CEPA

Centre for Efficiency and Productivity Analysis

Working Paper Series
No. 04/2005

Title

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Date: June 2005

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Measuring Efficiency externalities from Trade and Alternative Forms of Foreign Investment

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Abstract

The literature has concentrated on evaluating technological spillovers from trade and inflows of foreign direct investment (FDI). Little effort has been directed towards identifying efficiency externalities arising from international linkages. We evaluate these for a sample of 20 OECD countries between 1982 and 2000 using a stochastic frontier approach. The analysis includes trade, inflows and outflows of FDI, foreign portfolio investment (FPI), and other foreign investment (OFI), and a measure of the absorptive capacities of host economies. We find trade and all foreign investment inflows to lead to increased efficiency. Outflows of FDI are found to exacerbate inefficiency.

JEL Classification: F21, F23

Keywords: technical efficiency; externalities; stochastic frontier approach; international linkages; foreign investment.

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Introduction

The expectation of technological transfer and spillovers has been the main argument underlying many expensive, publicly funded incentive schemes used for promoting trade and inflows of foreign direct investment (FDI). The doctrine of exploring foreign technologies as a means to advancing the competitiveness of the domestic economy is popular in both developed and developing economies. Motivated by these important policy implications, substantial efforts have been directed toward measuring the externalities from trade and FDI inflows, but the empirical results are mixed (Görg and Greenaway 2001; Saggi 2000).

A possible reason for the ambiguity in the empirics was a lack of distinction between the technological externalities and efficiency externalities associated with trade and FDI. The two differ in that technological externalities enhance the technological capability of economies while efficiency externalities contribute towards better utilization of the existing resources, including technology. Separating the two types of externalities is important not only in ensuring the measurement of externalities is accurate, but also in understanding the required pre-conditions to maximize the benefit of trade and foreign investment.

In normal circumstances, trade and foreign investment will not lead to negative technological change because what is known can not be undone. However, the same cannot be said about efficiency change. Exposure to foreign competition through trade or capital flow is generally considered to be competition promoting. Notwithstanding, sizeable foreign firms might exercise monopolistic powers in the host countries leading to the contraction of domestic competitors, which could further lead to contraction of other forward and downward linking domestic productions. For instance, take the case of Symantec's Norton AntiVirus software in the China market. The software was offered at a promotional price of 59 yuan per suite, while its usual price was 280 yuan per suite[3]. The promotional offer was willingly lapped up a majority of users and, as a result, numerous domestic antivirus software manufacturing enterprises had to close down. This scenario is of great practical relevance because in many cases incentive schemes are designed to attract large multinational corporations (MNCs), which may possess superior technologies but also carry substantial market power at the same time. Moreover, capital can be flowing out as well as flowing in an open economy. Efficiency may suffer if massive outflows of capital lead to a hollowing out of the industrial base, depletion of the capital market and rising unemployment. Therefore, efficiency externalities should be examined in parallel to, but separated from, technological externalities when designing and evaluating policies and incentive schemes for attracting trade and foreign investment.

This paper aims to fill this gap in the literature, modelling and measuring the efficiency externalities arising from trade and foreign investment. The stochastic frontier model proposed in Battese and Coelli (1995) (SFM-BC) is applied to measure the externalities arising from these alternative channels. The SFM-BC, like the other frontier techniques, decomposes total factor productivity (TFP) growth into two mutually exclusive and exhaustive components – one relating to technological progress (technical change) and the other to the efficiency in utilizing factor inputs (efficiency change). However, it has a merit over other frontier techniques in that it allows tracing the determinants of efficiency using a one stage approach rather than the traditional two stage approach.[4] The efficiency

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[3] It was reported on China Economic Net on 18/11/2004: http://en.ce.cn/main/index.shtml.

[4] With the traditional two stage approach, efficiency scores are estimated in stage one and the determinants of efficiency are identified in stage two by regressing the obtained efficiency scores on a set of appropriate exogenous variables. There are at least two problems with the two-stage approach. First, the individual

externalities associated with trade and foreign investment are estimated by their respective contributions towards enhancing the efficiencies in the utilization of existing factor inputs and technology.[5]

Another novelty of this paper is that it takes a much broader view of outward orientation than just trade and FDI inflows. Specifically, the model incorporates outflow of FDI, inflow and outflow of foreign portfolio invest investment (FPI) and other foreign investment (OFI)[6]. This broader scope in the measurement of outward orientation is warranted as FPI and OFI may affect domestic efficiency by influencing resource allocation and utilization across sectors. Moreover, the increasing share of these flows, particularly FPI, in international capital flows makes them difficult to ignore (see Figures 1 and 2).

The proposed stochastic frontier model also incorporates several control variables representing human capital stock (HC), financial market development (FMD) and relative

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efficiency scores from stage one are assumed to be normal, independent and identically distributed. However, while regressing the efficiency scores in stage two it is assumed that the efficiency scores are not identically distributed. Second, the efficiency scores are bounded between zero and one, thus necessitating the application of dependent variable methods. However, these methods are problematic in this type of study because a significant number of countries need to be at full efficiency.

