Measuring Spillovers from Alternative Forms of Foreign Investment

Krishna G. Iyer

Alicia N. Rambaldi

and

Kam Ki Tang

School of Economics, University of Queensland

St Lucia, QLD 4072, Australia

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Address correspondence to: Dr. Alicia N. Rambaldi, School of Economics, University of Queensland, St Lucia, QLD 4072, Australia. Ph: +61 7 33656576, Fax: +61 7 33657299, Email: a.rambaldi@uq.edu.au

Abstract

Much of the endogenous growth literature has dwelled on evaluating the spillover effects of trade on growth, but much less efforts have been directed towards tracing and quantifying the spillover effects of foreign investments. This paper, in incorporating the effects of various types of foreign investments, namely foreign direct investment (FDI), foreign portfolio investment (FPI) and other foreign investment (OFI) fills this gap in the literature. Adopting the stochastic frontier approach, this paper constructs an OECD frontier based on a panel dataset of 20 OECD countries over the 1981-2000 period. Spillover effects of FDI, FPI, OFI and trade are gauged by their respective contributions towards reducing technical inefficiencies, which are represented by the distance of each country from the constructed frontier. Results from the multiple models examined in the paper indicate that inflows of foreign investment and trade have been instrumental in reducing inefficiencies across OECD countries, whereas outflows of foreign investment exacerbate inefficiencies. The study also confirms some previous findings that the spillover effects of FDI inflows are larger than that of trade but does not find evidence in favour of the view that the spillover effects of trade are overestimated when FDI flows are excluded from the analysis. Moreover, the impact of FDI inflows is larger than those of FPI and OFI inflows. The importance of absorptive capacities of host economies in capturing spillover gains from FDI inflows is also examined. Amongst the various measures of absorptive capacity considered, only human capital was found to be important.

JEL Classification: F21, F23

Keywords: technical efficiency; spillovers; stochastic production frontier; foreign direct investment; foreign portfolio investment; other foreign investment.

Introduction

The recent endogenous growth theory has revitalized the interest in the measurement of total factor productivity (TFP) in that it identifies TFP as the main source of long run economic growth. There exists sizable literature on the determinants of TFP. A significant part of this literature has dwelled on evaluating the spillover effects of trade on growth; see, for instance, Grossman and Helpman (1991); Coe and Helpman (1995); Coe, Helpman and Hoffmaister (1997). However, other potential channels of spillovers across national boundaries, such as investment, international alliances, labour migration, licensing, patenting, overseas education and research publications have been largely neglected in the empirical literature. The lack of research on disentangling the channels through which spillovers are transmitted is attributed usually to non-availability of appropriate data.

In partially addressing this void in the literature, Lichtenberg and van Pottelsberghe de la Potterie (1996) and Hejazi and Safarian (1999) augment the Coe and Helpman (1995) model by including inward and outward foreign direct investment (FDI) as additional channels for spillovers. Hejazi and Safarian observe that excluding the effects of FDI results in overestimation of the spillovers from trade and that the spillovers from FDI were indeed larger than those from trade. On the other hand, Lichtenberg and van Pottelsberghe de la Potterie find that while FDI outflows transmitted foreign technology back to the source country, FDI inflows were not associated with knowledge spillovers. In fact, most studies using panel data have failed to find evidence of positive spillovers associated with FDI inflows and few have even obtained evidence of negative spillovers (Görg and Greenaway 2001). Blomström, Kokko and Globerman (2001) attribute this to the host countries lacking of absorptive capacity. At the same time, there is growing recognition in the literature of the importance of FPI and OFI flows in the development process; see, for instance, Errunza (2001). It has been argued that inflows of foreign portfolio investment (FPI) and other foreign investment (OFI),[1] in addition to developing the local financial markets, necessitate creation of new institutions and services, transfer of technology and better managerial performance.

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[1] 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-

Based on these new, but isolated, developments in the literature, this paper aims to provide a comprehensive model on the effects of foreign investments and trade on endogenous economic growth. The empirical work employs a panel dataset covering 20 OECD countries between 1981 and 2000.[2] Most of the research in this area has concentrated in developing countries although the OECD accounts for the bulk of foreign investment by both source and destination.

The present study represents an improvement over previous studies on three counts. First, most of the studies on endogenous growth focus solely on the spillovers from trade and in few cases on the spillovers from both trade and FDI inflows. The present study accounts for spillovers from trade and all types of foreign investment inflows and outflows. Moreover, it accommodates several control variables to ensure that the spillover effects of trade and foreign investments are not overestimated as a result of omission bias. Second, it recognizes that the spillovers from foreign investments may be dependent on the absorptive capacity of host economies. It evaluates the importance of human capital, financial market development and technology gap as measures of absorptive capacity.[3] Third, it also differs from earlier studies in terms of methodology. The present study adopts a method based on the estimation of stochastic frontier production model as proposed by Battese and Coelli (1995). Regression methods typically applied in analyses of productivity growth implicitly assume efficient use of all resources including technology. This leads to inaccurate measurement of productivity in that TFP is presumed synonymous with technological change. The stochastic frontier approach (SFA), on the other hand, allows for inefficiency and decomposes TFP growth into the technical change and efficiency change components.[4] Moreover it permits tracing and quantifying the effect of chosen explanatory variables on technical efficiency. The spillover effects of foreign investments, trade or the other control variables are fully captured by their

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border investment in equity and debt securities. OFI includes bank loans and trade-related lending which covers commercial bank lending and other private credits.

[2] The choice of countries within the OECD and the time frame of the study were determined by data availability. Appendix 1 lists the countries in the sample.

[3] These measures of absorptive capacity are suggested by Xu (2000), Blomström and Kokko (2003) and Blomström, Kokko and Globerman (2001).

[4] The technical change and efficiency change components are mutually exclusive and exhaustive.

respective coefficients in explaining technical efficiency.[5] The use of SFA in examining the macroeconomic issues is relatively recent and this study, to our best knowledge, is the first application of the SFA technique in examining the macroeconomic effects of foreign investments.

The remainder of the paper is structured as follows. The next section explains briefly the SFA 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 paper.

The Methodology

The stochastic frontier approach (SFA) 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 constructed below in equation (1) is based on the Battese and Coelli (1995) model. 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.

