6% over the period of 1986-1990, 20% over 1991-1995, and 30.1% over 2005-2007. Studying the impact of international R&D diffusion on TFP, Hejazi and Safrian (1999) point out that excluding FDI may result in "attributing to trade spillovers that are actually occurring through FDI" (p.492). The authors find that FDI is an important channel of transferring foreign knowledge stock, which has a positive impact on domestic country's TFP (see also Xu & Wang, 2000). Furthermore, a recent study by Keller and Yeaple (2009) investigates the effect of the international technology spillovers on the growth of TFP in the U.S. manufacturing industry. Keller and Yeaple argue that productivity spillovers can come from either FDI or imports. Using firm level data over 1987-1996, they find that the spillover effect of inward FDI is significantly stronger than the spillover effect of imports on domestic firms' TFP growth (Wang & Blomström, 1992; Rodriguez-Clare, 1996; Brambilla, Hale, & Long, 2009).

Following Coe and Helpman (1995) and Coe, *et al.* (1997), we take 20 developed OECD countries (OECD20) as the source of international R&D. We employ data from 77 countries over the time period of 1986- 2007. Complementing Henry, *et al.* (2009) and Mastromarco and Ghosh (2009) on technical efficiency, our paper is the first to study both inward FDI and imports as channels for foreign R&D transfer systematically. Comparing the impact of inward FDI-transferred R&D to the impact of imports-transferred R&D, we can also draw inferences on, for example, which one has a larger influence on technical efficiency.

To preview our results, we find that foreign R&D transferred through FDI and imports has a positive impact on domestic technical efficiency. Our findings also suggest a complementarity between FDI-transferred foreign R&D and domestic human capital. For countries with higher level of human capital, the positive effect of FDI-transferred foreign R&D on domestic technical efficiency will be larger.

This finding is consistent with the argument that the level of human capital is positively related to a country's capacity to absorb new knowledge and technology (Kneller & Stevens, 2006). Other factors such as infrastructure, political stability, and urbanization also help to improve the technical efficiency of a country.

In terms of the level of efficiency, OECD20 are among the most efficient countries in the world with an average efficiency score of 0.913 (maximum value of one, which indicates a country is operating on its production frontier). Among LDCs in our sample, Asian economies obtain the highest level of efficiency at 0.816 over the period of 1986-2007, while sub-Saharan countries tend to fall in the group of least efficient economies with an average efficiency score of 0.576.

We estimate that foreign R&D transferred through imports and FDI together account for 9.97% of the world technical efficiency. This means that the average level of technical efficiency would have been 9.97% *lower* were it not for the positive effect of foreign R&D transfer. Inward FDI-transferred foreign R&D plays an important role in improving a country's technical efficiency. Specifically, our results suggest that the potential improvement in world average technical efficiency is 3.1% with an increase in inward FDI-transferred R&D. On the other hand, an increase in imports-transferred R&D leads to a 3% improvement in world technical efficiency.

Our paper is organized as follows: Section 2 outlines the stochastic frontier model; section 3 presents empirical specification and data. We discuss empirical results in section 4 and offer conclusions in section 5.

2. Stochastic Frontier Model General Framework

We analyze countries' technical efficiency based on the approach of the stochastic frontier technique (Aigner, *et al.*, 1977). The stochastic frontier model estimates the maximum output level for a country based on a set of production inputs. The difference between a country's maximum output and its actual output is defined as the technical inefficiency. The general specification of a frontier model is as follows:

$$1nY_{it} = 1nX_{it}\beta + (v_{it} - u_{it}), \tag{1}$$

where subscripts i and t are country and year indexes, respectively; Y represents the real output of a country, X is a vector of production inputs, and β is the corresponding vector of coefficients. The error term $(v_{it} - u_{it})$ in equation (1) consists of two components: a random error, v_{it}, and the technical inefficiency, u_{it}. The random error term, v_{it}, is assumed to have an *iid* normal distribution, i.e., $v_{it} \sim N(0, \sigma_v^2)$; the technical inefficiency term, u_{it}, is defined by the truncation (at zero) of the normal distribution with mean, μ_{it} , and variance, σ_u^2. In addition, the inefficiency effects are assumed to be independently distributed for different countries and years.
The mean of the distribution can be represented as a linear function of certain determinants, included in the
vector *Z* (Battese & Coelli, 1995):

$$\mu_{it} = \mathrm{Z}_{it}\delta. \tag{2}$$

Kumbhakar, Ghosh, and McGuckin (1991) propose a single-stage maximum likelihood procedure to estimate equations (1) and (2). Battese and Coelli (1995) extend and modify this procedure for the use of panel data. In this context, technical efficiency (TE) is defined as the ratio of actual output to the maximum output level and can be calculated as:[3]

$$TE = E[exp(-u_{it})|\varepsilon_{it}]. \tag{3}$$

3. Empirical Specification and Data

(a) *Production function*

We model the production function (1) with the more flexible translog functional form. The translog functional form is preferred to the Cobb-Douglas functional form for frontier analysis given that the translog function does not impose constant elasticity of substitution (Kneller & Stevens, 2003; Kumbhakar & Wang, 2005). The log linear form of our translog production function gives:

$$\begin{aligned}\ln Y_{it} = {} & \beta_0 + \beta_K \ln K_{it} + \beta_L \ln L_{it} + \beta_H \ln H_{it} + \frac{1}{2}\beta_{KK}(\ln K_{it})^2 \\ & + \frac{1}{2}\beta_{LL}(\ln L_{it})^2 + \frac{1}{2}\beta_{HH}(\ln H_{it})^2 + \beta_{KL}(\ln K_{it} \times \ln L_{it}) \\ & + \beta_{KH}(\ln K_{it} \times \ln H_{it}) + \beta_{LH}(\ln L_{it} \times \ln H_{it}) + \beta_{Yr} Year \\ & + \beta_{Yrsq} Year^2 + \beta_{YrK}(Year \times \ln K_{it}) \\ & + \beta_{YrL}(Year \times \ln L_{it}) + \beta_{YrH}(Year \times \ln H_{it}) \\ & + \beta_R \, Regions + (v_{it} - u_{it})\end{aligned} \tag{4}$$

where K, L, and H represent physical capital, labor force, and human capital, respectively; $Regions$ are regional dummy variables representing Asia, Latin America and the Caribbean (LAC), Middle East and North Africa (MENA), and sub-Saharan Africa (SSA).[4] We include time trend ($Year$) and the time-squared variables to allow for non-monotonic technical change. The interaction variables between trend and production inputs are also included in equation (4) for the possibility of non-neutral technical change.

We measure output by real GDP in millions of constant 2000 dollars. Data on GDP and labor force come from the World Development Indicators (WDI) published by the World Bank. There are no readily available data on physical capital stock, and we estimate physical capital stock using the perpetual inventory method commonly adopted in the literature:

$$K_{i0} = \frac{investment_{i0}}{g_i + d}, \tag{5}$$

and

$$K_{it} = (1 - d)K_{it-1} + investment_{it}, \tag{6}$$

where K_{i0} represents the initial physical capital stock for country i; $investment_{i0}$ is the initial domestic investment in country i; g_i is a weighted average of the world and country i's GDP growth rate over the first decade of our sample period. Following Easterly and Levine (2001), the world average GDP growth rate is given the weight of 0.75 and country i's average GDP growth rate is given the weight of 0.25 to calculate g_i; d represents the depreciation rate of physical capital and is assumed to take the value of 0.07.5 Gross fixed capital formation data used to calculate physical capital stock are also collected from the WDI.

Our measure of human capital comes from Barro and Lee (2000) and is the average years of secondary schooling in the total population over the age of 15. The schooling data are reported every five years (1960, 1965, 1970, …). As a result, schooling for 1985 reported in Barro and Lee is used in our sample for human capital over 1985-1989; schooling reported for 1990 is used in our sample for 1990-1994; and so on. Since the data are available up to 2000, linear interpolation is used for schooling data over 2004-2007. In addition, we also employ an alternative measure of human capital, secondary school enrollment rate, for robustness check. The enrollment rate is provided by the United Nations Educational, Scientific, and Cultural Organization (UNESCO).[6]

(b) *Inefficiency function*

Variables included in the average technical inefficiency function represent a country's infrastructure, openness, urbanization, political stability, and knowledge stock transferred by foreign investment and imports. The average technical inefficiency function is represented as follows:

$$\mu_{it} = Z_{it}\delta = \delta_0 + \sum_{n=1}^{8} \delta_n z_{n,it} = \delta_0 + \delta_1 \ln INFRA_{it} + \delta_2 OPEN_{it} + \delta_3 URB_{it} + \delta_4 \ln PS_{it} + \delta_5 \ln RD_{it}^{FDI} + \delta_6 \ln RD_{it}^{M} + \delta_7 \left(\ln RD_{it}^{FDI} \times \ln H_{it}\right) + \delta_8 \left(\ln RD_{it}^{M} \times \ln H_{it}\right) \tag{7}$$

where $\left(\ln RD_{it}^{FDI}\right)$ is the log value international R&D transferred by inward FDI and $\left(\ln RD_{it}^{M}\right)$ is the log of international R&D transferred by imports into country i .[7]