[5] Some studies have also evaluated the determinants of technological change using the SFA. However, such an approach is not meaningful because the SFA imposes a common rate of technological progress on all countries in the sample.

[6] International Financial Statistics of IMF group foreign investments into three categories – direct (FDI), portfolio (FPI) and a residual group (OFI). FDI represents capital invested in an enterprise by an investor in another country, which gives the investor a ‘significant influence’ (either potentially or actually exercised) over the key policies of the enterprise. Ownership of 10 percent or more of the ordinary shares or voting stock of an enterprise is usually considered to indicate ‘significant influence’ by an investor. FPI refers to non-FDI cross-border investment in equity and debt securities. OFI includes bank loans and trade-related lending which covers commercial bank lending and other private credits.

R&D (RRD). These variables are included to ensure that efficiency changes due to these domestic variables are not interpreted as externalities from trade or foreign investments. Additionally, these domestic variables are modelled as measures of absorptive capacity in that the externalities from trade and foreign investment may depend upon the level of these variables.[7] Specifically, the efficiency externalities from FDI inflows are modelled as being contingent upon HC, RRD and FMD. Likewise, the externalities from FPI and OFI inflows may depend on the level of FMD.

Much of the existing work exploring the externalities from outward orientation has concentrated on developing countries, despite the fact that the OECD accounts for the bulk of the foreign investment (and to a lesser extent, trade) as both the source and the destination. This paper focuses on a sample consisting of only OECD countries. An advantage of focusing on the OECD group is that data are collected by types of foreign investment, providing accurate measurements to differentiate various types of foreign investment. Pooling of data from both the OECD and non-OECD countries is specifically avoided given that the frontier techniques impose a common production technology frontier across all the countries in the sample. Accordingly, a panel dataset covering 20 OECD countries from 1982 to 2000 is used in the analysis.[8]

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[7] The choice of the domestic variables is based on Xu (2000), Blomström and Kokko (2003) Blomström, Kokko and Globerman (2001) and Alfaro, Chanda, Kalemli-Ozcan and Sayek (2003).

[8] The following countries are included in the sample: Australia, Austria, Belgium, Canada, Denmark, Spain, Finland, France, United Kingdom, Germany, Ireland, Italy, Japan, Luxembourg, Netherlands, New Zealand, Norway, Portugal, Sweden and United States.

The remainder of the paper is structured as follows. The next section explains briefly the methodology. Section 3 introduces the model estimated in the paper and discusses the variables included in the analysis. Section 4 reports the empirical results and Section 5 concludes.

The Methodology

The stochastic frontier approach constructs an efficient frontier by imposing a common production technology across all countries in the sample. Deviations from the frontier are decomposed into two components, inefficiency and noise. Introducing a disturbance term representing noise reduces the volatility in the temporal patterns of efficiency measures. Specifically, the stochastic frontier production function presented in equation (1) is based on the Battese and Coelli (1995) model (SFM-BC). This model assumes country effects to be distributed as truncated normal random variables, which are also permitted to vary systematically with time. Inefficiency effects are directly influenced by a number of explanatory variables.

$$y_{it} = \exp\left(x_{it}\beta + v_{it} - u_{it}\right) \qquad (1)$$

y_{it} denotes the output of country i in period t. x_{it} represents a ($1\times K$) vector of inputs, usually expressed in logarithmic terms which enables the inefficiency term to be interpreted as the percentage deviation from the observed performance of each individual country with respect to the frontier. β is a ($K\times 1$) vector of unknown parameters to be estimated. The u_{it}'s and v_{it}'s jointly comprise the error term. While the v_{it}'s represent the time specific idiosyncratic and stochastic part of the frontier, u_{it}'s represents technical inefficiency. The distributional assumptions of the error terms are specified below:

$$v_{it} \sim N[0, \sigma_v^2] \qquad (2)$$

$$u_{it} = |U_{it}| \quad where\ U_{it} \sim N[0, \sigma_u^2] \tag{3}$$

From (2) it is clear that the stochastic part of the frontier, v_{it}, could be either positive or negative. On the contrary, (3) implies that u_{it}, which represents technical inefficiency, must be non-negative. This ensures that, for a given level of technology and levels of inputs, the observed output at best equals its potential output.

The technical inefficiency effects can be modelled in terms of various explanatory variables:

$$u_{it} = z_{it}\delta + w_{it} \tag{4}$$

where z_{it} is a $(1\times M)$ vector of observable explanatory variables and δ is an $(M\times 1)$ vector of unknown parameters to be estimated. The w_{it}'s are unobservable random variables, which are assumed to be independently distributed and to follow a truncated normal distribution.

Given the specification in (1) and (4), the technical efficiency (TE) of country i in period t is predicted by

$$TE_{it} = E\left[\exp(-u_{it})|(v_{it} - u_{it})\right] \tag{5}$$

The Model

Table 1 introduces the stochastic frontier model (SFM) applied in the paper. The explanatory variables in the model have been classified as factor inputs and technical inefficiency determinants.