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

y_{it} denotes the output of the i-th country in the t-th time period. x_{it} represents a $(1 \times K)$ vector whose values are usually logarithmic functions of inputs which, enables the inefficiency term to be interpreted as the percentage deviation of observed performance from the individual country's own frontier performance. 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:

[5] Technology embedded in the explanatory variables can cause shifts in the constructed frontier (technical change). But the need to examine the technical change effects of the explanatory variables is circumvented by including both domestic R&D stock and a quadratic function of time in the production function.

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

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

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:

$$u_{it} = z_{it}\delta + w_{it} \quad (4)$$

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), technical efficiency (TE)[6] of the i-th country at the t-th year is predicted by

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

Efficiency change between two adjacent periods, s and t, is then calculated as:

$$EC_{it} = TE_{it} / TE_{is} \quad (6)$$

An index of technical change (TC) between the two periods s and t can be directly calculated from the estimated parameters of the stochastic production frontier by evaluating the partial derivative of the production function with respect to time (at a particular data point). If TC is non-neutral, the index may vary with different input vectors. Hence a geometric mean should be used to estimate the TC index between the adjacent periods. Following Coelli, Rao and Battese (1998), the TC index is calculated as:

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[6] Scale efficiency effects are not considered explicitly although it is possible to factor-out the scale effects from technical efficiency. This is mainly because the scale efficiency may reflect country-specific characteristics.

$$TC_{it} = \left[\left(1 + \frac{\partial f(x_{is}, s, \beta)}{\partial s} \right) \times \left(1 + \frac{\partial f(x_{it}, t, \beta)}{\partial t} \right) \right]^{0.5} \quad (7)$$

The indices of EC and TC obtained by using equations (6) and (7) respectively can be multiplied to obtain the Malmquist TFP index:

$$TFP_{it} = EC_{it} * TC_{it} \quad (8)$$

To summarise, TC measures the shift of the production frontier; TE indicates how far a sample country lags behind the best practice as represented by the production frontier; and, on the other hand, EC can be interpreted as how fast a country catches up with the best practice.

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 (i.e., x_{it} vector) and technical inefficiency effects (i.e., z_{it} vector).[7]

Table 1: Variables and Expected Effects

Variables	*Notation*	**Expected Effect on output/inefficiency** [a]
Output (Real GDP)	Y	
Factor Inputs		
Capital Stock	K	Positive
Total Labour Force	L	Positive
Domestic R&D Stock	R&D	Positive
Human Capital	HC	Positive
Time	T	Positive
Inefficiency Effect Variables		
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
Technology Gap	TGAP	Negative
FDI Inflows x Technology Gap	FDII x TGAP	Negative
FDI Inflows x Human Capital	FDII x HC	Negative
FDI Inflows x Financial Market Development	FDII x FMD	Negative

[7] The compilation and construction of the data on variables is explained in Appendix 2.

FPI Inflows x Financial Market Development	OFII x FMD	Negative
OFI Inflows x Financial Market Development	OFII x FMD	Negative
Time	T	Positive/ Negative

[a]: A negative sign implies a decrease in inefficiency

The SFM presents an improvement over an OLS function only if technical inefficiency effects are present. The presence of technical inefficiencies, therefore, needs to be established before adopting the SFM. This is easily achieved by testing the significance of the ratio of error variances from equation (1) using a generalized likelihood ratio (LR) test. As indicated earlier, the stochastic frontier approach imposes a common production technology across countries. This has been argued as a significant shortcoming of the methodology in the literature. Many researchers have, therefore, chosen to use of relatively flexible production functions such as the translog in lieu of the traditional Cobb-Douglas or the CES. Adopting flexible functional forms minimizes the risk of errors in model specification. The functional form of the SFM, in the present case, is determined by testing the adequacy of the Cobb-Douglas relative to the translog using, once again, 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 2.

Table 2: Generalized Likelihood-Ratio Tests of Null Hypotheses for Parameters in the Stochastic Frontier Production Function for selected OECD Economies

Null Hypothesis (H_0)	**LR-Test Statistic**	**Critical Value (0.01)**	**Decision**
No inefficiency effects	230.003	$\chi 2_{.01,\ 13} =$ 27.026	Reject H_0
A Cobb- Douglas Function is adequate	618.794	$\chi 2_{.01,\ 15} =$ 30.578	Reject H_0
There is no technical change	175.911	$\chi 2_{.01,\ 6} =$ 16.812	Reject H_0
Technical change is Hicks Neutral	339.208	$\chi 2_{.01,\ 4} =$ 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).

Rejection of the null of no inefficiency effects provides support for the SFM specification. The translog production frontier is chosen based on the rejection of the Cobb-Douglas function as adequate. This implies that the input and substitution elasticities vary across countries. The hypotheses of no technical change and Hicks neutral technical change are also rejected, calling for the incorporation of a time trend and its cross products with conventional factor inputs in the production function.

The choice of other explanatory variables to be included in the inefficiency effect model is discussed next.

FDI Inflows and interaction terms with Technology Gap, Human Capital (HC) and Financial Market Development (FMD)[8]

The theoretical literature on FDI inflows has identified four main channels through which spillover gains may be transmitted to host economies. First, there is the direct transfer of technology and its diffusion through vertical (backward and forward) linkages (Blomström and Kokko 1998).[9] Second there are "demonstration effects" in that domestic firms learn by watching FDI firms (Balasubramanyam, Salisu and Sapsford 1996). Third, there is a "competition effect" in that domestic firms improve their efficiency in order to compete with FDI firms. Fourth, spillovers may occur through movement of labour, whereby workers trained by FDI firms relocate to domestic firms (Görg and Strobl 2002). However, in summarizing the empirical results obtained thus far on an aggregate level, Görg and Greenaway (2001) comment that most work fails to find positive spillovers.

The lack of unanimous empirical evidence in support of positive spillovers may be attributed to the implicit assumption in many studies that spillovers are an automatic consequence of FDI inflows. Studies on developing countries like Balasubramanyam (1998) argue against such an assumption and suggest that host country characteristics determine the impact of FDI inflows. A similar observation has been made by Blomström, Kokko and Globerman (2001) in the context of developed economies. Specifically, they point to the dependence of spillovers on productivity or technology gaps. They observe that small gaps encourage spillovers while large gaps inhibit them, however, if the gaps are too small, spillovers are

[8] More discussion about the measurements of technology gap, human capital and financial market development will follow later.