Previous literature has discussed the important role of domestic absorptive capacity in adopting new technologies from foreign countries (Borensztein, *et al.*, 1998; Cohen & Levinthal, 1989; Findlay, 1978; Glass & Saggi, 1998). Findlay (1978) theoretically studies the relationship between relative backwardness and the speed of adopting new technologies and spillover benefits from multinational corporations. Findlay concludes that the positive effect of FDI spillovers is stronger the larger the technology gap between home and host countries. However, more recent studies tend to argue differently. For example, Glass and Saggi (1998) take the technology gap as an indicator of the host's absorptive capacity. The authors suggest that when the gap is large, the host country might not have a sufficient level of human capital to benefit from the technology transferred by FDI. Similarly, Borensztein, *et al.* (1998) argue that inward FDI will promote a host country's economic growth only when that host country achieves a certain absorptive capacity, measured by a threshold level of average years of secondary schooling. In other words, there exists a complementarity between inward FDI and a host country's human capital in promoting that host country's economic growth. To explore whether a similar complementarity exists in our model and the extent to which human capital affects a country's adoption of foreign R&D, we include the two interactive terms in the regression, $\ln RD_{it}^{FDI} \times \ln H_{it}$ and $\ln RD_{it}^{M} \times \ln H_{it}$. If a country needs to achieve a certain level of human capital to benefit from foreign R&D in terms of reducing inefficiency, we should observe negative and significant coefficients on the interactive terms. World R&D activities tend to be concentrated in developed OECD countries (Coe & Helpman, 1995; Coe, *et al.*, 1997). As mentioned previously, approximately 60% of world total R&D expenditure (UNESCO, 2009) in 2007 came from the U.S., Japan, Germany, France, and the U.K. Following Coe and Helpman (1995) and Coe, *et al.* (1997), we take 20 developed OECD countries (OECD20) as the source of international knowledge stock, which can be transferred to country i through FDI from OECD20 $\left(RD_i^{FDI}\right)$ and through imports in country i from OECD20 $\left(RD_i^M\right)$.[8] All other non-OECD20 countries in our sample are categorized as LDCs. For each of the LDCs in our sample, RD^{FDI} is the bilateral-inward FDI-share weighted sum of OECD20's domestic R&D capital stock and RD^M is the bilateral-imports-share weighted sum of OECD20's domestic R&D stock. For any one of the OECD20 countries, RD^{FDI} and RD^M represent the bilateral-inward FDI-share weighted sum and the bilateral-imports-share weighted sum of the other 19 OECD countries' domestic R&D capital stock, respectively. In particular, for any year t:

$$RD_{it}^{FDI} = \sum_{j\epsilon\{OECD20\}} \frac{FDI_{jit}}{FDI_{jt}} \times RD_{jt}, \text{ for } j \neq i \tag{8}$$

$$RD_{it}^{M} = \sum_{j\epsilon\{OECD20\}} \frac{M_{jit}}{E_{jt}} \times RD_{jt}, \text{ for } j \neq i \tag{9}$$

where RD_{jt} is the level of domestic R&D capital stock in country j, for $j\epsilon\{OECD20\}$, and $i\epsilon\{OECD20, LDCs\}$. In equation (8), the term FDI_{ji} represents inward FDI in country i from country j, and FDI_j represents total FDI outflows from country j to all i s. In equation (9), M_{JI} represents imports in country i from country j and E_j is the total exports from country j to all i s.[9]

To calculate the real value of domestic R&D capital stock in each of the OECD20 countries, we employ data on real gross domestic R&D expenditure, which is used as a proxy for annual R&D investment. Then a perpetual inventory method similar to the one used for constructing physical capital stock is applied (equations (5) and (6)) to estimate the R&D capital stock.[10] We obtain data on annual bilateral FDI from OECD International Direct Investment Database. Trade data are from the OECD Monthly Statistics of International Trade Database. Real gross domestic R&D expenditure in OECD20 is from the OECD Science and Technology Statistics.

Figure 1 represents our calculated foreign R&D transferred through inward FDI and imports for LDC regions in our sample over 1986-2007.[11] On average, Asian economies received the largest value of international knowledge stock transferred through inward FDI and imports from OECD20. Latin America and the Caribbean (LAC) and Middle East and North Africa (MENA) had comparable levels of international R&D transferred through different channels. Countries in sub-Saharan Africa (SSA) received the smallest amount of foreign R&D among all LDCs. For example, the foreign R&D stock transferred into Asia was 6100% larger than that into SSA through FDI, and 3900% larger than that into SSA through imports. R&D transferred into LAC was 354% and 256% larger than that into SSA through FDI and imports, respectively. Similarly, R&D transferred into MENA through FDI was 285% larger than that in SSA, and 245% larger than that in SSA through imports. Furthermore, Asian countries experienced the most stable increase in foreign R&D transferred through inward FDI. The foreign knowledge stock transferred through FDI rose in other LDC regions in 1986-2007 as well, but fluctuated quite considerably, especially in MENA and SSA. In contrast, the knowledge stock transferred through imports into LDCs was much more stable. Asia and LAC had shown a stronger growth in foreign R&D transferred through imports than MENA and SSA. MENA and SSA illustrated very similar dynamic patterns in terms of knowledge stock transferred through imports.

[FIGURE 1 ABOUT HERE]

The significance of infrastructure (*INFRA*) in the process of economic development has long been recognized. An adequate and reliable supply of infrastructure (e.g., infrastructure associated with communication and transportation) facilitates mobility and efficient allocation of inputs as well as final products, reduces transaction costs, and improves productivity (Roller & Waverman, 2001). In addition, access to phones, power, and paved roads provides individuals with improved choice and can lead to a higher living standard. A number of studies (Fedderke, Perkins, & Luiz, 2006; Um, Straub, & Vellutini, 2009) have illustrated the significant impact of infrastructure on economic growth and productivity. Infrastructure in our paper is proxied by the number of cell phone and land-line phone subscriptions per 100 people in a country (Ding, Haynes, & Liu, 2008). We expect better infrastructure to promote technical efficiency.

While economic theory is fairly clear on the effect of infrastructure, the effect of openness of a country (*OPEN*) on technical inefficiency can be rather uncertain. On the one hand, openness of a country allows dissemination of knowledge in the economy, encourages competition, and promotes economic growth (Young, 1991; Dollar & Kraay, 2004). On the other hand, Sachs and Warner (1999) point out that trade liberalization can have a long-term negative impact on a country's development if it leads to specialization in extractive sectors (Rodriguez & Rodrik, 1999). In our study, we include a measure of openness, which is the sum of imports and exports as a share of GDP. The potential impact of openness on efficiency is ambiguous.

Urbanization is an important factor that can affect technical efficiency through several channels. But it has long been omitted from studies on economic performance. Jayasuriya and Wodon (2005) argue that "with the presence of universities, research centers, and many firms, cities thrive… facilitating spillovers" (p.122). In addition, Adams (2001) and Quigley (1998) point out cities help to maintain personal contacts and also provide a better match between skills and needs. We include as a measure of urbanization (*URB*) in our regressions the share of a country's population living in urban areas. We expect that an increase in urbanization will decrease technical inefficiency.

The last variable included in the inefficiency function is the political stability of a country (*PS*). Better institutions and political stability help to secure property rights and reduce information costs and in turn help to promote technical efficiency (Klein & Luu, 2003). Countries with poor institutional quality tend to exhibit worse growth performance (Rodrik, 1999). We employ the political risk index from the *International Country Risk Guide* to measure a country's institutional and political stability. This index is a composite score from individual rankings of 12 components and ranges from zero (very risky) to 100 (very stable).[12] We expect that an improvement in political stability will reduce inefficiency in a country.

Our data on infrastructure, openness, and urbanization are collected from WDI. The *International Country Risk Guide* is published by the Political Risk Service Group, Inc. We provide the summary statistics for our sample in Table 1.

[TABLE 1 HERE]

4. Empirical Results

Empirical results are provided in Table 2. We report five regressions for robustness checks. These five models are different in terms of R&D depreciation rates, measures of human capital, and whether we treat human capital as a factor of production or a productivity-enhancing factor. We start with model 1 in which human capital (years of schooling) is taken as a factor of production and R&D is assumed to depreciate at 5%. In model 2, we change the R&D depreciation rate to 10% (Kneller & Stevens, 2006; Mastromarco & Ghosh, 2009). Models 3-5 all have 10% R&D depreciation rates. In Model 3, human capital is measured by the secondary school enrollment rate (*Enroll*) (Skidmore & Toya, 2002). In model 4, we treat human capital as a productivity enhancing factor instead of a factor of production (Tallman & Wang, 1994). In model 5, we control for potential endogeneity problem in the inefficiency function. For example, a more efficient country might attract more FDI, hence more FDI-transferred R&D. To address this endogeneity concern, we use lagged variables concerning FDI- and import-transferred R&D, which are predetermined, instead of contemporaneous R&D transfers in model 5.[13]

Table 2 is divided into three panels. Panel A shows results for the production function and panel B includes results for the technical inefficiency function. Note that in panel B we are estimating an inefficiency function, so a negative coefficient on a variable indicates that an increase in the value of this variable will decrease inefficiency, or increase efficiency. In panel C, we report results of four likelihood ratio (LR) tests.

[TABLE 2 HERE]

As shown in Table 2, all five models provide similar qualitative results. For the purpose of brevity, our future empirical discussions will be based solely on results from model 2.[14]

We first compare the Cobb-Douglas functional form with the translog form. The LR test indicates that the null hypothesis of the Cobb-Douglas functional form can be rejected at the 1% level. Given the specification of the translog function, the Cobb-Douglas is not an adequate representation of the data. In addition, empirical results also indicate non-neutral technical change over time. The coefficient on the interaction between time and capital is in general positively significant and the coefficient on the interaction between time and labor negative. Theoretically, our results imply that technical change has been capital saving and labor using. The isoquant in the production process is shifting inwards at a faster rate over time in the capital-intensive part of the input set (Coelli, Rao, O'Donnell, & Battese, 2005).

We define $\gamma = \sigma_u^2/\sigma^2$, where $\sigma^2 = \sigma_u^2/\sigma_v^2$ (Battese & Coelli, 1995).[15] The traditional ordinary least squares (OLS) method will generate consistent estimates only when the inefficiency effects do not exist. A likelihood-ratio test can be applied with a null hypothesis of $H_0: \gamma = \delta_0 = \delta_1 = \cdots = 0$. If the null hypothesis is true, the test statistic has approximately a chi-square (or a mixed chi-square) distribution. Rejecting this null hypothesis suggests that technical inefficiency is present in the model and the maximum likelihood method is preferred to the traditional OLS.

The null hypothesis of no technical inefficiency is rejected at the 1% level in all regressions in Table 2. Given the specification of the stochastic frontier model that is estimated, we cannot conclude that the technical inefficiency effects do not exist. According to the value of γ (model 2), 90.4% of the variations in σ^2 can be accounted for by technical inefficiency. In addition, the likelihood ratio test on whether the inefficiency is a function of our Z factors indicates that the null hypothesis can be rejected at the 1% level, suggesting that variables included in the technical inefficiency function explain the sources of inefficiency. Furthermore, a significant γ also tells us that the maximum likelihood estimation technique is preferred to OLS.