[Table 1]

Factor inputs include standard variables in growth models such as capital, labour and human capital (HC), plus R&D. The compilation and construction of all the variables is provided in Appendix. Output, capital and labour are standard measurements and are expressed in logarithms. Human capital is measured as a percentage of the population with higher school attainment (Barro and Lee 2000). We argue that this measurement is more appropriate than primary or secondary schooling given that the sample is restricted to the OECD. R&D stock is constructed from annual expenditures on research and development using the perpetual inventory method. It is also expressed in logarithms.

The inefficiency effect model contains an array of variables that measure the outward orientation of an economy, including trade openness; and inflow and outflow of FDI, FPI and OFI, respectively. We combine both export and import in the measure of trade openness instead of distinguishing them because of the high collinearity between the two trade components. Inflows and outflows of various types of foreign investment and trade openness are of standard measurements and are expressed as a percentage of GDP.

In the literature, it has been suggested that a country with a greater knowledge stock, a greater endowment of human capital and more developed financial market is better equipped to absorb foreign technology sourced through FDI.[9] This paper aims to examine if the externality effect of FDI inflow on efficiency change is also contingent on the same domestic economic characters. Therefore, the inefficiency model incorporates the interaction terms of FDI inflow with a few measures of domestic absorptive capacity, including relative R&D

[9] See, Blomström, Kokko and Globerman (2001) and Balasubramanyam (1998), Cohen and Levinthal (1989; 1990), Xu (2000), Blomström and Kokko (2003), and Alfaro, Chanda, Kalemli-Ozcan and Sayek (2003),

(RRD), HC and financial market development (FMD). RRD of a country is constructed as the country's stock of R&D as a percentage of OECD R&D. FMD is measured as the contribution of the financial sector (direct as well as indirect) to the total value added in the economy. It should be noted that RRD instead of R&D is used in the inefficiency effect model. This is because while it is the absolute amounts of R&D from all countries that collectively defines the state of the frontier technology, it is the relative technology capability of an individual country that determines how efficient it is in exploring the resulting frontier technology, which is mostly contributed by other countries. RRD, HC and FMD also enter the inefficiency model as independent variables to avoid biasing the estimations of the interaction terms as these variables might have a distinct effect on efficiency change.[10]

Lastly, the inefficiency model includes the interaction terms of FPI and OFI inflows with FMD. All interaction terms of capital inflows with FMD are expected to have a positive sign because the smaller the domestic capital market, the greater the importance of foreign capital in ensuring the allocation of resources is efficient. The summary statistics of the inefficiency model variables are presented in Table 2.

The Econometric Model

The SFM presents an improvement over least squares estimation of the production function only if technical inefficiency effects are present. The presence of technical inefficiencies, therefore, needs to be established first. This is empirically assessed by testing the significance of the ratio of error variances from equation (1) using a generalized likelihood ratio (LR) test.

[10] For instance, Kneller and Stevens (2002) find HC to be important in reducing relative inefficiencies of OECD countries, and Naurzad (2002) finds that economies with more developed financial intermediaries sector and equity markets tend to be more efficient.

As discussed earlier, technical efficiency (TE) measures how far a sample country lags behind the production frontier. In that, the appropriate specification of the production function underlying the frontier is imperative to ensure the accurate measurement of TE. The functional form of the SFM is determined by testing the adequacy of the Cobb-Douglas relative to the more flexible translog functional form using a LR test. LR tests are also used to examine the existence and nature of technical change, which in turn determine the incorporation of a time trend in the production function. Results of the hypotheses tests are reported in Table 3.

[Table 3]

Firstly, rejection of the null of no inefficiency effects provides support for the SFM specification over least square estimation. Secondly, the translog production frontier is chosen based on the rejection of the Cobb-Douglas function being adequate. This implies that input and substitution elasticities vary across countries. Lastly, the hypotheses of no technical change and Hicks neutral technical change are also rejected, thus we include a time trend and its cross products with conventional factor inputs in the production function.

Empirical Results and Discussion

The parameter estimates for the translog stochastic frontier production function are reported in Table 4.[11] A total of 18 out of the 20 coefficients (excluding the constant) included in the frontier function are significantly different from zero at the 5 percent level. Four of the five direct effects, all the squared terms and nine cross products have coefficients significantly

[11] The software Frontier 4.1 (Coelli 1996) was used to obtain the empirical results.

different from zero. This reaffirms the adoption of the translog model over a Cobb-Douglas one. Estimates from several nested models are also reported. While the results were robust across the alternative specifications, the nested models were rejected based on LR tests. The nested models are however useful as auxiliary models to illustrate the robustness of the reported results and to shed light on whether the omission of specific variables is likely to cause bias in the coefficient of others.

