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Trade Openness and Aggregate Productive Efficiency

Georgios E. Chortareas[*]
Evangelia Desli[*]
and
Theodore Pelagidis[*]

Abstract

We consider whether openness is related to the aggregate technical efficiency in the OECD countries. We obtain efficiency measures using Data Envelopment Analysis and we find that our measure of openness is positively related to the technical efficiency scores.

** Corresponding author*
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1. Introduction

A widespread conviction shared by policymakers and academics is that, in general, more open economies tend to outperform the closed ones in terms of growth or productivity. For example, Dollar (1992), and Sachs and Warner (1995) find that there exists a positive link between a country's openness and economic growth. This consensus has not remained unchallenged, however. Edwards (1993) surveys the relevant literature and concludes that the studies that relied on cross-country regressions to address this topic suffer from both empirical and conceptual shortcomings. More recently, Rodriguez and Rodrik (1999) review the most influential studies of the 1990s and argue that because of weaknesses of the methodological strategies employed the results are not reliable and open to many alternative interpretations. Other work focuses more explicitly on the relationship between total factor productivity and openness. Coe et al (1997) find that trade openness is positively related to total factor productivity in developing countries. Edwards (1998) examines if trade openness is related to total factor productivity

[*] International Economic Analysis Division Monetary Analysis Bank of England, Threadneedle Street, London EC2R 8AH, UK**Email:** **georgios.chortareas@bankofengland.co.uk**

[*] Lloyd's of London One Lime Street, London, EC3M 7HA,UK, Email: evangelia.desli@lloyds.com

[**] Department of European Studies, Panteion University of Athens, 136 Syngrou Av., 17671 Athens, Greece, Email: pelagidi@panteion.gr

growth using nine different measures of trade policy openness. Six out of the nine measures emerge as positively related to total factor productivity.

In this paper we examine a similar but less explored issue, namely the relationship between openness and the overall productive performance of an economy in terms of technical efficiency. In particular, we examine whether greater openness affects the technical efficiency of economies, as measured by a linear programming technique --Data Envelopment Analysis (DEA). Our results indicate that countries that are more open to the international economy tend to operate closer to their maximum potential output.

2. Literature Review

The relationship between productive efficiency and openness to the international economy should in principle be relatively uncontroversial. The very basic effects of increased trading activity as underlined by A. Smith's work (such as improved labor division, increased specialization, increased market size, and so on) should have apparently positive implications for productive efficiency.

A higher degree of openness implies a more competitive operational environment for the productive units. Firms have to increase their productivity levels to compete with imported goods. Enhanced competition not only forces firms to become more efficient but also drives the weaker competitors –which are probably the least efficient productive units- out of the market. In addition, openness may help to reduce monopolistic phenomena. For example, Hoekman et al (2001) find that the higher the import volume to domestic consumption ratio is the lower the industry markups are.

The new endogenous growth models (e.g., Romer, 1986, Lucas, 1988) provide another plausible channel through which trade openness may affect efficiency and growth. In endogenous growth models technology accumulates through domestic innovation and international technology diffusion. The growth rate of innovation depends typically on the level of human capital and the initial technology stock. For international technology diffusion and flow of ideas and know-how to take place, however, openness is a necessary prerequisite. In Lucas' (1988) model the differences in the rate of growth across countries can be explained by the differential degree of leaning across sectors within a given economy. The specialization of a country in activities implied by the initial endowments should be reinforced by the degree of learning that takes place in the specialized sector. Romer (1990, 1993), Grossman and Helpman (1991), and Aghion and Howitt (1998) further suggest that activities such as research and development (R&D) explicitly give rise to innovations which contribute to economic growth. Such innovations, however, should give a parallel boost to efficiency. Openness may influence either the rate of innovation or the rate of adoption of existing technologies. Thus, spillover opportunities emerge through which domestic firms can gain access to improved technology at less than full cost. Imports in this context are an important channel for technology diffusion since they allow access to foreign products that embody new technology. Of course, such spillovers may refer to other factors besides technology, such as managerial skills. In general, openness affects the cross-border flow of knowledge and knowledge in turn affects productivity and efficiency. For example, Coe and Helpman (1995) find that there is a positive link between R&D activities and total factor productivity in the OECD countries. In addition Tybout (2000) finds that firms that are export-oriented are more productive than those targeting the domestic market. Of course such results may need further robustness checks since they may be due to self-selection behavior by firms. While the effects mentioned above have their "first-order" effects on intra-industry trade and initially affect the traded-goods sector, the diffusion of knowledge and the competitive effects spillover to the non-traded goods sector as well.