Estimated coefficients in the translog function do not directly represent the elasticity of output with respect to different inputs. As a result, we calculate the elasticity as:

$$E_x = \frac{\partial \ln Y}{\partial \ln x} = \beta_x + \beta_{x^2} \ln x + \beta_{xw} \ln w + \beta_{tx} t, \text{for } x, w \in \{K, L, H\}, \text{and } x \neq w. \quad (10)$$

The average elasticity of output with respect to physical capital (E_k) is 0.76, the average elasticity with respect to labor (E_L) is 0.18, and the elasticity of output with respect to human capital (E_H) is 0.15. On average, our results suggest that output is more sensitive to a change in physical capital than a change in labor and human capital. These results are consistent with findings in Miller and Upadhyay (2000). Miller and Upadhyay study the effect of trade openness and human capital on total factor productivity. They find that E_k is higher than E_L using a sample including both developed and developing economies (see also, Koop *et al*., 1999, and Senjadij, 2000). Figure 2 displays box plots of output elasticity with respect to individual inputs at different points of the distribution over different regions. For regional elasticities, the estimated E_k values in our study are within the range of those in Henry *et al*. (2009) and Senhadji (2000).[16]

[FIGURE 2 HERE]

One implication that emerges from our inefficiency function results is the importance of infrastructure, urbanization, and political stability in affecting the domestic country's technical efficiency. Infrastructure, urbanization, and political stability all have significantly negative coefficients, indicating that these factors have positive effects on technical efficiency. For example, the estimated coefficient on infrastructure suggests that a 1% increase in cell phone and land-line phone subscriptions decreases a country's technical inefficiency by 0.114%, holding other things constant. Similarly, a 1% increase in the urbanization rate decreases the country's inefficiency by 0.45% and a one unit increase in the log value of political stability index decreases the country's inefficiency by 0.23%, ceteris paribus. In other words, increasing urbanization and political stability along with an improvement in infrastructure lead to higher technical efficiency. The coefficient on the openness measure is positive and significant in all regressions, indicating that trade openness actually increases technical inefficiency. We do not have an a priori expectation for the coefficient on openness given the mixed evidence in the literature. Our results are consistent with conclusions of Sachs and Warner (1999), and Rodriguez and Rodrik (1999).

The coefficient on the international R&D transferred through imports $(\ln RD^{M})$ is negative and significant at the 1% level, which implies that international R&D diffusion through imports helps improve a country's technical efficiency and confirms findings in Henry, *et al.* (2009) and Mastromarco and Ghosh (2009). The estimated coefficient on inward FDI-transferred foreign R&D $(\ln RD^{FDI})$ is negative and significant at the 5% level, suggesting that FDI is also an important channel of international R&D diffusion and helps individual countries to move closer to their production frontiers.

The positive effect of foreign R&D on efficiency is robust across different regions. We plot the estimated technical efficiency for individual countries against their FDI-transferred R&D and import-transferred R&D by regions in Figure 3. International R&D transfers are positively associated with the level of technical efficiency in the developed OECD20 group as well as in all LDC regions in our sample (Asia, LAC, MENA, and SSA). Figure 3 also shows that the marginal effect of FDI- and import-transferred R&D may be the smallest in the OECD20 group, which could be caused by diminishing marginal product of foreign R&D.

[FIGURE 3 HERE]

The interaction between $\ln RD^{FDI}$ and human capital is negative and significant at the 1% level, while the coefficient on the interactive term, $\ln RD^{M} \times \ln H$, is positive. These results suggest that FDI-transferred foreign R&D will further improve the host country's technical efficiency if the host country achieves a higher level of human capital. Consequently, continued government efforts in increasing the level of human capital and focusing on investment in secondary education will strengthen the beneficial effect of foreign R&D transfer on domestic efficiency. These results are consistent with Borensztein, *et al.* (1998). Similar results are also obtained by Li and Liu (2005) and, at the industry level, by Girma and Gorg (2007), who find that an absorptive capacity is more important for a country to benefit from FDI than from international trade.

We present average efficiency scores for individual countries in the Appendix (Table A). In our sample, the estimated average level of technical efficiency across all countries is 0.78**,** implying a mean technical inefficiency of 0.25.[17] If the log value of inward FDI-transferred foreign R&D rises by one unit, the technical inefficiency will change by $-0.0127 - 0.021 \times \ln H$ units, depending on the level of human capital in individual countries**.** In terms of the impact of foreign R&D transferred through imports**,** a one unit increase in the log value of import-transferred foreign R&D changes inefficiency by $-0.0138 - 0.034 \times \ln H$ units, other things constant. In figure 4, we present box plots of the impact of FDI- and imports-transferred foreign R&D on inefficiency for countries in our sample. It appears that import-transferred foreign R&D has a larger impact in general on decreasing inefficiency (an average of -0.13) than FDI-transferred foreign R&D (an average of - 0.02).

[Figure 4 Here]

(a) *Regional efficiency*

On average, world technical efficiency rose by 15.8% from 0.734 in 1986 to 0.85 in 2007. The U.K. was the most efficient country in the world with an average level of technical efficiency at 0.98 over 1986-2007. The technical efficiency level in LDCs improved on average from 0.665 in 1986 to 0.832 in 2007, representing a 25.1% increase**.** There exist considerable differences across LDCs regions as shown in Figure 5. Asian countries operate at a higher efficiency level than other LDC groups. Obtaining an average efficiency score of 0.82 over the period of 1986-2007, Asian economies are 7.2% more efficient than countries in LAC, 2.15% more efficient than MENA economies, and 41.5% more efficient than sub-Saharan African countries.

[Figure 5 Here]

It is worth emphasizing that Asia, LAC, MENA, and sub-Saharan Africa experienced very different dynamics in technical efficiency change. The efficiency score in Asia rose consistently over 1990-1996. It plunged in 1997 and reached a trough in 1998, which might be due to the negative impact of the Asian financial crisis in 1997 on the macroeconomy. But the level of technical efficiency in Asia soon recovered and began rising again in 1999.

In contrast, LAC endured a long span of stagnant efficiency from 1986 to the early 2000s. This stagnation of efficiency for almost two decades in LAC could be explained by its unstable macro environment. In the 1980s and 1990s, LAC suffered from 36 severe banking/balance of payments crises. The inflation in LAC was at an average rate of 176.9% in the 1980s and 49.5% in the 1990s and the growth of productivity in both time periods in LAC was negative (Fraga, 2004).

The increase in the level of technical efficiency is also evident for MENA economies. With the exception of 1986-1991, countries in MENA are on a path of fast improvement in efficiency. As pointed out by Yousef (2004), MENA countries experienced a drastic decrease in physical capital accumulations in the 1980s, which was caused by a decline in public revenue. But by the early 1990s, debt levels and inflation rates in MENA were brought under control. In addition, "governments also began a gradual transition to structural adjustment – a move strongly supported by international financial institutions and Western governments – including privatization of state-owned enterprises, trade liberalization, deregulation and strengthening the institutional foundations for a market-led economy" (Yousef, 2004, p. 99). The level of technical efficiency in sub-Saharan Africa fluctuated over the period of 1986-1995 without an evident increase. But starting the second half of the 1990s, we observe a consistent upward trend in technical efficiency in sub-Saharan Africa.

Large variations in individual countries' performance within each region are quite evident as well. Table 3 presents the level of technical efficiency in different regions in five periods 1986-1989, 1990-1994, 1995-1999, 2000-2004, and 2005-2007 as well as our entire sample span of 1986-2007. We also report the efficiency scores of the 10 most efficient LDCs and the 10 least efficient LDCs in Table 4. Over our sample period, Latin America (Argentina, Brazil, Chile, Mexico, Uruguay) and Asia (Hong Kong, India, Singapore) dominate the list of the most efficient LDCs, while sub-Saharan African countries account for the majority of the least efficient countries. As illustrated in Table 3, although the average efficiency score in sub-Saharan Africa was around 0.58, South Africa, the most efficient country in sub-Saharan Africa, achieved a level of efficiency above 0.9 in all five periods. On the other hand, Malawi and Togo are in the group of least efficient countries in sub-Saharan Africa with a score of 0.38 or lower. In other words, over 1986-2007, the most efficient country in sub-Saharan Africa was 165.5% more efficient than the least efficient country in the same region. This indeed is not a unique phenomenon in sub-Saharan Africa. In Latin America, Argentina and Uruguay were able to achieve a technical efficiency level above 0.95, comparable to the OECD20 group**.** In contrast, the efficiency score for Guyana varied between 0.23 and 0.35. The average level of technical efficiency in Uruguay (0.946) was 222% higher than the average level of technical efficiency in Guyana (0.294) over our entire sample period. Similar patterns also exist in Asia and MENA, but the difference between the most and the least efficient economies in Asia and MENA is not as dramatic as in Latin America and sub-Saharan Africa. For example, Hong Kong (0.941), the most efficient economy in Asia, was on average 76.6% more efficient than Sri Lanka (0.53), the least efficient economy in Asia. Egypt (0.86) as the most efficient country in MENA was 22.9% more efficient than Syria (0.7), the least efficient country in the region.

[TABLES 3, 4 HERE]

(b) *Contributions of foreign R&D to efficiency*

We provide, in this section, estimations of the contribution of foreign R&D transferred through FDI and imports to technical efficiency in Tables 5 and 6. Table 5 presents the overall contribution of R&D transferred through different channels to the current level of technical efficiency as in Henry, *et al.* (2009). Table 6 presents the potential efficiency ratio based on calculations proposed by Coelli, Perelman, & Romano, 1999).

The technical efficiency score (TE) is calculated as (Battese & Coelli, 1995; Coelli, *et al.*, 1999):

$$TE_{it} = E[\exp(-u_{it})|\varepsilon_{it}] = \left[\exp\left(-\mu_{it} + \frac{1}{2}\sigma_*^2\right)\right] \times \left\{\left[1 - \Phi\left(\sigma_* - \frac{\mu_{it}}{\sigma_*}\right)\right] / \left[1 - \Phi\left(-\frac{\mu_{it}}{\sigma_*}\right)\right]\right\}, \quad (11)$$

where $\Phi(\cdot)$ denotes the cumulative distribution function of the standard normal variable and:

$$\mu_{it} = (1-\gamma)\left(\delta_0 + \sum_{n=1}^{8} \delta_n \mathcal{Z}_{n,it}\right) - \gamma\varepsilon_{it}, \sigma_*^2 = \gamma(1-\gamma)\sigma^2, \text{and } \gamma = \sigma_u^2/(\sigma_u^2 + \sigma_v^2), \quad (12)$$

where $[z_1, \cdots, z_8] = \{\ln INFRA_{it}, OPEN_{it}, URB_{it}, \ln PS_{it}, \ln RD_{it}^{FDI}, \ln RD_{it}^{M}, \ln RD_{it}^{FDI} \times \ln H_{it}, \ln RD_{it}^{M} \times \ln H_{it}\}$.

In Table 5, we present the percentage of current technical efficiency that is accounted for by foreign R&D transfer, following Henry, *et al.* (2009). In this case, we calculate an upper limit and a lower limit of the contribution of foreign R&D. The $\delta_0 + \sum_{n=1}^{8} \delta_n \mathcal{Z}_{n,it}$ in equation (12) is replaced by min $\left(\delta_0 + \sum_{n=1}^{4} \delta_n \mathcal{Z}_{n,it}\right)$ for the lower limit of the contribution of foreign R&D transfer to efficiency score, and by max $\left(\delta_0 + \sum_{n=1}^{4} \delta_n \mathcal{Z}_{n,it}\right)$ for the upper limit. The contribution of foreign R&D reported in Table 5 is an average of the upper and lower limits.