[9] For some time now it has been recognized that Multi National Enterprises (MNEs) may benefit the host country through the backward and forward linkages they generate. Backward linkages are relations with suppliers; forward linkages refer to relations with buyers – either consumers or other firms using the MNEs' products as intermediates in their own production process (Fortanier 2001).

unlikely to occur either. On the other hand, Xu (2000) and Blomström and Kokko (2003), amongst others, concentrate on HC as a measure of absorptive capacity. They observe that countries endowed with a larger stock of HC are likely to capture greater spillover gains. Finally, Alfaro, Chanda, Kalemli-Ozcan and Sayek (2002), in examining the role of FMD, note that countries with more sophisticated financial markets are more likely to gain from FDI inflows.

FDI Outflows

Where the intention of the foreign company is to tap the knowledge base of the technologically advanced host economy, knowledge spillovers may accrue to the investing firm and consequently to the source country. For instance, Kogut and Chang (1991) and Yamawaki (1993) find that this was the primary aim of Japanese FDI in the US and Europe. Similar results have been obtained in studies relating to other OECD countries. For instance, see, Neven and Siotis (1996); van Pottelsberghe de la Potterie and Lichtenberg (2001). However, it can also be argued that FDI outflows are indicative of better opportunities elsewhere in the world. In that sense, FDI outflows are likely to capture the relative unattractiveness of the source economy. The effect of FDI outflows on technical efficiency, therefore, is an empirical issue.

Foreign Portfolio Investment (FPI) and Other Foreign Investment (OFI) Inflows, and interaction terms with Financial Market Development (FMD)

Portfolio and other foreign investment inflows have, to our best knowledge, not been modeled as channels of spillovers. This, despite findings in the literature that these flows may enhance efficiency by bringing about improvements in accounting, information reporting systems and corporate governance (see, Errunza 2001). Moreover, these flows have grown enormously over the last two decades, as shown in Figures 1 and 2. The rising capital flows can provide domestic firms a greater access to foreign savings and thus easing financial constraints that might have prevented them from investing in potentially more efficient technology.

Furthermore, there exists substantial evidence that the participation of FPI and OFI inflows increases the sophistication levels in domestic financial markets (for instance, see, Levine 2001). There is also evidence that the share of FPI inflows in the total capital flows increases with financial market development (Lusinyan 2002). But it is not clear if spillover gains from FPI and OFI inflows are in turn dependent on the sophistication levels of the domestic financial markets.

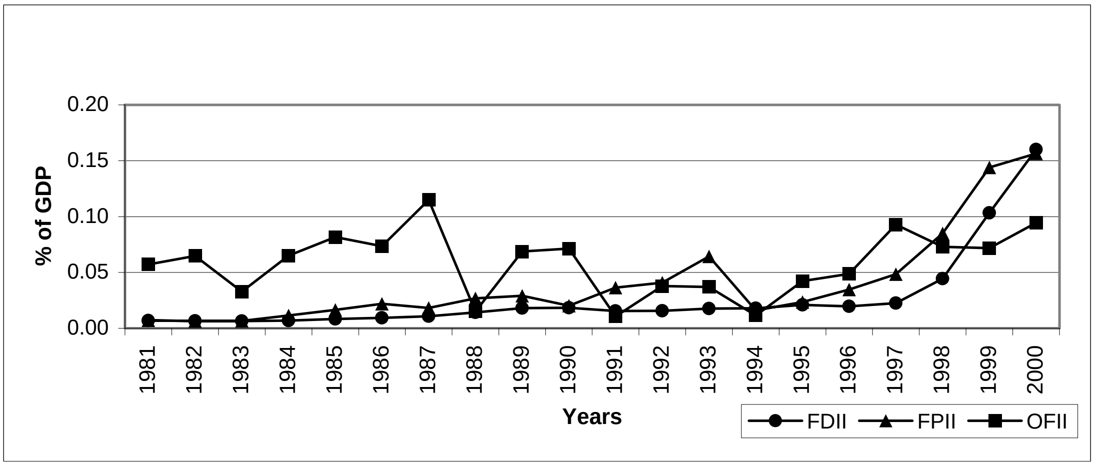

Figure 1. FDI, FPI and OFI Inflows (OECD Average)

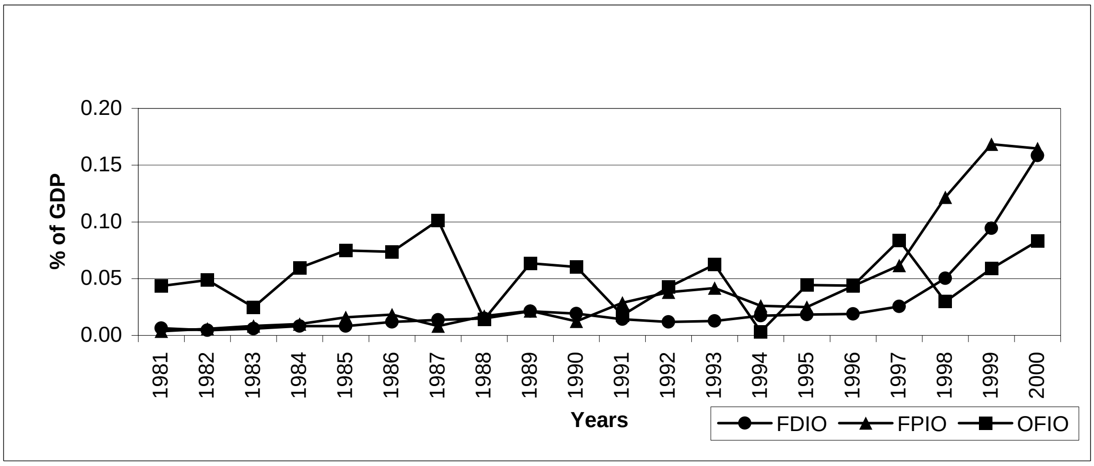

Figure 2. FDI, FPI and OFI Outflows (OECD Average)

FPI and OFI Outflows

As with inflows, FPI and OFI outflows could also be argued as potential channels for spillovers. Both FPI and OFI outflows force domestic firms to perform better by inducing competition for domestic savings. However, as with FDI outflows, to the extent FPI and OFI outflows reflect the relative unattractiveness of the source economy as an investment destination, their impact on technical efficiency may be statistically negative.