Evidence exists that increased openness results to increased manufacturing efficiency. For example Tybout (2001) finds that foreign competition improves manufacturers efficiency. Other studies use a more explicit technical efficiency analysis framework to consider the effects of openness. Karunaratne (2001), for example, uses a stochastic production frontier model to consider how trade reforms may have affected technical efficiency in Australian manufacturing. Such attempts, however, are focused on single countries emphasizing the regional or sectoral aspects of efficiency. Very little research exists, however, on the relationship between openness and aggregate productive efficiency measures derived from DEA or stochastic frontier analysis. An exception is Chortareas and Desli (1999) who consider cross-country evidence covering a global sample.

In this paper we use a framework that allows evaluating the performance of production units on the basis of their inputs and outputs. The methodology that we employ broadly relies on using Farrell's (1957) radial measure of efficiency for an individual production unit, measured by the equal proportional reduction in used input levels to produce predetermined levels of output. The units can be evaluated either in terms of their ability to minimise input usage in the production of given outputs, or to maximise output production with given inputs, relative to the observed performance of other production units in some comparison set. This can be empirically implemented either in a non-parametric, non-stochastic mathematical programming framework or in a parametric, stochastic, statistical framework.[1] In this paper we chose to use the linear programming technique, known as Data Envelopment Analysis[2] to obtain efficiency scores of aggregate efficiency. Other work that uses DEA to rank the productive performance of entire nations includes Land et. al. (1994), Fare et. al. (1994), and Ray and Desli (1997).

3. Methodology and Data

Methodology

The use of DEA allows evaluating the relative technical efficiency (TE) of comparable decision making units essentially performing the same task. Based on information on the performance of the units and some preliminary assumptions on the production technology, DEA allows us to empirically characterize the efficient frontier based on the set of available observations and to project all the observed points radially to this frontier. The efficient frontier, derived from the examples of best practice contained in the data that are considered, represents a standard of performance that the units not on the efficient frontier should try to achieve. If a

[1] For a survey of the techniques see Lovell (1993).

[2] This methodology was originally developed by Charnes et. al. (1978) and extended by Banker et. al. (1984).

decision making unit is on the frontier, it is referred to as an efficient unit, otherwise it lies below the frontier and it is referred as an inefficient unit. By projecting each unit onto the frontier, it is possible to determine the level of inefficiency by comparison to a single reference unit or to a convex combination of other reference units. The projection refers to a virtual efficient decision making unit that is a non-negative linear or convex combination of one of more efficient decision making units. Thus, the projected point may not itself be an actual decision making unit. Overall technical (in)efficiency is the discrepancy between the observed position of a decision making unit and the corresponding virtual efficient decision making unit and it is measured by the radial distance of the observed input-output bundle from the frontier. Thus, if a decision making unit lies on the frontier (i.e. it is efficient) then it is assigned a technical efficiency value equal to one (TE=1). Otherwise, if a decision making unit lies below the frontier (i.e. it is inefficient) then it is assigned a technical efficiency value less than one (TE<1).

First one needs to specify the production technology, which can be completely characterised by the production possibility set

$P(x, y) = \{(x,y)\text{: } y \text{ can be produced from } x\}$.

Additionally, we assume that the production possibility set satisfies the assumptions that all observed input-output bundles are feasible, there is free disposability of inputs and output and finally it is convex. More formally those assumptions can be written as follows:

(i) Feasibility: $(x_i,y_i) \in P(x,y)$ for every decision making unit *i*,

(ii) Free input disposability: if $(x^0, y^0) \in P(x,y)$ and $x^1 \geq x^0$ then $(x^1, y^0) \in P(x,y)$,

(iii) Free output disposability: if $(x^0, y^0) \in P(x,y)$ and $y^1 \geq y^0$ then $(x^0, y^1) \in P(x,y)$,