Over the period of 1986-2007, the average contribution of foreign R&D transferred through inward FDI and imports to efficiency across all countries is estimated to be 9.97%. This indicates that for a country with an average level of technical efficiency of 0.85, its efficiency score would have dropped to about 0.72 if it did not receive any international R&D through FDI and imports.

At the regional/group level, the effect of foreign R&D appears to be the strongest in OECD20 countries, with an average contribution of foreign R&D transfer to domestic technical efficiency at 12.18%**.** Among LDCs, the average effect of foreign R&D to efficiency is the strongest in Asia and MENA at around 10.3%, followed by 9.77% in LAC. The contribution of foreign R&D to technical efficiency is the weakest in sub-Saharan Africa, with foreign R&D accounting for 6.65% of the current level of technical efficiency. For instance, the average level of technical efficiency in Asia over 1986-2007 was 0.82 and 0.58 in sub-Saharan Africa. Our results suggest that efficiency scores in Asia and sub-Saharan Africa would have dropped to 0.736 and 0.542, respectively, if these two regions did not receive any foreign R&D through FDI and imports.

[TABLE 5 HERE]

An alternative measure of the contribution of foreign R&D to efficiency, the "net technical efficiency", is suggested by Coelli, Perelman, and Romano (1999). While the calculation based on Henry, *et al.* (2009) illustrates the technical efficiency score if a country *did not* receive any foreign R&D transfer (it can be thought as a "backward" comparison with its status quo), Coelli, *et al.* (1999) provide a "forward" comparison by showing the potential domestic technical efficiency if a country received *more* foreign R&D. We construct the net technical efficiency by replacing $\sum_{n=5}^{8} \delta_n \mathcal{Z}_{n,it}$ with min $\left(\sum_{n=5}^{8} \delta_n \mathcal{Z}_{n,it}\right)$ in (12) and recalculating the efficiency scores. These adjusted predictions (or the "net technical efficiency") are predictions of efficiency scores when all countries face identical foreign R&D transfer conditions (i.e. the most favorable foreign R&D transfer condition). The difference between the net and the actual technical efficiency scores can be interpreted as the potential improvement in country i's level of efficiency if country i's foreign R&D transfer through inward FDI and imports increases.

Table 6 reports the net technical efficiency (panel A) and the ratio of net technical efficiency to the actual level of technical efficiency across different regions (panel B), which we refer to as the *potential efficiency ratio* (PER). Panel C in Table 6 presents the potential efficiency ratio for foreign R&D transferred through inward FDI and Panel D the potential efficiency ratio for foreign R&D transferred through imports.

The average potential efficiency ratio over our entire sample period is 1.035 for all countries, 1.011 for OECD20, and 1.059 for non-OECD20 groups. If foreign R&D transferred through both inward FDI and imports in different countries improves to the most favorable condition in our sample (i.e. the level of foreign R&D received by the U.S.), the average technical efficiency score would rise by 1.1% in OECD20 countries, and by 5.9% in non-OECD20 countries. As OECD20 countries are among the most efficient countries and already receive a large value of foreign R&D, their "room" for improvement in efficiency by receiving more foreign R&D is small (1.1%). However, LDCs can experience a considerable improvement in efficiency with increasing foreign R&D. If LDCs receive the same level of foreign R&D transferred through FDI and imports as in the U.S., their level of technical efficiency would increase, on average, by about 5.9%.

These results have important policy implications for developing countries. LDCs may have limited resources devoted to their domestic R&D capital stock. However, governments of LDCs can employ preferential policies to encourage international trade and to attract foreign investment. With R&D diffusion through imports and capital inflows, LDCs may benefit substantially in terms of efficiency improvement. Our results also provide information on how much improvement LDCs could achieve if they further liberalize their goods and capital markets.

The average potential gain in efficiency over 1986-2007 was 6.9% for sub-Saharan countries, 4.4% for MENA economies, 3.9% for LAC countries, and 2.3% for Asian economies. For example, countries in LAC had an average efficiency score of 0.76 over 1986-2007. Our estimates suggest that if foreign R&D received in LAC increased to the level of foreign R&D received in the U.S., then the average technical efficiency in Latin America would have risen to 0.79. Similarly, if the foreign R&D received by countries in sub-Saharan Africa were the same as the foreign R&D received by the U.S., the average level of technical efficiency in SSA would have improved to 0.62 from 0.58.

[TABLE 6 HERE]

Given that international R&D transfer through both imports and FDI inflows can improve the country's efficiency, how should governments evaluate different policy options toward trade and FDI? Again, this question is of particular importance to LDCs as they have more room for efficiency improvement by receiving more foreign R&D. In order to answer this question, it is necessary to further look at contributions of FDI-transferred R&D and imports-transferred R&D separately.

As shown in the lower panels of Table 6, the average potential efficiency ratio is 1.031 with improvement in foreign R&D transferred through inward FDI, and 1.03 with improvement in foreign R&D transferred through imports over the period of 1986-2007.

At the regional level for all LDCs, the average potential efficiency ratio ranges between 1.03 in Asia and 1.059 in sub-Saharan Africa based on improvements in FDI-transferred R&D, and ranges between 1.02 in Asia and 1.05 in sub-Saharan Africa based on improvements in imports-transferred R&D. Take the estimated potential efficiency ratios in 1995-1999 as an example. The actual efficiency scores in Asia, LAC, MENA, and sub-Saharan Africa in 1995-1999 are 0.817, 0.762, 0.804, and 0.563, respectively. The potential efficiency ratio for FDI transferred R&D in 1995-1999 is 1.033 for Asia, 1.034 for LAC, 1.044 for MENA, and 1.059 for sub-Saharan Africa. These results suggest that holding everything else constant, if the FDI-transferred foreign R&D received in these regions rose to the amount received by the U.S., then the level of technical efficiency would have increased to 0.844 in Asia, 0.788 in LAC, 0.839 in MENA, and 0.596 in sub-Saharan Africa. The potential efficiency ratios due to improvement in imports-transferred R&D in 1995-1999 are 1.024, 1.031, 1.041, and 1.056 in Asia, LAC, MENA, and sub-Saharan Africa, respectively. Consequently, this indicates that holding everything else constant, if imports-transferred R&D in these LDCs could reach the level of imports-transferred R&D in the U.S., the level of technical efficiency would have risen to 0.837 in Asia, 0.786 in LAC, 0.837 in MENA, and 0.595 in sub-Saharan Africa.

Focusing on individual non-OECD20 countries, we find that the largest potential improvements in efficiency due to an increase in FDI-transferred foreign R&D are between 6-7% in Mozambique, Malawi, Mali, and Papua New Guinea and the smallest potential improvements in efficiency are between 0.5-1% in Korea, Hong Kong, Argentina, and Mexico. In terms of the potential improvements in efficiency due to an increase in imports-transferred foreign R&D, the strongest effects are between 7-9% for Gambia, Congo, and Sri Lanka. The smallest effects are in Mexico and Brazil at 0.1-0.3%.

Our results show that the potential improvements in efficiency due to imports-transferred foreign and inward FDI-transferred foreign R&D are comparable. These positive impacts are especially important to low- and middle-income countries.

5. Concluding Remarks

The dissemination of knowledge allows countries to benefit from foreign R&D. Our paper contributes to the literature by focusing on both FDI and imports as conduits of international technology spillovers and studying to what extent FDI- and imports-transferred foreign R&D affect domestic technical efficiency. Using stochastic frontier analysis and panel data from both LDCs and developed OECD countries over the period of 1986-2007, we find that cross-country differences in technical efficiency can be explained by differences in foreign R&D

spillovers, domestic country's absorptive capacity, and other macro conditions.

Our results confirm that imports are an important channel for international R&D spillovers and also highlight the significant impact of inward FDI-transferred foreign R&D on domestic technical efficiency. Foreign R&D transferred through both inward FDI and imports on average account for 9.97% of the world technical efficiency over 1986-2007, with the largest contribution in OECD20 at 12.18% and the smallest contribution in sub-Saharan Africa at 6.65%. In addition, we show that with an increase in the FDI-transferred R&D (to the most favorable level in our sample), the world current level of technical efficiency would improve by 3.1%. Similarly, with an increase in imports-transferred foreign R&D, the world current level of technical efficiency would improve by 3%.

There exist substantive variations in the level of efficiency across countries in our sample. Not surprisingly, developed OECD countries on average achieve the highest level of technical efficiency at 0.91. Among LDCs, Asian economies (0.82) typically obtain a higher level of efficiency than other LDCs. Sub-Saharan African countries consistently are among the least efficient economies with an average technical efficiency score of 0.58 over our sample period.

Our results are meaningful to policymakers, especially policymakers in LDCs. As LDCs may not have adequate domestic resources to promote R&D stock accumulation, our study suggests that adopting preferential policies to promote trade and capital flows and increase the access to foreign R&D can be extremely important to the improvement in efficiency for LDCs.

Efficiency also depends on other factors such as infrastructure and political stability. Improvements in infrastructure and political stability as well as increases in urbanization all help improve technical efficiency in a country.

Endnotes

[1] See Keller (2004) for a detailed survey of the international R&D spillovers literature.

[2] The stochastic frontier model is initially used to study technical efficiency of individual firms and later generalized to macroeconomic research (Aigner, Lovell, & Schmidt, 1977; Battese & Coelli, 1988; Nourzad, 2008; Meeusen & van den Broeck, 1977).

[3] For further technical details of the stochastic frontier model, we refer readers to Battese & Coelli (1988, 1995).

[4] We follow the theoretical framework of production function in Borensztein, De Gregoio, and Lee (1998), in which human capital is considered as a factor of production. For the purpose of robustness check, we also estimate the model where human capital is assumed to be a labor-enhancing factor (Tallman & Wang, 1994). Detailed estimated results are presented in Section 4.

[5] Values of physical capital stock were also calculated using *d* = 0.1 and the empirical results are qualitatively similar to the results with *d* = 0.07 for physical capital.

[6] When using enrollment rate as the measure of human capital, our sample includes 86 countries.

[7] In regressions, we take $\left(\ln RD_{it}^{FDI} + 1\right)$ and $\left(\ln RD_{it}^{M} + 1\right)$.

[8] OECD20 includes Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Ireland, Italy, Japan, Netherlands, New Zealand, Norway, Portugal, Spain, Sweden, Switzerland, the U.K., and the U.S.

[9] For example, if in year *t*, 5% of total FDI outflows from the U.S. went to Thailand, then $FDI_{US,Thailand} / FDI_{US} = 0.05$. In this case, we can calculate the knowledge stock transferred into Thailand from the U.S. through FDI as $0.05 \times RD_{US}$.