Trade Openness

FDI and international trade are highly correlated; see, Pfaffermayr (1996); Brainard (1997); and United Nations (1996). Hejazi and Safarian (1999) observe that the high correlation between the variables leads to overestimation of the spillover effects of trade when FDI flows are excluded from the analysis. Along similar lines, it is argued that models attempting to evaluate spillovers from FDI should specifically control for the effects of international trade. A large number of studies have examined the possibility of spillovers through international trade, including Grossman and Helpman (1991), Coe and Helpman (1995), Ben-David and Rahman (1996), Coe, Helpman and Hoffmaister (1997) and Lichtenberg and van Pottelsberghe de la Potterie (1998). Nevertheless, many of the aforementioned studies have focused exclusively on imports, arguing that high technology imports cause knowledge spillovers. It is argued that imports could also generate spillover gains by inducing competition in the host economy and increasing the export ability of domestic firms. Exports by domestic firms also act as a channel for spillover gains in providing exposure to global competition. In order to successfully compete in global markets, domestic producers will have to necessarily raise efficiency levels. Including the effects of both exports and imports seems more pertinent where the focus is not on technology spillovers in particular but on efficiency in general. The aggregation of exports and imports into a single measure of trade openness is justified in that it is used primarily as a control variable in measuring the spillover effects of foreign investments. The unique spillover effects of imports and exports, while constituting an interesting area of study, are not central to this paper's objective.

FMD and Technology Gap

A well developed financial system can provide for better allocation of capital and spur technological innovation and adaptation by identifying and funding those entrepreneurs with the best chance of successfully implanting innovative products and production processes (Schumpeter 1912). Naurzad (2002) empirically examined the role of financial development in enhancing productive efficiency and found that economies with more developed financial intermediaries sector and equity markets tend to be more efficient in the production of output. Rajan and Zingales (2000) show that the forces opposing financial development will be weaker when a country is open to international trade and capital flows. The suggested correlation of financial market development (FMD) with trade and capital flows implies that excluding FMD might result in attributing to foreign investments or trade, efficiency gains that are actually occurring through FMD. A similar argument can be made for considering the effects of technology gap in the analyses of spillovers. This is because our measurement of technology gap is accumulated domestic R&D expenditure as a percentage of accumulated world R&D expenditure, and there could be correlation between FDI inflows and domestic R&D.

Human Capital

Notwithstanding the substantial theoretical literature on the importance of human capital (HC) in economic growth, the modeling of HC has remained controversial from an empirical standpoint. Aghion and Howitt (1998) distinguish between two major alternative frameworks for the modeling of HC – the Lucas approach and Nelson and Phelps approach.[10] While the former hypothesizes that difference in growth rates are due to differences in the accumulation of HC, the latter assumes that HC affects growth because it affects countries' abilities to innovate as well as to adapt and absorb new technologies. The Nelson and Phelps approach is supported by evidence from Engelbrecht (1997;2002). In adopting an approach similar to that of Nelson and Phelps, Kneller and Stevens (2002) found HC to be important in reducing relative inefficiencies of OECD countries. Keeping with the Nelson and Phelps approach, this paper incorporates HC as both an x_{it} vector variable in the frontier function and a z_{it} vector variable explaining the technical inefficiency effects.[11]

Empirical Results and Discussion

The translog stochastic frontier production function is estimated using Frontier 4.1 (Coelli 1996). The package, in addition to providing the parameter estimates, generates measures of technical efficiency (TE) for each country on a yearly basis, which are reported in Appendix 3. According to the annual averages of TE levels for all countries, USA, Sweden, Luxembourg and Denmark appear to be the most efficient countries, followed by Ireland and Canada. On the other hand, Spain, Japan, Germany, Italy and Portugal appear to be the least efficient countries. Notwithstanding the variation in the level of TE, measures of EC do not vary significantly across countries (range from 0.9813 to 1.0016), thereby offering no

[10] For details, see Lucas (1988), which was inspired by Becker (1964), and Nelson and Phelps (1966).

[11] Instances of a variable occurring in both x_{it} vector and z_{it} vector can be found in several other empirical applications. See, for instance, Coelli, Rao and Battese (1998) and Kneller and Stevens (2002).

evidence of "catching up" within the OECD. For details, see Appendix 4. Denmark, Finland, Ireland and New Zealand are the only countries that register positive EC over the 1981-2000 period. The ranking of the countries in terms of TE, with few exceptions, has remained fairly constant across the two decades (See Appendix 5).

The parameter estimates for the translog stochastic frontier production function are reported in Table 3.

Table 3: Maximum Likelihood Estimates for Parameters of Translog Stochastic Frontier Production Function for selected OECD Countries

Variable	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7
Frontier Function							
Constant	0.261*	0.273*	0.260*	0.250*	0.269*	0.315*	0.124*
ln K	0.204*	0.203*	0.204*	0.198*	0.192*	0.189*	0.141*
ln L	0.889*	0.891*	0.890*	0.888*	0.893*	0.914*	0.860*
ln R&D	-0.049*	-0.050*	-0.050*	-0.043*	-0.044*	-0.062*	0.023
HC	-0.076*	-0.078*	-0.076*	-0.077*	-0.079*	-0.079*	-0.011**
T	0.026*	0.025*	0.026*	0.025*	0.025*	0.024*	0.019*
Inefficiency Model#							
Constant	0.910*	0.916*	0.918*	0.940*	0.943*	0.982*	0.410*
FDI Inflows	0.077	-0.459	-0.137	-0.549*	-0.544*	0.439	
FDI Outflows	0.435**	0.477**	0.433**	0.588*	0.585*	0.151	
FPI Inflows	-0.336*	0.184	-0.333*	-0.331*	-0.304**		
FPI Outflows	0.319**	0.322**	0.322**	0.311**	0.269		
OFI Inflows	-0.866*	-0.805*	-0.860*	-0.934*	-0.465*		
OFI Outflows	0.362*	0.371*	0.362*	0.397*	0.380*		
HC	-8.711*	-8.902*	-8.773*	-9.283*	-9.373*	-8.938*	-1.611
TGAP	-0.690*	-0.709*	-0.691*	-0.673*	-0.712*	-0.804*	-0.349*
FMD	-0.746*	-0.683*	-0.769*	-0.752*	-0.661*	-0.728*	-0.671*
TOP	-0.232*	-0.226*	-0.233*	-0.233*	-0.227*	-0.225*	-0.218*
FDII x HC	-14.306*	-14.763*	-13.561*			-17.431*	
FDII x TGAP		-0.354					
FDII x FMD		1.798**	0.580				
FPII x FMD		-2.044					
OFII x FMD	1.516*	1.297*	1.495*	1.585*			
T	0.016*	0.016*	0.016*	0.015*	0.014*	0.013*	0.009*
Variance Parameters							
Sigma-squared	0.003*	0.003*	0.003*	0.003*	0.003*	0.003*	0.005*
Gamma	0.693*	0.714*	0.687*	0.700*	0.730*	0.782*	0.690*
Log-Likelihood	624.357	625.748	624.634	620.941	618.767	615.924	550.598
LR-Test+	NA	2.783	0.553	6.833*	11.180*	16.866*	147.517*

Legend: * significant at 5 percent level or less.** significant at 10 percent level or less. + compares the log likelihood of the nested models with that of the model 1. # A negative sign on the coefficient of a z_{it} vector variable represents a reduction in inefficiencies.