[Table 4]

The coefficients on Capital, Labour, R&D, HC and time trend reported in the upper part of Table 4 are the corresponding elasticities calculated at the sample means.[12] Labour is the single most important input with an output elasticity of 0.7489 followed by capital and R&D at 0.2634 and 0.0244 respectively. The elasticity of HC is negative in the examined model (negative in all of the nested models as well). However, this cannot be interpreted to imply that HC has a negative impact on output. As argued in length by Islam (1995) and Krueger and Lindahl (2001), it is not uncommon to obtain negative estimates of HC in the production function.[13] The coefficient on the time trend variable indicates that there is rapid technological progress. The frontier is shifting upwards at an annual rate of 2.96 percent, indicating rapid technological progress.

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[12] The individual coefficients of the x_{it} vector variables cannot be directly interpreted as elasticities. The reported elasticities of the factor inputs at sample means are obtained by mean differencing the variables prior to estimation.

[13] For instance, it has been observed that growth regressions including both physical and human capital, due to strong endogeneity, are not likely to produce a clear estimate of the effect of education on growth. There have also been arguments against the application of formal education data to measure human capital in that skills may develop in a number of alternative ways.

Table 5 summarizes the findings on TE. The second column of the table shows the annual average of the technical efficiency over the sample period of 1982 to 2000. The efficiency score lies between 0 and 1, with a higher score indicating greater efficiency. A country which is fully efficient will lie on the constructed frontier and its efficiency score will consequently be 1. The figures indicate that over this period Canada exhibited the highest average efficiency, closely followed by New Zealand. On the other end of the ladder are a number of Southern European countries such as Portugal, Spain, and Italy. It is observed from Table 2 that while Canada and New Zealand had the highest levels of human capital, Portugal, Spain and Italy had the lowest. The need to incorporate domestic absorptive capacity in the modelling of efficiency externalities is thus verified. The third column of the table shows the arithmetic means of annual efficiency changes of the countries over the sample period. Ireland has the highest efficiency change of 0.4 percent per year on average. Since all sample countries are assumed to share the same technology represented by the production frontier, this means that Ireland had made the biggest progress in closing its gap with the frontier of all the countries included in the sample.[14] The finding is in accordance to the fact that Ireland has implemented a series of economic reforms in the past decade that eventually transformed the country into a hotspot for high-tech industry and FDI. Nevertheless, countries with positive efficiency changes are the minority. Out of the 20 countries, 15 have negative efficiency changes. Countries like Portugal and Demark see their efficiencies falling by almost two percent per annum.

[14] It does not, however, mean that Ireland is the closest to the frontier. A country which is a technology leader will be close to the frontier at the very beginning and therefore may not make as much progress as Ireland.

The negative estimates of efficiency change should be read along side with the upward shift of the technological frontier (2.96 percent per year). As TE measures the distance of a country from the constructed frontier, it is likely to decline if the frontier is being pushed upwards rapidly.[15] Besides this methodological explanation, there are also theoretical explanations for the apparently inverse relationship between technological progress and efficiency change. Firstly, since technological innovation involves large fixed costs in R&D, it is feasible only if innovators are given a certain period of time (till imitators emerge) to extract sufficient rents to justify the effort and risk born in the innovation process. Therefore, the estimated inefficiency could be partly a result of the monopolistic behaviour of innovators. Secondly, new technology requires new knowledge to operate. Before workers are fully equipped with the new knowledge, a new technology will not be 100 percent utilized. As a consequence, there could be an apparently rise in inefficiency during the adaptation period. In fact, as the life time of new technology products is continuously shortened, it has been argued that it is increasingly difficult to explore the full capacity of a product before it is replaced by the next version.

[Table 4]

The coefficients of the inefficiency model (see Table 4) will be negative when the variable increases efficiency. The coefficient on FDI inflows is not independently significant across most of the models. However, the coefficient of the interaction term of FDI inflows and RRD is both large and significant across all model specifications. This result implies that the insignificance of the coefficient on FDI inflows alone should not be interpreted as FDI

[15] Rao & Coelli (1998) have also found a similar negative relationship between TC and TE.

inflows bearing no efficiency externalities. Rather, the efficiency externalities from FDI inflows are conditional on the gap between the country's and the world's technological frontier. Thus, the same amount of FDI inflows will have a greater impact on an economy which has a greater role in defining the frontier. This result is in accordance with Cohen and Levinthal (1989; 1990) who observe that the competence to evaluate and utilize outside knowledge is largely a function of prior related knowledge.

The efficiency externalities of FDI inflows are also found to be contingent on the level of FMD, as evidenced in the significant coefficient of their interaction term. A host country with a more developed financial market will have greater efficiency gains from FDI inflows. This result is in contrast to that of FPI and OFI (see below). Furthermore, the efficiency externalities of FDI inflows do not seem to be conditional on the human capital stock of the host country, as reflected in the insignificance of the FDII x HC variable across all the examined models.