[10] In terms of the depreciation rate for R&D capital stock, Bureau of Labor Statistics (BLS) considers that R&D in applied research is depreciated at a rate of 10%, and R&D stock in basic research is not depreciated at all (BLS, 1989). Coe and Helpman (1995) and Coe, *et al.* (1997) calculate R&D stock based on a 5% depreciation rate. We report in our paper results based on depreciation rates of both 5% and 10% for R&D capital stock.

[11] Figure 1 is constructed based on a 10% depreciation rate for R&D stock.

[12] The 12 individual components include government stability, socioeconomic conditions, investment profile, internal conflict, external conflict, corruption, military in politics, religion in politics, law and order, ethnic tensions, democratic accountability, and bureaucracy quality.

[13] A few existing studies discuss the endogeneity concern in frontier models, but mainly focus on X-variable (variables in the production function)

endogeneity (Guan, Kumbhakar, Myers, & Oude-Lansink, 2009). Potential endogenous inefficiency factors have not been discussed in the literature. Basic stochastic frontier models as well as most software packages for this type of analysis cannot account for endogenous variables, either in the production function or in the inefficiency function. Fully addressing the potential endogeneity problem in the inefficiency function is beyond the scope of this paper. We use in the inefficiency function lagged values of FDI transferred- and imports transferred- R&D instead of contemporaneous values to control for endogeneity.

[14] Post-estimation discussions based on other models are available upon request.

[15] γ is bounded between zero and one.

[16] Senhadji (2000) points out that the size of E_k in developing countries relative to E_k in developed countries can be ambiguous although the literature suggests that E_k in developing countries is larger than that in developed countries. E_k is calculated as the product of marginal product of capital ($\partial Y \partial K$) and the capital-output ratio (K/Y). Senhadji argues the marginal product of capital (MPK) is high in developing countries, but their capital-output ratio is low, which leads to uncertainty in the value of E_k. Similarly, the high capital-output ratio in developed countries can be offset by their low value of MPK due to diminishing returns and therefore the size of E_k can be uncertain in developed countries as well. In Koop *et al*. (1999), the authors focus on 17 OECD countries and they observe that countries with very high K/L ratio may have very low output elasticity with respect to physical capital. In some cases, the value of E_K can be up to 0.9 and much higher than the value of E_L.

[17] The level inefficiency is $-\ln(0.78) = 0.25$.

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Table 1. *Descriptive statistics*

Variable	No. of Obs.	Mean	Std. Dev.	Min	Max
Y (in million)	1622	359613.6	1153633	259.42	1.15E+07
K (in million)	1622	739404	2299230	356.474	2.15E+07
L (in million)	1622	28.483	91.818	0.13	782.791
SYR	1622	1.888	1.289	0.056	5.687
Enroll	1688	64.92	34.53	3.67	161.66
RD^{FDI}	1622	50544.22	124712.3	0	1132966
RD^{M}	1622	51448.11	94323.95	88.585	617410.9
INFRA	1622	39.356	46.267	0.040	214.79
OPEN (in unit)	1622	0.74	0.51	0.12	4.57
URB (in unit)	1622	0.57	0.23	0.09	1
PS	1622	67.215	14.712	27.333	96.083

Table 2. *Production function and technical inefficiency estimates*

Panel (a): production function	R&D with 5% Dep. Rate (1)		R&D with 10% Dep. Rate (2)		R&D with 10% Dep. Rate and Enrollment (3)		R&D with 10% Dep. Rate (Effective Labor) (4)		R&D with 10% Dep. Rate (Lagged Values) (5)	
	Coefficient	Std. Err.	Coefficient	Std. Err.	Coefficient	Std. Err.	Coefficient	Std. Err.	Coefficient	Std. Err.
$\ln K$	-0.237***	[0.084]	-0.236***	[0.084]	-0.208***	[0.060]	-0.342***	[0.075]	-0.228***	[0.085]
$\ln L$	1.068***	[0.095]	1.066***	[0.095]	0.866***	[0.066]			1.065***	[0.094]
$\ln H$	0.69***	[0.16]	0.693***	[0.158]	0.55***	[0.12]			0.682***	[0.161]
$\ln(H \times L)$							0.975***	[0.087]		
$(\ln K)^2$	0.0985***	[0.0083]	0.0984***	[0.0083]	0.0902***	[0.0092]	0.1064***	[0.0076]	0.0979***	[0.0084]
$(\ln L)^2$	0.082***	[0.011]	0.082***	[0.011]	0.052***	[0.011]			0.083***	[0.011]
$(\ln H)^2$	0.032	[0.033]	0.032	[0.033]	-0.018	[0.053]			0.037	[0.034]
$\ln(H \times L)^2$							0.064***	[0.011]		
$\ln K \times \ln L$	-0.0886***	[0.0094]	-0.0884***	[0.0094]	-0.067***	[0.010]			-0.0887***	[0.0093]
$\ln K \times \ln H$	-0.061***	[0.015]	-0.061***	[0.015]	-0.017	[0.023]			-0.061***	[0.015]
$\ln L \times \ln H$	0.093***	[0.016]	0.092***	[0.016]	0.028	[0.023]			0.093***	[0.016]
$\ln K \times \ln(H \times L)$							-0.0779***	[0.0087]		
Year	-0.069***	[0.013]	-0.069***	[0.013]	-0.0449***	[0.0089]	-0.066***	[0.012]	-0.071***	[0.013]
Year Squared	0.00044**	[0.00022]	0.00044**	[0.00022]	0.00046*	[0.00025]	0.00044**	[0.00022]	0.00062**	[0.00024]
Year × $\ln L$	-0.0053***	[0.0013]	-0.0052***	[0.0013]	-0.0094***	[0.0013]			-0.0052***	[0.0014]
Year × $\ln K$	0.0056***	[0.0013]	0.0056***	[0.0013]	0.0093***	[0.0013]	0.0052***	[0.0011]	0.0055***	[0.0013]
Year × $\ln H$	-0.0030	[0.0018]	-0.0029	[0.0018]	-0.0153***	[0.0028]			-0.0027	[0.0019]
Year × $\ln(H \times L)$							-0.0043***	[0.0012]		
Regional Dummies	YES		YES		YES		YES		YES	
Constant	7.14***	[0.44]	7.13***	[0.44]	5.91***	[0.39]	7.76***	[0.38]	7.09***	[0.45]
Panel (b): Technical Inefficiency										
$\ln(INFRA)$	-0.115***	[0.019]	-0.114***	[0.019]	-0.121***	[0.016]	-0.105***	[0.018]	-0.11***	[0.018]
OPEN	0.215***	[0.035]	0.216***	[0.035]	0.203***	[0.032]	0.215***	[0.033]	0.224***	[0.035]
URB	-0.450***	[0.088]	-0.450***	[0.088]	-0.399***	[0.072]	-0.466***	[0.086]	-0.403***	[0.090]
$\ln(PS)$	-0.229***	[0.071]	-0.231***	[0.071]	-0.199***	[0.053]	-0.220***	[0.072]	-0.274***	[0.074]
$\ln RD^{FDI}$	-0.0120**	[0.0056]	-0.0127**	[0.0059]	0.058***	[0.019]	-0.0148**	[0.0056]		
$\ln RD^{M}$	-0.140***	[0.019]	-0.138***	[0.019]	-0.238***	[0.028]	-0.157***	[0.018]		
$\ln RD^{FDI} \times \ln H$	-0.0191***	[0.0061]	-0.0211***	[0.0065]	-0.0159***	[0.0052]	-0.0255***	[0.0057]		
$\ln RD^{M} \times \ln H$	0.0315***	[0.0082]	0.0335***	[0.0086]	0.0240***	[0.0073]	0.0457***	[0.0054]		
$\ln RD^{FDI}(t\text{-}1)$									-0.0135**	[0.0060]
$\ln RD^{M}(t\text{-}1)$									-0.139***	[0.019]
$\ln RD^{FDI} \times \ln H(t\text{-}1)$									-0.0209***	[0.0064]
$\ln RD^{M} \times \ln H(t\text{-}1)$									0.0317***	[0.0083]
Constant	2.660***	[0.319]	2.59***	[0.31]	2.67***	[0.23]	2.68***	[0.31]	2.74***	[0.33]
Mean Efficiency	0.78		0.78		0.72		0.78		0.79	
Gamma	0.90		0.90		0.86		0.91		0.90	
Log Liklihood	565.82		566.63		508.17		548.90		551.10	
Observations	1622		1622		1688		1622		1545	
Panel C. likelihood ratio tests on model specifications										
H_0: Cobb-Douglas Specification	326.25***		325.29***		450.50***		308.23***		307.00***	
H_0: Neutral Technological Change	39.08***		38.94***		58.23***		32.15***		36.84***	
H_0: $\gamma = \delta_0 = \ldots = \delta_8 = 0$	796.51***		798.14***		792.41***		818.26***		767.08***	
H_0: $\delta_1 = \ldots = \delta_8 = 0$	629.84***		631.46***		723.84***		632.21***		600.40***	

Note: Standard errors are in parentheses to the right of the respective estimated coefficients. The interaction term of labor (L) and human capital (H) is included in (4) where human capital is considered as a productivity enhancing factor instead of a factor of production.

Comparing regression (2) with (4), the Vuong statistic (V = 2.94***) suggested by Vuong (1989) indicates that the null hypothesis of human capital as a productivity enhancing factor is rejected.

* Significant at the 10% level, ** Significant at the 5% level, and *** Significant at the 1% level.