Model 1 is the basic model adopted in the paper. All tests of hypotheses and measures of efficiency and technical change have been derived from this model. This model, despite being nested in models 2 and 3, is not rejected by the LR tests reported in Table 3.[12] Results from Model 1 reveal that a total of 17 coefficients out of the 20 included in the frontier function, i.e. x_{it}, are significantly different from zero at 5 percent level (excluding the constant).[13] All five direct effects, their squared terms and seven cross products have coefficients significantly different from zero. This confirms that rejection of the Cobb-Douglas model as an adequate representation of the data is justified, because the function is non-linear in some dimensions and there are important interactions among the variables.

The coefficients on Capital (K), Labour (L), R&D, Human Capital (HC) and time trend reported in Table 3 are their respective elasticities calculated at the sample means.[14] Labour comes across as the single most important input with an output elasticity of 0.889 followed by capital at 0.204. The elasticities of R&D and HC are negative in all of the examined models (excepting model 7). However, this cannot be interpreted to imply that they have a negative impact on output. It is not uncommon to obtain negative estimates of HC in the production function (see, for instance, Islam 1995).[15] The negative elasticities obtained for HC and R&D in the present case is perhaps due to the inability of the chosen proxies to capture the factor inputs adequately (see Appendix 2).

Furthermore, the coefficient on the time trend variable indicates that there is rapid technological progress. The frontier is shifting upwards at an annual rate of 2.6 percent. The magnitude of technical change across countries is estimated by equation (7). The estimates of technical change are reported in the Appendix 6. The rapid technological progress offers an

[12] The LR test statistic reported in Frontier 4.1 is used to determine the existence of inefficiency effects. The LR test statistic reported in Table 3 is different in that it is calculated by comparing the log likelihood functions of model 1 with the other models. For instance, the LR statistic reported for model 3 compares the log likelihood value of model 1 with that of model 3. Since the statistic is not significant, model 1 which is nested in model 3 is preferred. The LR statistic reported for model 4, which is nested in model 1, is significant. This inference here is that model 4 is not preferred over model 1.

[13] The hypotheses tests in Section 2 have shown that a non-neutral translog stochastic frontier model is the appropriate representation among the alternatives considered. Accordingly, the production function is estimated with 20 terms, which include the four conventional factor inputs, time trend, their squared terms and cross products. The results for those squared terms and cross products are not reported for brevity but available from authors on request.

[14] When adopting a translog specification, the individual coefficients of the x_{it} vector variables cannot be directly interpreted as elasticities. The elasticities of output with respect to the inputs depend on the levels of the explanatory variables as well as the subsets of the parameters. Elasticities of the factor inputs at sample means are obtained easily by mean differencing the variables prior to estimation.

[15] Krueger and Lindahl (2001) presented evidence that, due to strong endogeneity, including physical capital and human capital in the same growth regression is not likely to produce a clear estimate of the effect of education on growth.

explanation for the declining level of technical efficiency across the sample. Since technical efficiency measures the distance of the countries from the constructed frontier, the computed measures could decline (even if efficiencies have actually improved) due to the frontier being pushed upwards rapidly.

Appendix 7 presents the Malmquist TFP index obtained using equation (8). It has been argued that for the Malmquist index to be a TFP measure it is necessary to restrict the technology to the constant returns to scale (CRS) case (Färe, Grosskopf and Roos 1996). The indicator of returns to scale is the sum of the coefficients on the four conventional inputs, which is 0.968. The null hypothesis of CRS was examined using a simple t-test as suggested in Coelli, Rahman and Thirtle (2003).[16] The null hypothesis of CRS was not rejected. The obtained Malmquist TFP index can, therefore, be interpreted as a measure of TFP growth. All countries in the sample, including those experiencing efficiency declines, report positive TFP change over 1981-2000. This can, once again, be attributed to the rapid technological progress in the OECD countries. We are not going to further analyze the trends in technical efficiency, technological progress and TFP growth, as the principal interest of this study is the spillover effects of foreign investment – the subject that we now turn to.

The coefficient on FDI inflows is not significant in model 1. The coefficient of the variable representing the interaction between FDI inflows and HC is, however, both large and significant. This result implies that the insignificance of the coefficient on FDI inflows needs to be interpreted cautiously. It cannot be construed to imply that FDI inflows are unimportant for economic progress. The appropriate inference is that when a variable representing FDI inflow's interaction with HC is included, the coefficient on FDI inflows is not empirically discernible. This is highlighted by the significance of FDI inflows in model 4 and model 5 wherein the interaction variable FDII x HC is excluded.[17] The significance of the FDI inflows variable either individually or in an interaction form contrasts with the findings of Carkovic and Levine (2002) who observed that FDI inflows becomes insignificant once the effects of

[16] The sum of the elasticities minus 1, divided by the square root of the covariance matrix gives the t test.

[17] Model 4 differs from model 1 only by its exclusion of the FDII x HC variable, but model 5 excludes all interaction terms including FDII x HC and OFII x FMD both of which are present in model 1.

trade openness (TOP), black market premium or financial market development (FMD) are controlled for.[18]

Among the interaction variables of FDI inflows, only FDII x HC comes across as being significant in any of the examined models implying that efficiency gains from FDI inflows will be higher in economies with higher stocks of HC. The other variables used to capture the absorptive capacity of host economies, i.e. FDII x TGAP and FDII x FMD, are insignificant in all of the examined models. This finding goes against the results in Blomström, Kokko and Globerman (2001) that points to the dependence of spillovers on technology gaps and Alfaro, Chanda, Kalemli-Ozcan and Sayek (2002) who suggest that spillovers from FDI inflows are dependent on FMD. However, the results herein are not strictly comparable to that in Alfaro *et al.*, where a mixed sample of 71 developed and developing countries was used as opposed to our sample of 20 OECD countries.