In considering the growth impacts of FPI inflows, it is usually assumed that the spillover gains relate to the beneficial impact of FPI inflows on stimulating the development of domestic financial markets (see, for instance, McLean and Shrestha 2002). Our results are that the coefficient on FPI inflows is significant even after controlling for the effects of FMD. Similarly, OFI inflows have a negative and significant impact on inefficiency, providing support for its inclusion in the model. The estimate of the interactions between FMD and inflows of FPI and OFI confirms the expectations that foreign capital inflow will enhance efficiency in economies with a small capital market.

Neither outflow of FPI nor that of OFI seems to have any empirically discernible effect on efficiency. However, there is some evidence to suggest FDI outflows adversely affect efficiency (models B, C and D). This finding assumes importance in that governments across the world are beginning to show enthusiasm in facilitating outward investments by domestic firms with several countries even establishing outward investment agencies. Admittedly, these outbound investments are encouraged as potential conduits of foreign technology. But with the bulk of the empirical evidence not finding technology spillovers from outward FDI[16], the observation that FDI outflows exacerbate inefficiency underlines the need for further research on the effects of FDI on the source countries.

The negative and significant coefficient on the TOP variable is consistent with most research within the endogenous growth literature that evaluates spillovers from trade. It is reiterated that the externalities evaluated herein are not those accruing directly from technological transfers. Instead, these gains have resulted from increased competition and scale economies. The importance of accounting for trade in models examining the efficiency effects of foreign investment inflows is highlighted by the independent significance and large magnitude of the FDII coefficient in the nested model excluding TOP (model C). The results also support the popular hypothesis that FMD impacts favourably on efficiency. The negative and significant coefficient on the FMD variable is consistent with Naurzad (2002). The negative coefficient of the HC variable is again in accordance with a priori expectations. Countries with greater investments in HC are observed to be more efficient than others. However, the coefficient on the RRD variable is positive. This implies that countries with a larger investment in R&D

[16] See, for instance, Kogut and Chang (1991), Anand and Kogut (1997), Martin and Velazquez (1997) and Narula and Wakelin (1997).

will be less efficient than those that are farther from the world's technological frontier. This result is consistent with the inverse relationship between technological progress and efficiency discussed earlier. In sum, all the control variables yield significant and theoretically consistent coefficients.

Concluding Remarks

This study evaluated the effect of trade and various types of foreign investments on efficiency using a sample of 20 OECD countries over the period of 1982–2000. The stochastic frontier approach was adopted to construct an efficient frontier. The efficiency externalities of foreign investments, trade and several control variables are quantified by their respective contributions towards reducing technical inefficiency, which is represented by the distance of each country from the constructed frontier. A series of hypothesis tests, based on likelihood ratio statistics, favoured the use of a non-neutral translog production function in estimating the frontier.

The results indicated that efficiency externalities from foreign direct investment (FDI) inflows would be greater in countries with a larger investment in domestic R&D and more developed financial markets. However, gains from FDI inflows were not found to be conditional on human capital. This result suggests that policies to attract FDI inflows must be complemented with initiatives to develop certain absorptive capacities in the host economies; otherwise externalities from FDI inflows cannot be fully captured. In finding that inward FPI is associated with efficiency externalities, this study highlights the need for countries to make themselves attractive not only for FDI inflows (as the case is now) but also for FPI inflows. This prescription makes even greater sense when viewed in the context of the large scale increases in FPI flows across the OECD over the 1980s and 1990s. As with inward FPI, OFI inflows are also found to enhance efficiency. Admittedly, the share of OFI in international capital flows has fallen over time, but it needs to be recognized that these flows are also increasing in absolute terms. Unlike FDI, both FPI and OFI inflows are observed to be more efficiency inducing in economies with relatively smaller capital markets. This finding points to the possible efficiency gains for growing economies within the OECD

While the efficiency effects of FPI and OFI outflows were not empirically discernible, outward FDI was associated with increased inefficiency. Further research evaluating the effects of FDI on the source countries is warranted in light of FDI outflows increasingly being perceived as conduits of foreign technology, although with little empirical support.

In accordance with previous studies, financial market development and human capital were found to be significant in reducing inefficiencies. The dual role of these domestic characters in enhancing efficiency is noteworthy. In addition to being sources of efficiency externalities independently, they are also instrumental in ensuring that gains from international linkages materialize. Countries with a larger investment in domestic R&D were found less efficient than those which rely on foreign R&D. This is consistent with the inverse relationship observed between technological progress and efficiency change.

As expected TOP was found to increase efficiency. Moreover, it was observed that the exclusion of TOP is likely to upwardly bias the coefficient of FDI inflows. This highlights the need to control for the effects of trade in models evaluating efficiency gains from FDI.