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Table 3. *Average technical efficiency*

		1986-89	1990-94	1995-99	2000-04	2005-07	1986-2007[a]
All Countries		0.7495	0.7576	0.7801	0.8013	0.8284	0.7798
		[0.195]	[0.198]	[0.183]	[0.171]	[0.163]	[0.179]
	Most Efficient Country	UK	UK	UK	UK	UK	UK
		0.9783	0.9750	0.9769	0.9758	0.9722	0.9758
	Least Efficient Country	Malawi	Guyana	Guyana	Guyana	Guyana	Guyana
		0.2655	0.2347	0.2942	0.3293	0.3496	0.2937
OECD20		0.9091	0.9085	0.9181	0.9172	0.9068	0.9126
		[0.047]	[0.052]	[0.051]	[0.056]	[0.058]	[0.046]
	Most Efficient Country	UK	UK	UK	UK	UK	UK
		0.9783	0.9750	0.9769	0.9758	0.9722	0.9758
	Least Efficient Country	Finland	Finland	Japan	Japan	Japan	Japan
		0.8180	0.7607	0.7638	0.7315	0.7393	0.7839
Sub-Saharan Africa		0.5553	0.5511	0.5631	0.6048	0.6419	0.5764
		[0.210]	[0.207]	[0.163]	[0.168]	[0.177]	[0.174]
	Most Efficient Country	South Africa	South Africa	South Africa	South Africa	South Africa	South Africa
		0.9345	0.9354	0.8959	0.9279	0.9436	0.9257
	Least Efficient Country	Malawi	Togo	Togo	Congo	Zimbabwe	Togo
		0.2655	0.2681	0.3613	0.3849	0.4123	0.3487
Middle East and North Africa		0.6940	0.7373	0.8036	0.8656	0.9096	0.7984
		[0.098]	[0.075]	[0.075]	[0.051]	[0.041]	[0.057]
	Most Efficient Country	Jordan	Iran	Egypt	Egypt	Egypt	Egypt
		0.7833	0.8177	0.9111	0.9488	0.9628	0.8604
	Least Efficient Country	Syria	Syria	Jordan	Jordan	Syria	Syria
		0.5032	0.6338	0.7102	0.8228	0.8450	0.7054
Latin America and the Caribbean		0.7484	0.7437	0.7621	0.7671	0.8075	0.7606
		[0.187]	[0.221]	[0.209]	[0.191]	[0.185]	[0.201]
	Most Efficient Country	Uruguay	Uruguay	Argentina	Brazil	Brazil	Uruguay
		0.9582	0.9589	0.9563	0.9450	0.9644	0.9462
	Least Efficient Country	Nicaragua	Guyana	Guyana	Guyana	Guyana	Guyana
		0.4082	0.2347	0.2942	0.3293	0.3496	0.2937
Asia		0.7151	0.7643	0.8165	0.8586	0.9128	0.8156
		[0.176]	[0.151]	[0.103]	[0.090]	[0.066]	[0.114]
	Most Efficient Country	Singapore	Malaysia	Hong Kong	Hong Kong	Pakistan	Hong Kong
		0.9220	0.9362	0.9301	0.9351	0.9595	0.9409
	Least Efficient Country	Sri Lanka	Sri Lanka	Sri Lanka	Sri Lanka	Sri Lanka	Sri Lanka
		0.3803	0.4560	0.5468	0.6063	0.7189	0.5329

Note: Standard derivations are in parentheses.

[a]The three countries with the highest efficiency scores in the period of 1986-2007 are: UK (0.9758), USA (0.9687), and France (0.9506). The three countries with the lowest efficiency scores are: Guyana (0.2937), Togo (0.3486), and Malawi (0.3653).

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Table 4. *Efficiency scores of individual LDCs, 1986-2007*

Panel (a): most efficient countries

	1986-89		1990-94		1995-99		2000-04		2005-07	
Rank	Country	Score	Country	Score	Country	Score	Country	Score	Country	Score
1	Uruguay	0.9582	Uruguay	0.9589	Argentina	0.9563	Egypt	0.9488	Brazil	0.9644
2	Mexico	0.9511	Argentina	0.9532	Uruguay	0.9528	Turkey	0.9454	Turkey	0.9639
3	Argentina	0.9447	Venezuela	0.9509	Guatemala	0.9477	Brazil	0.9450	Egypt	0.9628
4	South Africa	0.9345	Mexico	0.9419	Turkey	0.9404	Guatemala	0.9357	Argentina	0.9599
5	Turkey	0.9242	Turkey	0.9391	Venezuela	0.9386	Hong Kong	0.9351	Pakistan	0.9595
6	Singapore	0.9220	Malaysia	0.9362	Chile	0.9311	Mexico	0.9325	Uruguay	0.9594
7	Venezuela	0.9119	South Africa	0.9354	Hong Kong	0.9301	Korea	0.9301	Hong Kong	0.9576
8	Guatemala	0.9069	Guatemala	0.9319	Mexico	0.9281	South Africa	0.9279	India	0.9543
9	Malaysia	0.9053	Korea	0.9271	Brazil	0.9252	Greece	0.9235	Singapore	0.9482
10	Korea	0.9043	Singapore	0.9262	Dominican Republic	0.9171	India	0.9209	Philippines	0.9470

Panel (b): least efficient countries

	1986-89		1990-94		1995-99		2000-04		2005-07	
Rank	Country	Score	Country	Score	Country	Score	Country	Score	Country	Score
1	Malawi	0.2655	Guyana	0.2347	Guyana	0.2942	Guyana	0.3293	Guyana	0.3496
2	Togo	0.2726	Togo	0.2681	Togo	0.3613	Congo	0.3849	Zimbabwe	0.4123
3	Sri Lanka	0.3803	Malawi	0.2894	Congo	0.3913	Togo	0.4133	Malawi	0.4502
4	Ghana	0.3834	Nicaragua	0.3788	Malawi	0.3927	Ghana	0.4353	Togo	0.4556
5	Gambia	0.3907	Cameroon	0.4027	Gambia	0.4111	Malawi	0.4432	Congo	0.4587
6	Nicaragua	0.4082	Gambia	0.4134	Ghana	0.4131	Gambia	0.4768	Ghana	0.4678
7	Ecuador	0.4139	Ghana	0.4175	Nicaragua	0.4384	Nicaragua	0.4840	Nicaragua	0.5265
8	Mali	0.4177	Mali	0.4369	Ecuador	0.4656	Zimbabwe	0.4934	Gambia	0.5415
9	Cameroon	0.4492	Ecuador	0.4450	Cameroon	0.4712	Ecuador	0.5019	Ecuador	0.5624
10	China	0.4910	Sri Lanka	0.4560	Mali	0.5185	Paraguay	0.5454	Paraguay	0.6163

Table 5. *Contribution of international R&D transfer to technical efficiency (in percent)*

		1986-89	1990-94	1995-99	2000-04	2005-07	1986-2007
All Countries							
	Mean	10.053	9.911	10.374	10.072	9.680	9.971
	Conf. Interval	(3.61, 16.49)	(3.23, 16.59)	(3.46, 17.29)	(3.55, 16.59)	(2.62, 16.74)	(3.77, 16.17)
OECD20							
	Mean	12.350	12.458	12.182	11.684	12.259	12.182
	Conf. Interval	(4.76, 19.93)	(5.41, 19.50)	(4.02, 20.34)	(3.46, 19.91)	(4.21, 20.31)	(5.02, 19.34)
Sub-Saharan Africa							
	Mean	6.871	6.424	6.647	6.714	7.430	6.651
	Conf. Interval	(3.34, 10.40)	(3.01, 9.84)	(1.49, 11.80)	(2.64, 10.79)	(3.33, 11.53)	(2.69, 10.61)
Middle East and North Africa							
	Mean	10.972	10.919	10.918	9.723	8.680	10.342
	Conf. Interval	(8.04, 13.90)	(8.13, 13.70)	(8.80, 13.03)	(6.16, 13.28)	(3.09, 14.27)	(8.00, 12.68)
Latin America and the Caribbean							
	Mean	9.452	9.088	10.023	10.739	9.887	9.765
	Conf. Interval	(4.54, 14.36)	(3.66, 14.52)	(5.45, 14.59)	(6.69, 14.79)	(4.24, 15.53)	(5.65, 13.88)
Asia							
	Mean	9.833	9.965	11.865	10.660	8.340	10.220
	Conf. Interval	(4.93, 14.74)	(4.76, 15.17)	(6.61, 17.12)	(5.47, 15.85)	(2.14, 14.54)	(5.44, 15.00)

Note: The contribution to international R&D transfer is calculated by averaging the least and the most of contribution of international R&D transfer. The least contribution represents the perchange gain of the current technical efficiency from the technical efficiency without int'l R&D transfer, where the technical efficiency without int'l R&D transfer is obtained by replacing "$\Sigma^{8}_{n=1}\ \delta_n\ z_{n,it}$" with the minimum of "$\Sigma^{4}_{n=1}\ \delta_n\ z_{n,it}$" in equation (12). The most contribution is calculated based on the similar procedure where the maximum of "$\Sigma^{4}_{n=1}\ \delta_n\ z_{n,it}$" is used.

Table 6. *Net technical efficiency and potential efficiency ratio*

	1986-89	1990-94	1995-99	2000-04	2005-07	1986-2007
Panel (a): net technical efficiency						
All Countries	0.7704 [0.189]	0.7791 [0.191]	0.8038 [0.173]	0.8254 [0.160]	0.8502 [0.151]	0.8024 [0.170]
OECD20	0.9199 [0.039]	0.9188 [0.045]	0.9270 [0.046]	0.9261 [0.052]	0.9172 [0.053]	0.9223 [0.041]
Sub-Saharan Africa	0.5817 [0.212]	0.5820 [0.210]	0.6036 [0.167]	0.6472 [0.166]	0.6845 [0.172]	0.6133 [0.175]
Middle-East and North Africa	0.7243 [0.101]	0.7717 [0.070]	0.8433 [0.061]	0.9001 [0.035]	0.9331 [0.028]	0.8318 [0.048]
Latin America and the Caribbean	0.7745 [0.178]	0.7673 [0.215]	0.7862 [0.201]	0.7935 [0.183]	0.8296 [0.175]	0.7854 [0.194]
Asia	0.7321 [0.173]	0.7818 [0.144]	0.8355 [0.096]	0.8765 [0.080]	0.9256 [0.052]	0.8325 [0.106]
Panel (b): potential efficiency ratio (PER)						
All Countries	1.0329 [0.024]	1.0343 [0.027]	1.0367 [0.031]	1.0359 [0.031]	1.0318 [0.031]	1.0350 [0.028]
OECD20	1.0124 [0.012]	1.0119 [0.012]	1.0100 [0.008]	1.0101 [0.008]	1.0118 [0.009]	1.0111 [0.009]
Sub-Saharan Africa	1.0526 [0.021]	1.0611 [0.023]	1.0752 [0.021]	1.0754 [0.025]	1.0725 [0.028]	1.0688 [0.022]
Middle-East and North Africa	1.0446 [0.016]	1.0480 [0.018]	1.0512 [0.023]	1.0411 [0.021]	1.0265 [0.017]	1.0435 [0.018]
Latin America and the Caribbean	1.0406 [0.027]	1.0388 [0.028]	1.0387 [0.030]	1.0404 [0.027]	1.0330 [0.029]	1.0393 [0.028]
Asia	1.0270 [0.021]	1.0262 [0.023]	1.0254 [0.022]	1.0228 [0.022]	1.0155 [0.022]	1.0233 [0.021]
Panel (c): FDI-transferred R&D PER						
All Countries	1.0374 [0.022]	1.0332 [0.022]	1.0327 [0.023]	1.0285 [0.021]	1.0234 [0.021]	1.0313 [0.021]
OECD20	1.0118 [0.008]	1.0093 [0.007]	1.0085 [0.006]	1.0072 [0.007]	1.0076 [0.007]	1.0089 [0.006]
Sub-Saharan Africa	1.0563 [0.014]	1.0548 [0.013]	1.0587 [0.012]	1.0538 [0.015]	1.0499 [0.017]	1.0550 [0.013]
Middle-East and North Africa	1.0561 [0.004]	1.0500 [0.004]	1.0440 [0.013]	1.0313 [0.013]	1.0183 [0.010]	1.0409 [0.008]
Latin America and the Caribbean	1.0411 [0.019]	1.0348 [0.019]	1.0343 [0.020]	1.0324 [0.016]	1.0258 [0.018]	1.0339 [0.017]
Asia	1.0437 [0.018]	1.0366 [0.018]	1.0327 [0.017]	1.0249 [0.015]	1.0141 [0.013]	1.0300 [0.016]
Panel (d): import-transferred R&D PER						
All Countries	1.0280 [0.019]	1.0292 [0.020]	1.0315 [0.023]	1.0302 [0.022]	1.0275 [0.023]	1.0299 [0.021]
OECD20	1.0208 [0.016]	1.0202 [0.015]	1.0173 [0.013]	1.0165 [0.011]	1.0192 [0.012]	1.0187 [0.012]
Sub-Saharan Africa	1.0374 [0.018]	1.0429 [0.020]	1.0555 [0.019]	1.0541 [0.022]	1.0519 [0.024]	1.0497 [0.020]
Middle-East and North Africa	1.0324 [0.017]	1.0358 [0.018]	1.0413 [0.020]	1.0343 [0.019]	1.0243 [0.015]	1.0345 [0.016]
Latin America and the Caribbean	1.0325 [0.022]	1.0318 [0.023]	1.0311 [0.025]	1.0325 [0.023]	1.0269 [0.024]	1.0320 [0.023]
Asia	1.0207 [0.019]	1.0209 [0.018]	1.0237 [0.016]	1.0205 [0.017]	1.0147 [0.019]	1.0203 [0.017]