In measuring the growth impacts of FPI inflows, it is usually assumed that the spillover gains relate to the beneficial impact of FPI inflows on FMD (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. Notwithstanding, the interaction term between FPI inflows and FMD is not significant, implying that financial sector development is not a prerequisite to capture efficiency gains from FPI inflows. These results, however, do not preclude the possibility that FPI inflows may contribute towards improving the depth and level of sophistication of local financial markets.

OFI inflows are revealed to have a negative and significant impact on inefficiency; thus validating its inclusion in the model. However, the estimate of interaction between OFI inflows and FMD is counter-intuitive in that it is observed to exacerbate inefficiency. This probably reflects that bank and other forms of trade related lending are not the most efficient means of external finance in economies characterized by developed financial markets.

The negative and significant coefficient on the TOP variable is consistent with most research with the realm of endogenous growth theory that evaluates the technology spillovers from

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[18] The models in this paper have not controlled for the effects of black market premium as the sample covers only OECD countries.

trade. The efficiency gains evaluated herein are not restricted to those accruing from technology spillovers alone. Spillover gains resulting from increased competition and scale economies are also accommodated. 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 coefficients of TGAP and HC variable are again in accordance with a priori expectations. Countries with greater investments in R&D and HC are observed to be more efficient than others. In sum, all the control variables included in model yield significant coefficients, validating their inclusion in the model.

The coefficients on FDI, FPI and OFI outflows are both positive and significant, implying that outward flows of foreign investment impact adversely on efficiency. The positive sign of the coefficient on FDI outflows merits discussion in light of the recent empirical evidence in Lichtenberg and van Pottelsberghe de la Potterie (1996) (LV), Hejazi and Safarian (1999) (HS) and van Pottelsberghe de la Potterie and Lichtenberg (2001) (VL). The "Trojan horse" hypothesis of VL suggests that the principal objective underlying FDI is to source technology and that FDI has no productivity impact on host economies. Results obtained herein, while not supportive of this hypothesis, do not evidence against it either given the possibility that FDI outflows may capture the relative unattractiveness of the source economy. The positive coefficients on FPI and OFI outflows can also be argued to reflect upon the unattractiveness of the source economy.

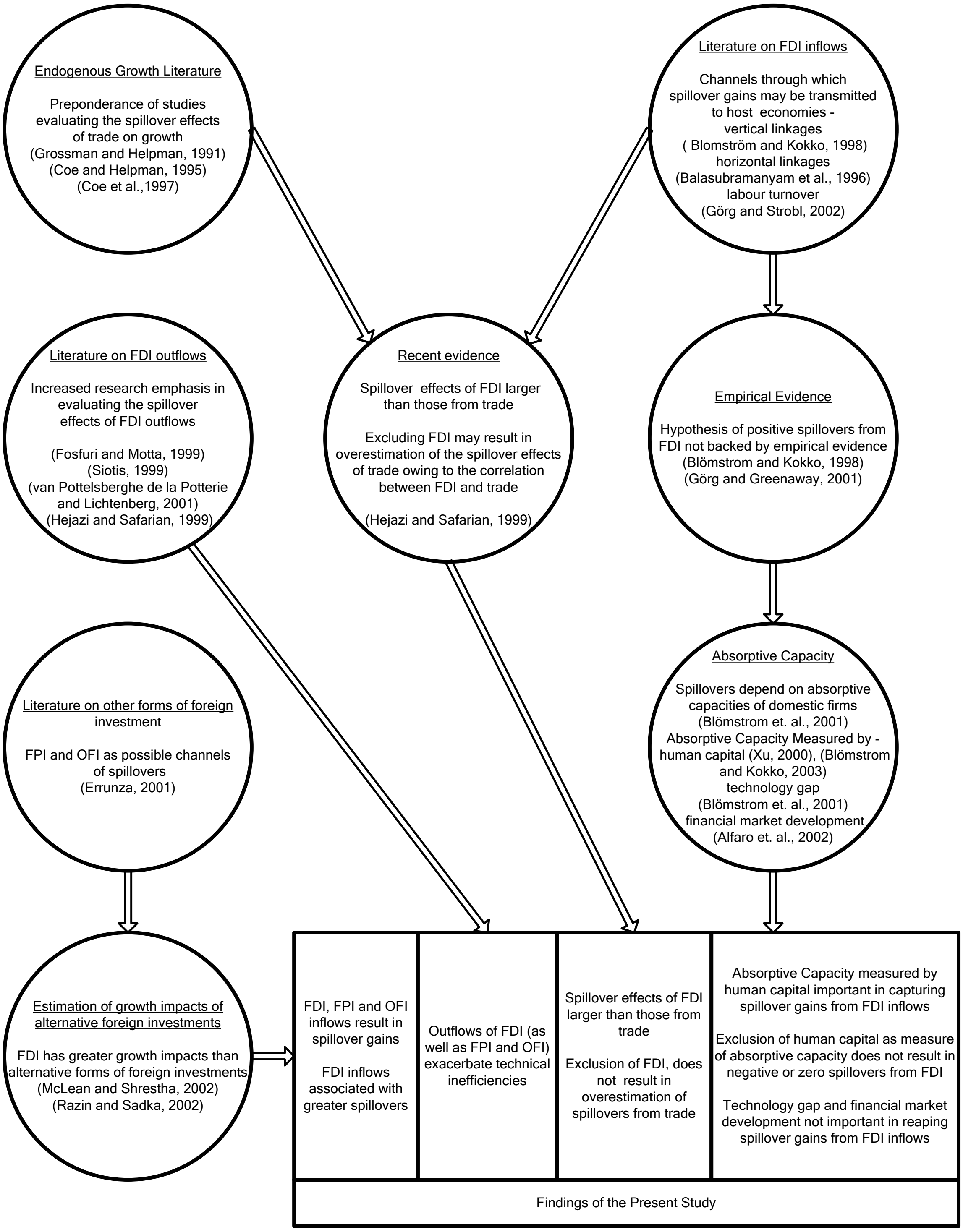
Model 7 excludes all foreign investment variables in order to examine if their exclusion results in overestimation of the spillover effects from trade as argued in Hejazi and Safarian (1999). Notwithstanding the high correlation between trade and foreign investment variables, the results obtained are robust in that the coefficient on trade remains roughly the same in Model 7 as in the other examined models. Model 6 excludes inflows and outflows of FPI and OFI in order to bring the specification closer to the ones advocated by LV, HS and VL. This model examines if the exclusion of FPI and OFI variables result in biased estimates of FDI. It is found that the signs on of the coefficients of the FDI variables and their significance remain robust despite changes in model specification.