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Table 1: Variables and Expected Effects

Variables	Notation	**Expected effect on output and inefficiency**
Output (Real GDP)	Y	
Factor Inputs		***Expected effect on output***
Capital Stock	Capital	Positive
Total Labour Force	Labour	Positive
Domestic R&D Stock	R&D	Positive
Human Capital	HC	Positive
Time	T	Positive
Inefficiency Effect Determinants		***Expected effect on inefficiency***[a]
Foreign Direct Investment Inflows	FDII	Negative
Foreign Direct Investment Outflows	FDIO	Positive/Negative
Foreign Portfolio Investment Inflows	FPII	Negative
Foreign Portfolio Investment Outflows	FPIO	Positive/Negative
Other Foreign Investment Inflows	OFII	Negative
Other Foreign Investment Outflows	OFIO	Positive/Negative
Trade Openness	TOP	Negative
Human Capital	HC	Negative
Financial Market Development	FMD	Negative
Relative R&D	RRD	Negative
FDI Inflows x Relative R&D	FDII x RRD	Negative
FDI Inflows x Human Capital	FDII x HC	Negative
FDI Inflows x Financial Market Development	FDII x FMD	Positive
FPI Inflows x Financial Market Development	FPII x FMD	Positive
OFI Inflows x Financial Market Development	OFII x FMD	Positive
Time	T	Positive/ Negative

Notes:

a: A negative sign implies a decrease in inefficiency.

Table 2: Summary Statistics of Inefficiency Effect Variables for 20 OECD Countries

(Annual Average)

Country	**FDII**	**FDIO**	**FPII**	**FPIO**	**OFII**	**OFIO**	**TOP**	**HC**	**FMD**	**RRD**
Australia	1.80	0.96	2.96	0.62	1.91	0.58	35.90	24.09	28.37	1.04
Austria	0.71	0.61	3.70	2.29	2.67	2.93	76.77	9.46	23.45	0.55
Belgium	5.84	4.86	10.11	14.70	24.65	23.21	136.68	14.24	27.78	0.94
Canada	1.33	1.68	3.14	1.11	1.18	1.14	60.42	44.58	24.13	2.42
Denmark	1.43	1.64	2.19	1.29	3.87	2.70	67.69	19.45	25.55	0.40
Spain	1.63	1.02	1.95	1.18	2.48	2.12	41.49	10.29	23.06	0.79
Finland	1.17	2.36	3.61	1.35	2.08	1.94	58.39	17.05	20.15	0.41
France	1.13	1.85	1.98	1.83	2.42	2.08	44.30	13.07	30.14	6.73
UK	2.24	3.79	3.72	4.17	10.84	8.29	52.91	14.94	25.84	6.83
Germany	0.37	1.43	2.68	2.11	2.59	2.90	53.38	11.93	28.07	10.35
Ireland	3.01	0.97	8.96	9.68	14.05	14.73	121.39	14.27	20.84	0.11
Italy	0.33	0.54	2.71	2.02	2.16	2.02	43.42	9.79	25.39	3.03
Japan	0.04	0.67	1.27	2.35	0.06	0.63	20.40	20.19	25.13	16.19
Luxembourg	5.84	4.86	10.11	14.70	24.65	23.21	217.05	14.24	49.73	0.04
Netherlands	2.91	4.88	3.43	4.69	4.94	4.31	107.80	17.03	23.75	1.63
Norway	1.17	1.58	1.48	1.68	1.81	0.97	73.23	18.42	21.77	0.38
New Zealand	3.69	1.18	0.17	0.36	-0.04	0.28	58.02	36.86	26.71	0.15
Portugal	1.61	0.64	2.46	1.80	4.62	2.81	66.66	8.02	21.42	0.12
Sweden	3.05	3.37	0.84	2.38	4.01	1.91	66.58	19.32	24.40	1.27
USA	0.97	0.82	1.75	0.78	1.70	1.27	20.62	42.58	29.14	45.12

Table 3: Generalized Likelihood-Ratio Tests of Null Hypotheses for Parameters in the Stochastic Frontier Production Function for 20 OECD Countries

Null Hypothesis (H_0)	**LR-Test Statistic**	**Critical Value (0.01)**	**Decision**
No inefficiency effects	292.161	$\chi2_{.01,\,16} = 31.353$	Reject H_0
A Cobb- Douglas Function is adequate	725.930	$\chi2_{.01,\,15} = 30.578$	Reject H_0
There is no technical change	212.452	$\chi2_{.01,\,6} = 16.812$	Reject H_0
Technical change is Hicks Neutral	81.534	$\chi2_{.01,\,4} = 13.277$	Reject H_0

Note: Critical values for the hypotheses tests, except for testing inefficiency effects, are obtained from the appropriate chi-square distribution. The critical value for testing the null hypothesis of no inefficiency effects is taken from Kodde and Palm (1986).