Note: Net technical efficiency is calculated by replacing "$\Sigma^8_{n=5}\ \delta_n\ z_{n,it}$" with the minimum of "$\Sigma^8_{n=5}\ \delta_n\ z_{n,it}$" in equation (12). Potential efficiency ratio (PER) is defined as the average of the net technical efficiency divided by the gross technical efficiency. Standard deviations are in parentheses.

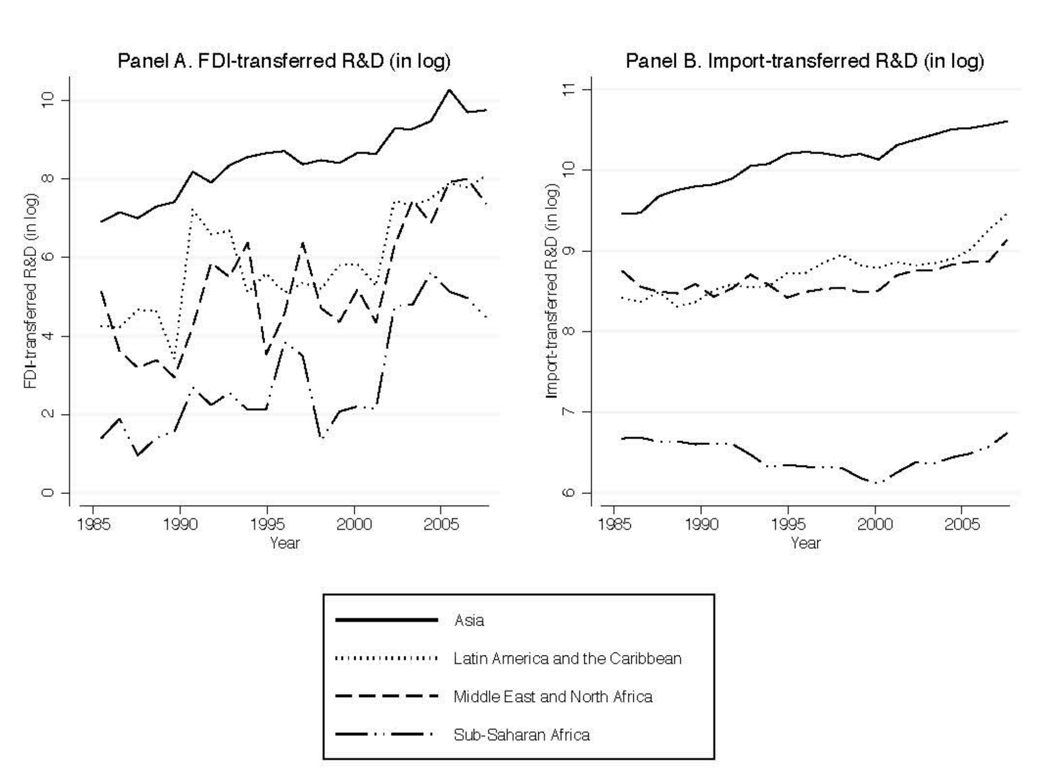

Figure 1. *International R&D transfer*

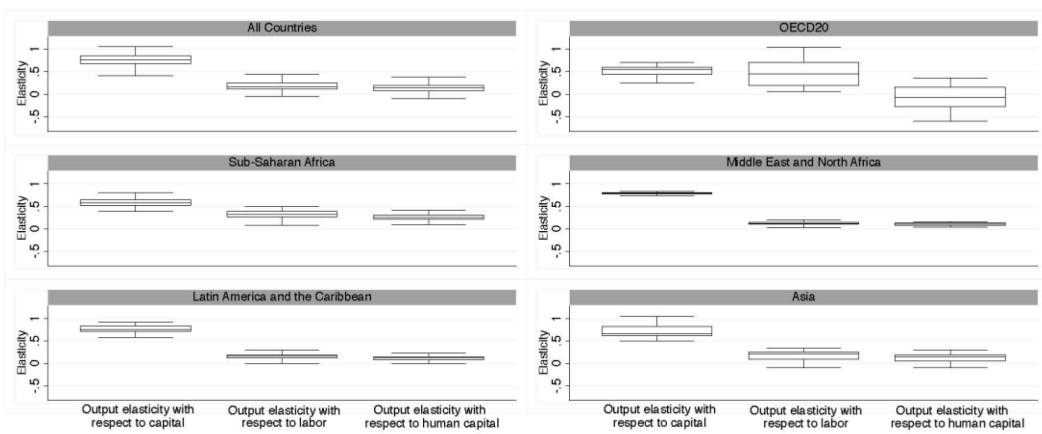

Figure 2. *Output elasticities with respect to factors of production*

World Development, Vol 40, No. 10 (October 2012): pg. 1982-1998. DOI.

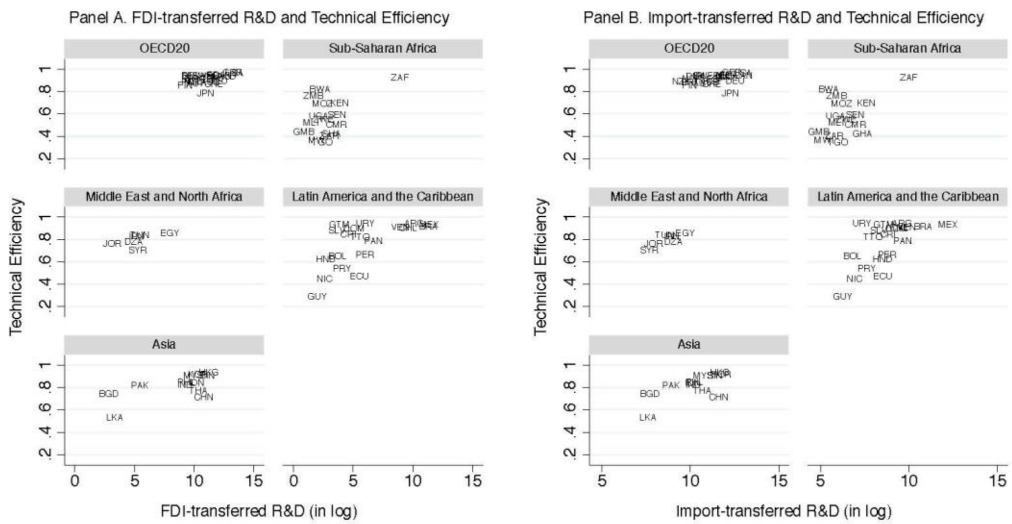

Figure 3. *Technical efficiency and international R&D transfer*

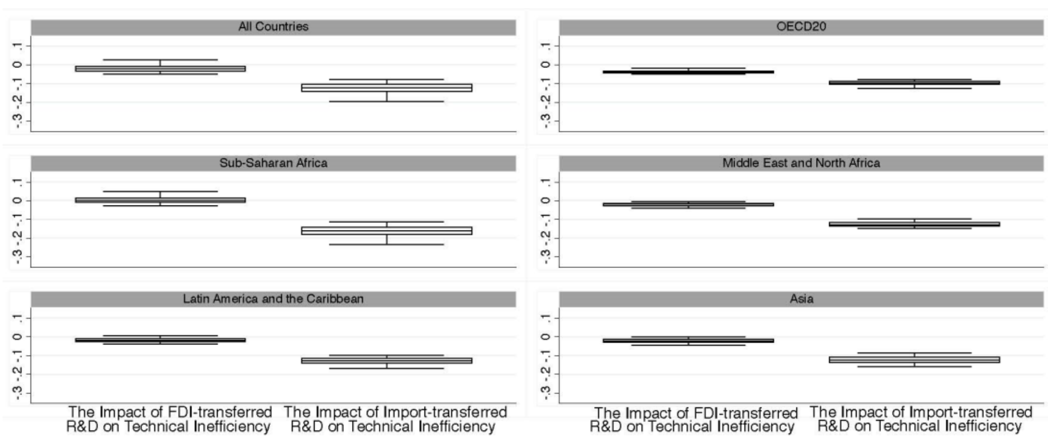

Figure 4. *Distributions of the impact of foreign R&D transferred through FDI and Imports on technical inefficiency*