Model 5 excludes all interaction terms. This model primarily aims to examine if the growth effects of FDI inflows are indeed greater than those of FPI and OFI inflows as argued in

McLean and Shrestha (2002) and Razin and Sadka (2002). The results obtained here are consistent with these studies in that the coefficient on FDI inflows is larger. But in contrast to the results in McLean and Shrestha, the coefficient on the OFI inflows variable is both negative and significant, underlining the importance of OFI inflows in the growth process.

In view that this study has tested a fair number of hypotheses and compared the findings with previous studies, we summarize them once again schematically in Figure 3 prior to presenting the concluding remarks.

<u>Figure 3: A Diagrammatic Summary</u>



Concluding Remarks

This study evaluated the effect of various types of foreign investments on aggregate efficiency for 20 OECD countries over the period of 1981–2000. The stochastic frontier approach (SFA) was adopted to construct an efficient frontier. Spillover effects of foreign investments, trade and other 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 conducted, based on likelihood ratio statistics, favoured the use of non-neutral translog production function in estimating the frontier.

There was evidence of rapid technological progress (i.e. technical change) and decreasing technical efficiency in most sample countries over the period, but the rankings of the countries in terms of technical efficiency remained fairly stable. Further, the measures of efficiency change did not vary significantly across countries. The gains from technical change outweighed the losses from technical efficiency, resulting in the Malmquist TFP index reporting positive productivity growth for all the countries in the sample.

The sources of inefficiency were examined with a focus on the role of foreign investments. The results indicated a greater stock of human capital facilitates capturing spillover gains from inflows of FDI. Portfolio and other foreign investment inflows were also identified as being an important channel for spillovers. However, when evaluated without the interaction terms, it is found that the coefficient on FDI inflows are larger than those on FPI and OFI inflows, confirming the view that FDI inflows are more growth inducing than alternative forms of foreign investment. In accordance with previous studies, trade openness, financial market development, technology gap and human capital were found to be significant in reducing inefficiencies. Notwithstanding the high correlation between the foreign investment variables and trade, it was found that the exclusion of the former from the model does not result in overestimation of the spillover effects from the latter. Similarly, the exclusion of FPI and OFI variables did not result in overestimation of spillovers from FDI. Outflows of FDI, FPI and OFI were observed to exacerbate inefficiencies. This is attributed to these variables reflecting the unattractiveness of the source economy.

Appendix 1: Countries included in the Study

Countries	Notation
Australia	AUS
Austria	AUT
Belgium	BEL
Canada	CAN
Denmark	DNK
Spain	ESP
Finland	FIN
France	FRA
UK	GBR
Germany	GER
Ireland	IRL
Italy	ITA
Japan	JPN
Luxembourg	LUX
Netherlands	NLD
Norway	NOR
New Zealand	NZL
Portugal	PRT
Sweden	SWE
USA	USA

Appendix 2: Compilation and Construction of the Dataset

This appendix explains the compilation and construction of the dataset used in the model.

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:

$$K_t = K_{t-1}(1- \theta) + I_t \quad (9)$$

where K is capital stock, I investment and θ the assumed 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, 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 2003 (WDI). Total labor 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). Foreign R&D stocks can be modeled based on the trade pattern of countries (see, Coe and Helpman (1995)). However, this approach implicitly assumes that technology can be transferred only through the trade channel. An alternative approach has been to construct an 'R&D pool' from the R&D stock of selected OECD countries (see, Kneller and Stevens (2002)). There are several problems associated with this approach including the assumption of free and immediate access to foreign R&D by all countries. We believe including a quadratic function of time is a better alternative, as the purpose is to capture the shift in the production frontier and not to measure the elasticity of foreign R&D.

Human Capital (HC): Education expenditure as a percentage of Gross National Income is used as a proxy of human capital. Average year of schooling (AYS) is another proxy of HC that the present authors considered. Results obtained were implausible and may be attributed to the negative temporal relationship between HC stocks and output growth, which apparently outweighs any positive cross-sectional relationship between them. Furthermore, AYS data are available only on a five-yearly basis necessitating interpolation of the data using a time trend.

FDI, FPI and OFI 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. Data on market capitalization was not available for the entire time frame included in the study. Models using other measures such as M2, liquid liabilities, private sector credit provided by commercial banks and domestic credit were constructed but results obtained were counter intuitive. Such results may be attributed to the inability of these measures to capture the entire spectrum of what constitutes FMD. Moreover, these measures 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).

Technology Gap (TGAP): This variable measures individual country's stock of R&D as a percentage of World R&D. The World R&D stock is proxied 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.

Appendix 3: Technical Efficiency of selected OECD Countries

Period	AUS	AUT	BEL	CAN	DNK	ESP	FIN	FRA	GBR	GER
1981-1985	0.8496	0.8362	0.9874	0.9529	0.9439	0.6168	0.8010	0.8798	0.8289	0.7865
1986-1990	0.7638	0.7922	0.9421	0.9204	0.9404	0.6215	0.7813	0.8523	0.7824	0.7446
1991-1995	0.7340	0.7373	0.8524	0.8743	0.9100	0.6219	0.7867	0.7884	0.7177	0.7000
1996-2000	0.7236	0.6892	0.6964	0.8537	0.9700	0.6038	0.7973	0.7397	0.7017	0.6467
1981-2000	0.7678	0.7637	0.8696	0.9003	0.9411	0.6160	0.7916	0.8150	0.7577	0.7195

Period	IRL	ITA	JPN	LUX	NLD	NOR	NZL	PRT	SWE	USA
1981-1985	0.9423	0.7826	0.6918	0.9838	0.9605	0.8551	0.8027	0.7248	0.9680	0.9880
1986-1990	0.8968	0.7300	0.6974	0.9778	0.8925	0.8290	0.7984	0.6593	0.9285	0.9827
1991-1995	0.8832	0.6832	0.6616	0.9733	0.7936	0.8625	0.8352	0.7230	0.9016	0.9336
1996-2000	0.9370	0.6644	0.6005	0.9816	0.7547	0.8130	0.8075	0.7469	0.9594	0.9010
1981-2000	0.9148	0.7151	0.6628	0.9791	0.8503	0.8399	0.8109	0.7135	0.9394	0.9513

Note: Efficiency scores lie between 0 and 1 with a higher score being indicative of greater efficiency. A country which is fully efficient would lie on the constructed frontier and its efficiency score will consequently be 1.