Table 4: Maximum Likelihood Estimates for Parameters of Translog Stochastic Frontier Production Function for 20 OECD Countries

Variable	Main Model	Nested Models				
		A	B	C	D	E
Frontier Function[a]						
Constant	0.1514	0.1510	0.1788	0.1043	0.1052	0.1502
Capital	0.2634	0.2701	0.2440	0.2620	0.2140	0.2754
Labour	0.7489	0.7440	0.7625	0.6837	0.7263	0.7489
R&D	0.0244	0.0240	0.0327	0.0543	0.0667	0.0147
HC	-0.0152	-0.0156	-0.0172	-0.0104	-0.0021	-0.0157
T	0.0296	0.0299	0.0320	0.0241	0.0202	0.0294
Inefficiency Model[#,b]						
Constant	0.5921**	0.6278**	0.6111**	0.3791**	0.0192	0.6204**
FDII	1.6765	0.4401	-0.8234	-2.2423*	-0.8403	1.5605
FDIO	0.3910	0.2606	0.6509**	0.8980**	1.3443**	----
FPII	-0.5711*	-0.7134**	----	----	-0.4430	-0.4790
FPIO	-0.0415	0.0197	----	----	0.0779	----
OFII	-0.8059**	-0.8704**	----	----	-0.7122**	-0.9695**
OFIO	-0.1778	-0.1737	----	----	0.0479	----
TOP	-0.1726**	-0.1772**	-0.2157**	----	-0.1204**	-0.1791**
HC	-0.0188**	-0.0198**	-0.0217**	-0.0104**	----	-0.0192**
FMD	-1.0375**	-1.1071**	-0.8317**	-1.4275**	----	-1.0804**
RRD	0.6972**	0.7008**	0.6109**	0.5805**	----	0.7101**
FDII x HC	-0.0514	----	-0.0014	0.0435	----	-0.0520
FDII x RRD	-18.2259**	-14.5668**	-14.4981**	-20.9349*	----	-17.9646**
FDII x FMD	-2.4765**	-2.1501**	1.3690	1.4145	----	-1.0770
FPII x FMD	2.2949**	2.8103**	----	----	----	1.6992
OFII x FMD	2.8326**	2.9392**	----	----	----	2.7969**
T	0.0288**	0.0298**	0.0319**	0.0256**	0.0174**	0.0290**
Variance Parameters						
Sigma-squared	0.0031**	0.0032**	0.0034**	0.0059**	0.0070**	0.0032**
Gamma	0.7692**	0.8189**	0.8255**	0.9604**	0.9187**	0.7862**
Log-Likelihood	627.2986	624.7032	608.9609	561.8872	519.9065	623.5451
LR Test[+]	NA	5.1908**	36.6754**	130.8228**	214.7842**	7.5070*

Notes:
** Significant at the 5 percent level.
* Significant at the 10 percent level.
+ Compares the log likelihood of the nested models with that of the main model.
# A negative sign on the coefficient of a z_{it} vector variable represents a reduction in inefficiencies.
a. Capital, Labour and R&D are in natural logarithms, while HC is in percentages.
b. First lag is used in the case of inefficiency variables to accommodate endogeneity issues.

Table 5: Technical Efficiency and Efficiency Change of 20 OECD Countries over 1982 to 2000 (Annual Average)

Country	Technical Efficiency	Efficiency Change (%)
	1982 to 2000	1982-1983 to 1999-2000
Australia	0.926	-0.5
Austria	0.723	-1.4
Belgium	0.902	-1.2
Canada	0.992	0
Denmark	0.852	-1.7
Finland	0.762	-0.9
France	0.792	-1.5
Germany	0.694	-1.2
Ireland	0.893	0.4
Italy	0.71	-1.2
Japan	0.711	-0.9
Luxembourg	0.986	0
Netherlands	0.868	-1.2
New Zealand	0.991	0
Norway	0.831	-1.1
Portugal	0.677	-1.8
Spain	0.679	-1.3
Sweden	0.861	-1.2
UK	0.767	-1.3
USA	0.975	0.2

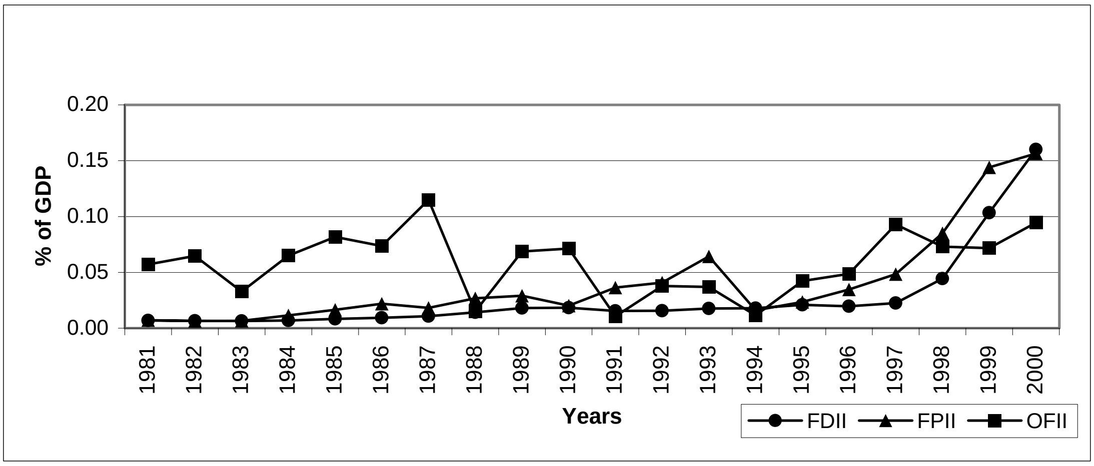

Figure 1. FDI, FPI and OFI Inflows (OECD Average)