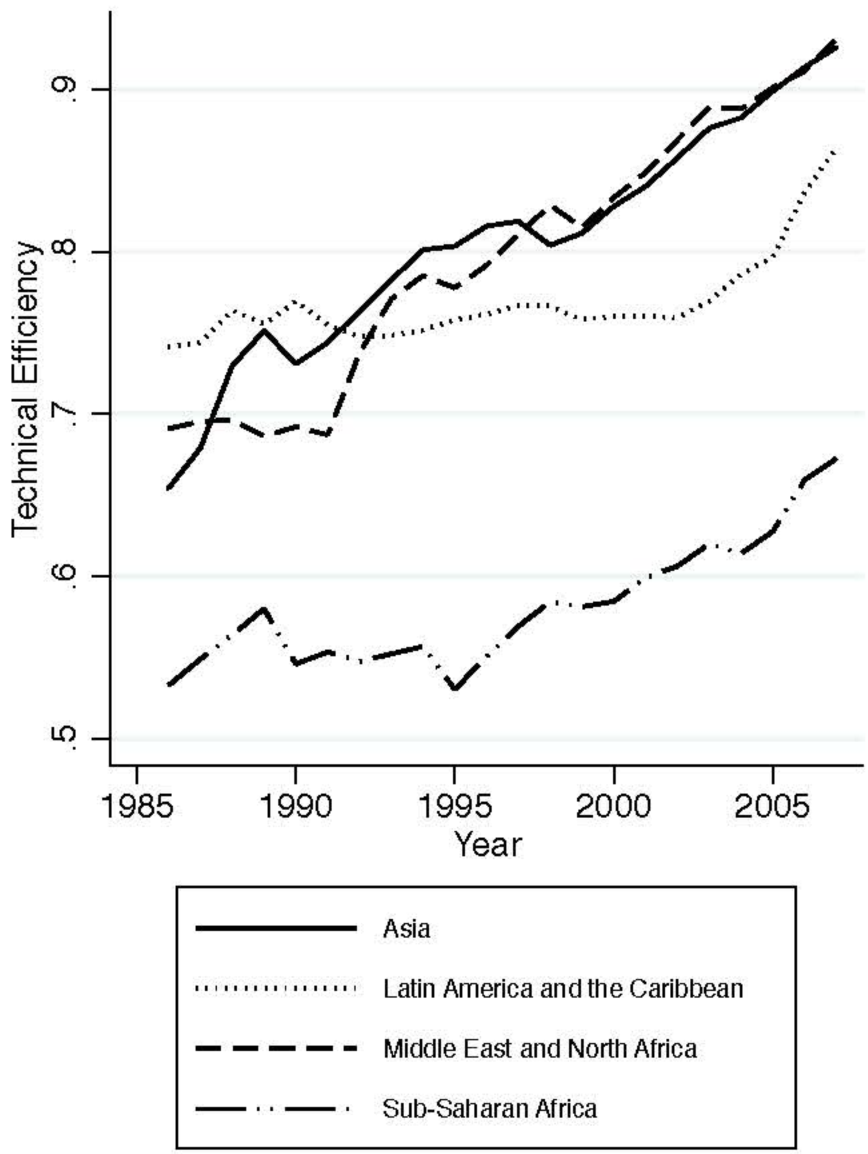

Figure 5. *Technical efficiency over time*

APPENDIX A

Table A. *List of countries with average efficiency scores and standard deviations*

Country	World Bank Code	1986-89	1990-94	1995-99	2000-04	2005-07	1986-2007	Std. Dev. 1986-2007	No. of Obs.
OECD 20									
Australia	AUS	0.858	0.872	0.908	0.914	0.879	0.888	0.024	22
Austria	AUT	0.858	0.878	0.872	0.875	0.876	0.872	0.010	22
Belgium	BEL	0.961	0.955	0.944	0.938	0.925	0.946	0.013	22
Canada	CAN	0.944	0.933	0.949	0.956	0.948	0.946	0.010	21
Denmark	DNK	0.924	0.928	0.951	0.943	0.929	0.936	0.012	22
Finland	FIN	0.818	0.761	0.863	0.921	0.933	0.854	0.070	22
France	FRA	0.956	0.953	0.951	0.951	0.940	0.951	0.006	22
Germany	DEU	0.888	0.911	0.905	0.898	0.891	0.900	0.011	22
Ireland	IRL	0.898	0.936	0.964	0.970	0.966	0.947	0.029	21
Italy	ITA	0.945	0.938	0.935	0.926	0.900	0.931	0.015	22
Japan	JPN	0.850	0.821	0.764	0.732	0.739	0.784	0.050	21
Netherlands	NLD	0.936	0.940	0.945	0.938	0.928	0.938	0.006	22
New Zealand	NZL	0.856	0.866	0.909	0.919	0.907	0.891	0.029	21
Norway	NOR	0.853	0.885	0.945	0.949	0.947	0.916	0.043	22
Portugal	PRT	0.914	0.913	0.898	0.856	0.814	0.883	0.039	22
Spain	ESP	0.943	0.923	0.907	0.899	0.861	0.909	0.027	22
Sweden	SWE	0.943	0.929	0.945	0.959	0.962	0.947	0.013	22
Switzerland	CHE	0.893	0.881	0.856	0.857	0.855	0.869	0.018	21
United Kingdom	GBR	0.978	0.975	0.977	0.976	0.972	0.976	0.002	22
United States	USA	0.968	0.971	0.973	0.968	0.961	0.969	0.004	22
Sub-Saharan Africa									
Botswana	BWA	0.755	0.763	0.802	0.895	0.934	0.824	0.077	22
Cameroon	CMR	0.449	0.403	0.471	0.598	0.670	0.508	0.100	22
Congo, Dem. Rep.	ZAR			0.391	0.385	0.459	0.404	0.037	13
Gambia, The	GMB	0.391	0.413	0.411	0.477	0.542	0.441	0.054	22
Ghana	GHA	0.383	0.418	0.413	0.435	0.468	0.421	0.029	22
Kenya	KEN	0.701	0.704	0.698	0.681	0.732	0.701	0.025	22
Malawi	MWI	0.265	0.289	0.393	0.443	0.450	0.365	0.079	22
Mali	MLI	0.418	0.437	0.519	0.618	0.653	0.523	0.095	22
Mozambique	MOZ	0.610	0.624	0.664	0.758	0.863	0.694	0.098	22
Senegal	SEN	0.562	0.556	0.587	0.635	0.656	0.596	0.041	22
South Africa	ZAF	0.934	0.935	0.896	0.928	0.944	0.926	0.018	22
Togo	TGO	0.273	0.268	0.361	0.413	0.456	0.349	0.076	22
Uganda	UGA	0.510	0.478	0.578	0.651	0.712	0.584	0.089	20
Zambia	ZMB	0.882	0.883	0.695	0.660	0.678	0.762	0.105	22
Zimbabwe	ZWE	0.639	0.545	0.568	0.493	0.412	0.550	0.068	20
Middle East and North Africa									
Algeria	DZA	0.737	0.714	0.748	0.826	0.899	0.785	0.069	19
Egypt, Arab Rep.	EGY	0.690	0.797	0.911	0.949	0.963	0.860	0.106	22
Iran, Islamic Rep.	IRN	0.716	0.818	0.852	0.874	0.893	0.831	0.066	20
Jordan	JOR	0.783	0.672	0.710	0.823	0.920	0.769	0.094	22
Syrian Arab Republic	SYR	0.503	0.634	0.763	0.825	0.845	0.705	0.132	21
Tunisia	TUN	0.733	0.789	0.838	0.897	0.938	0.840	0.071	21
Latin America and the Caribbean									
Argentina	ARG	0.945	0.953	0.956	0.920	0.960	0.945	0.022	20
Bolivia	BOL	0.559	0.621	0.670	0.683	0.784	0.657	0.070	22
Brazil	BRA	0.865	0.848	0.925	0.945	0.964	0.919	0.041	18
Chile	CHL	0.878	0.920	0.931	0.906	0.898	0.909	0.024	22
Costa Rica	CRI	0.753	0.815	0.864	0.890	0.926	0.847	0.062	22
Dominican Republic	DOM	0.843	0.875	0.917	0.905	0.939	0.902	0.034	19
Ecuador	ECU	0.414	0.445	0.466	0.502	0.562	0.473	0.049	22
El Salvador	SLV	0.805	0.859	0.910	0.910	0.920	0.880	0.046	22
Guatemala	GTM	0.907	0.932	0.948	0.936	0.940	0.933	0.015	22
Guyana	GUY		0.235	0.294	0.329	0.350	0.294	0.043	15
Honduras	HND	0.629	0.633	0.603	0.612	0.680	0.627	0.029	22
Mexico	MEX	0.951	0.942	0.928	0.932	0.921	0.935	0.013	22
Nicaragua	NIC	0.408	0.379	0.438	0.484	0.527	0.448	0.050	17
Panama	PAN	0.683	0.778	0.791	0.817	0.910	0.791	0.073	22
Paraguay	PRY	0.507	0.523	0.537	0.545	0.616	0.541	0.037	22
Peru	PER	0.706	0.595	0.642	0.659	0.756	0.664	0.059	20
Trinidad and Tobago	TTO		0.867	0.769	0.838		0.825	0.058	15
Uruguay	URY	0.958	0.959	0.953	0.909	0.959	0.946	0.025	22
Venezuela, RB	VEN	0.912	0.951	0.939	0.852	0.922	0.915	0.047	22
Asia									
Bangladesh	BGD	0.597	0.672	0.767	0.837	0.892	0.747	0.106	22
China	CHN	0.491	0.579	0.766	0.865	0.915	0.716	0.166	22
Hong Kong, China	HKG			0.930	0.935	0.958	0.941	0.013	10
India	IND	0.663	0.752	0.869	0.921	0.954	0.828	0.110	22
Indonesia	IDN	0.808	0.848	0.847	0.836	0.895	0.844	0.049	22
Korea, Rep.	KOR	0.904	0.927	0.910	0.930	0.934	0.920	0.021	21
Malaysia	MYS	0.905	0.936	0.875	0.900	0.940	0.909	0.032	22
Pakistan	PAK	0.689	0.740	0.833	0.904	0.960	0.819	0.100	22
Papua New Guinea	PNG	0.526	0.574	0.659	0.610	0.636	0.601	0.062	22
Philippines	PHL	0.806	0.802	0.836	0.889	0.947	0.850	0.055	22
Singapore	SIN	0.922	0.926	0.879	0.883	0.948	0.907	0.033	20
Sri Lanka	LKA	0.380	0.456	0.547	0.606	0.719	0.533	0.113	22
Thailand	THA	0.700	0.770	0.738	0.797	0.891	0.773	0.071	22
Others									
Greece	GRC	0.896	0.898	0.909	0.924	0.907	0.907	0.013	21
Hungary	HUN	0.771	0.696	0.744	0.820	0.837	0.768	0.056	22
Iceland	ISL	0.890	0.866	0.904	0.918	0.903	0.896	0.023	22
Turkey	TUR	0.924	0.939	0.940	0.945	0.964	0.942	0.014	21

Note: The mean, standard deviation, and number of observations are for the entire sample. Others are non-OECD20 countries.