Appendix 4: Efficiency Change of selected OECD countries

Period	AUS	AUT	BEL	CAN	DNK	ESP	FIN	FRA	GBR	GER
1981-1985	0.9789	0.9860	0.9979	0.9860	0.9949	0.9648	0.9884	0.9929	0.9888	0.9874
1985-1990	0.9819	0.9906	0.9882	0.9913	0.9913	1.0256	0.9989	0.9971	0.9844	0.9889
1990-1995	0.9968	0.9855	0.9547	0.9901	1.0050	0.9957	0.9969	0.9786	0.9912	0.9837
1995-2000	0.9947	0.9896	0.9877	1.0057	1.0138	0.9914	1.0166	0.9914	0.9934	0.9913
1981-2000	0.9886	0.9880	0.9813	0.9937	1.0016	0.9959	1.0008	0.9898	0.9895	0.9879

Period	IRL	ITA	JPN	LUX	NLD	NOR	NZL	PRT	SWE	USA
1981-1985	0.9843	0.9834	1.0006	0.9935	0.9838	0.9853	0.9696	0.9551	0.9927	0.9991
1985-1990	0.9905	0.9765	1.0032	1.0021	0.9847	0.9945	1.0209	1.0103	0.9931	0.9965
1990-1995	1.0078	1.0009	0.9764	1.0009	0.9773	1.0156	1.0193	0.9989	1.0033	0.9887
1995-2000	1.0158	0.9924	0.9833	1.0015	0.9978	0.9801	0.9848	1.0178	1.0084	0.9956
1981-2000	1.0004	0.9886	0.9904	0.9998	0.9860	0.9943	1.0002	0.9977	0.9997	0.9948

Note: Efficiency change is the ratio of technical efficiency in period t to technical efficiency in period t-1. A number greater than 1 implies that the efficiency in period t is greater than the efficiency in period t-1 and a number less than 1 is indicative of reduced efficiency.

Appendix 5: Efficiency Rankings of selected OECD countries

Ranking	1981-1985	1986-1990	1991-1995	1996-2000
1	USA	USA	LUX	LUX
2	BEL	LUX	USA	DNK
3	LUX	BEL	DNK	SWE
4	SWE	DNK	SWE	IRL
5	NLD	SWE	IRL	USA
6	CAN	CAN	CAN	CAN
7	DNK	IRL	NOR	NOR
8	IRL	NLD	BEL	NZL
9	FRA	FRA	NZL	FIN
10	NOR	NOR	NLD	NLD
11	AUS	NZL	FRA	PRT
12	AUT	AUT	FIN	FRA
13	GBR	GBR	AUT	AUS
14	NZL	FIN	AUS	GBR
15	FIN	AUS	PRT	BEL
16	GER	GER	GBR	AUT
17	ITA	ITA	GER	ITA
18	PRT	JPN	ITA	GER
19	JPN	PRT	JPN	ESP
20	ESP	ESP	ESP	JPN

Appendix 6: Technical Change of selected OECD Countries

Period	AUS	AUT	BEL	CAN	DNK	ESP	FIN	FRA	GBR	GER
1981-1985	1.0237	1.0280	1.0293	1.0165	1.0193	1.0247	1.0261	1.0301	1.0325	1.0379
1985-1990	1.0263	1.0277	1.0327	1.0170	1.0167	1.0220	1.0264	1.0315	1.0329	1.0366
1990-1995	1.0232	1.0287	1.0321	1.0127	1.0143	1.0183	1.0181	1.0300	1.0270	1.0349
1995-2000	1.0228	1.0287	1.0431	1.0137	1.0111	1.0161	1.0195	1.0265	1.0240	1.0323
1981-2000	1.0240	1.0283	1.0346	1.0149	1.0151	1.0201	1.0223	1.0295	1.0289	1.0353

Period	IRL	ITA	JPN	LUX	NLD	NOR	NZL	PRT	SWE	USA
1981-1985	1.0161	1.0245	1.0324	1.0466	1.0273	1.0287	1.0303	1.0088	1.0228	1.0249
1985-1990	1.0164	1.0270	1.0320	1.0505	1.0277	1.0274	1.0231	1.0110	1.0263	1.0316
1990-1995	1.0183	1.0282	1.0368	1.0505	1.0300	1.0198	1.0128	1.0074	1.0192	1.0292
1995-2000	1.0213	1.0227	1.0373	1.0510	1.0310	1.0204	1.0107	1.0050	1.0153	1.0266
1981-2000	1.0182	1.0257	1.0347	1.0498	1.0291	1.0238	1.0186	1.0080	1.0208	1.0282

Note: A number greater than 1 implies that positive technical change or technological progress in period t relative to period t-1. In terms of percentages, the average annual technical change for Australia (AUS), as an example, in the period 1981-1985 is 2.37 percent.

Appendix 7: Total Factor Productivity Index of selected OECD countries

Period	AUS	AUT	BEL	CAN	DNK	ESP	FIN	FRA	GBR	GER
1981-1985	1.0022	1.0136	1.0271	1.0023	1.0141	0.9887	1.0142	1.0227	1.0209	1.0248
1985-1990	1.0077	1.0181	1.0205	1.0082	1.0079	1.0481	1.0253	1.0285	1.0167	1.0250
1990-1995	1.0200	1.0137	0.9852	1.0027	1.0193	1.0140	1.0149	1.0080	1.0180	1.0180
1995-2000	1.0174	1.0180	1.0302	1.0195	1.0251	1.0073	1.0364	1.0177	1.0172	1.0233
1981-2000	1.0123	1.0160	1.0152	1.0085	1.0167	1.0159	1.0231	1.0190	1.0181	1.0227

Period	IRL	ITA	JPN	LUX	NLD	NOR	NZL	PRT	SWE	USA
1981-1985	1.0001	1.0075	1.0330	1.0397	1.0107	1.0135	0.9990	0.9635	1.0154	1.0240
1985-1990	1.0067	1.0028	1.0354	1.0528	1.0119	1.0217	1.0445	1.0214	1.0192	1.0279
1990-1995	1.0263	1.0291	1.0123	1.0514	1.0066	1.0358	1.0324	1.0064	1.0225	1.0176
1995-2000	1.0375	1.0149	1.0199	1.0526	1.0288	1.0000	0.9953	1.0229	1.0238	1.0221
1981-2000	1.0186	1.0139	1.0247	1.0496	1.0147	1.0180	1.0188	1.0057	1.0205	1.0228

Note: A number greater than 1 implies that positive TFP growth. In terms of percentages, the average annual productivity growth for Australia (AUS), as an example, in the period 1981-1985 is 0.22 percent.

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