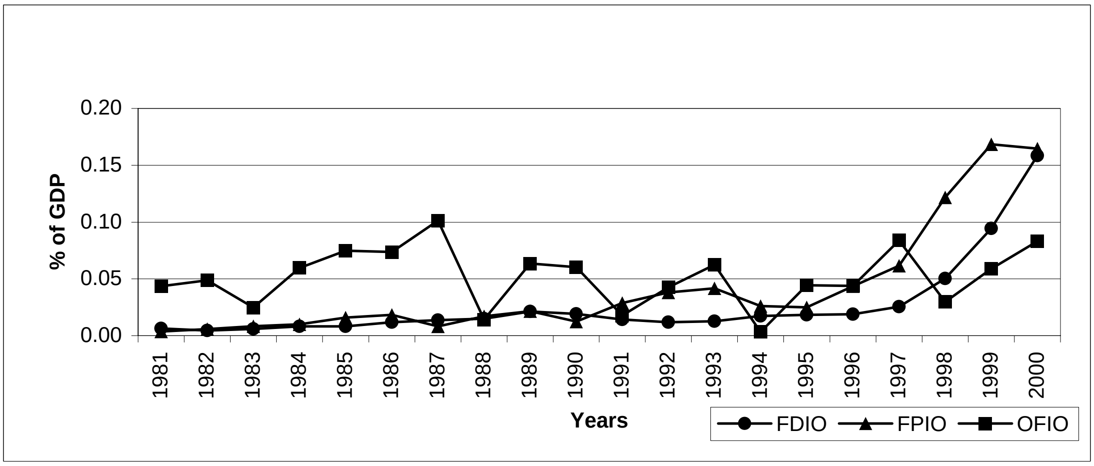

Figure 2. FDI, FPI and OFI Outflows (OECD Average)

Appendix

Compilation and Construction of the Dataset

Output: Data are sourced from Heston, Summers and Aten, Penn World Table Version 6.1 (PWT 6.1) (2002). Measured in 1996 international dollars, this series is constructed after adjusting for price differences across countries and over time.

Capital: Constructed using the perpetual inventory method (PIM). Raw data are sourced from PWT 6.1. The use of PIM is common and necessitated by the lack of capital stock data across all the countries. K is constructed as:

$$K_t = K_{t-1}(1- \theta) + I_t \quad \text{(A1)}$$

where K is capital stock, I investment and θ the rate of depreciation. θ is assumed as 6 percent along the lines of Hall and Jones (1999) and Bernanke and Gurkaynak (2001). Initial capital stocks are constructed by the assumption that capital and output grow at the same rate. Specifically, for countries with investment data beginning in 1950 we set the initial capital stock $K_{1949} = I_{1950} / (g + \theta)$ where g is the 10 year growth rate of output (e.g., from 1950 to 1960). In order to arrive at the capital stock net of residential capital stock, the ratio of residential capital as a fraction of non-residential capital is used. This ratio is computed from PWT 5.6 for the years until 1992. For all subsequent years, the average ratio over the 1987 to 1992 period is used.

Labour: Data are sourced from World Development Indicators (WDI) 2003. Total labour force comprises people who meet the International Labour Organization definition of the economically active population.

Stock of R&D: Constructed using time series estimates of annual expenditures on R&D extracted from Source OECD. PIM is used and depreciation is assumed as 10 percent. Initial R&D stock is estimated in the same way as initial capital stock was estimated except that g in this case is the 5-year growth rate of R&D expenditures. The obtained measures were similar when 10-year growth rate of R&D expenditures was used. Only domestic R&D stock is included in the production function along the lines of Driffield and Munday (2001).

Human Capital (HC): Percentage of population with higher school attainment. Data are sourced from Barro and Lee (2000).

FDI, FPI and OFII inflows and outflows: Measured as percentages of GDP. Data are sourced from International Financial Statistics (IFS).

Trade Openness (TOP): Defined as the ratio of total trade (exports and imports) to GDP. Data are sourced from WDI.

Financial Market Development (FMD): FMD is measured as the contribution of the financial sector (direct as well as indirect) to the total value added in the economy. Other measures such as M2, liquid liabilities, private sector credit provided by commercial banks and domestic credit, which have been used in studies involving developing countries may not be appropriate for the given sample of advanced nations, which are characterized by a greater variety of investment opportunities (see, Creane, Goyal, Mobarak and Randa 2003).

Relative R&D (RRD): This variable measures individual country's stock of R&D as a percentage of OECD R&D. It is known that the World R&D stock is adequately accounted for by the R&D stock in OECD countries. R&D stocks are obtained using PIM on time series estimates of annual expenditures on R&D extracted from Source OECD.