(iv) Convexity: if $(x^0, y^0) \in P(x,y)$ and $(x^1, y^1) \in P(x,y)$ then $\left(\lambda x^0 + (1-\lambda)x^1, \lambda y^0 + (1-\lambda)y^1\right) \in P(x,y)$ for $\lambda>0$,

where the vectors x^i and y^i represent, respectively, the input and output bundles of the *i*-th decision-making unit. Following Afriat (1972), the production possibility set (i.e. input-output correspondence) for an industry with *n* decision making units producing a vector of *M* outputs, $y=(y_1, y_2, \ldots, y_M)$, from a vector of *K* inputs, $x=(x_1, x_2, \ldots, x_K)$ is defined as:

$$P(x,y) = \{ (x,y) : y \leq \sum_{i=1}^{n} \lambda_i y^i, \ x \geq \sum_{i=1}^{n} \lambda_i x^i, \ \sum_{i=1}^{n} \lambda_i = 1, \ \lambda_i \geq 0; \ i = 1, 2, \ldots, n \} .$$

The convexity constraint ($\sum_{i=1}^{n} \lambda_i = 1$) allows for variable returns to scale to be exhibited by the data. If the constant-returns-to-scale assumption is considered more appropriate then, this constraint should be omitted. This representation of the production possibility set allows for multiple inputs and multiple output combinations to be taken into account. Note, that no assumptions are made on the functional form of the production technology and no statistical assumptions on the distribution of the deviations from the frontier. The Farrell (1957) output measure of technical efficiency (TE) for any particular decision-making unit "0" is given by

$$TE_0 = TE(x^0, y^0) = 1/\max\{\phi : (x^0, \phi y^0) \in P(x,y)\},$$

and it can be calculated as the solution to the DEA output-oriented model under the assumption of variable returns to scale:

$$\max \varphi$$

$$s.t. \sum_{i=1}^{n} \lambda_i y_m^i \geq \varphi y_m^0; \text{ for } m = 1,2,\ldots,M$$

$$\sum_{i=1}^{n} \lambda_i x_k^i \leq x_k^0; \text{ for } k = 1,2,\ldots,K$$

$$\sum_{i=1}^{n} \lambda_i = 1;$$

$$\lambda_i \geq 0 \quad \textit{for } i = 1,2,\ldots,n,$$

where n is the number of decision making units in the sample, M and K is the number of outputs and inputs respectively.

The model can be interpreted as follows. Any particular decision making unit "0" has the latitude to choose the set of weights that maximise its efficiency relative to other decision making units of the sample provided that no other decision making unit or convex combination of decision making units could produce higher level of output(s) without using any more input or reducing other outputs for the case that more than one output is considered. The solution to the above linear programming, $\phi_0 = \max\{\phi : (x^0, \phi y^0) \in P(x,y)\}$, refers to the amount of maximum possible proportional expansion in the vector of output y^0 while maintaining the same level of inputs x^0. This increase is applied simultaneously to all outputs -if there are more than one- and results in a radial movement toward the frontier. The resulting $\phi_0\, y^0$ level of output(s) is the optimum level of output(s) that the virtual efficient decision making unit could achieve. The technical (in)efficiency for the output oriented DEA is defined as the inverse of the scale parameter, ϕ_0:

$$TE_0 = \frac{1}{\varphi_0}.$$

If the productive unit is efficient then the parameter used to scale up the outputs, φ_0, takes the value of one. It should be emphasised that a linear program of this form must be solved for each of the decision-making units.

To obtain country specific efficiency DEA results we construct a world production frontier for every year in our sample over the period 1970-1990. The estimation of separate frontiers for every year is necessary in order to take into account the technological changes that took place over the studied period and they affect the productive efficiency. Thus, for every year, t, we solve one DEA linear program for each country using only the observations from this particular year, i.e. for country "0" during year t we solve

$$
\begin{aligned}
& \max \varphi \\
s.t. & \sum_{i=1}^{n} \lambda_i GDP_t^i \geq \varphi GDP_t^0; \\
& \sum_{i=1}^{n} \lambda_i L_t^i \leq L_t^0; \\
& \sum_{i=1}^{n} \lambda_i K_t^i \leq K_t^0; \\
& \sum_{i=1}^{n} \lambda_i = 1; \\
& \lambda_i \geq 0 \quad \text{for } i = 1,2,...,n.
\end{aligned}
$$

where *GDP* is the aggregate output and *L* and *K* are the inputs. Thus, the estimated technical efficiency varies across time for every country.

Data

We consider a sample of 26 OECD countries over the period 1970-1979 and 27 OECD countries over the period 1980-1990. The OECD countries for which the necessary data were available for the period 1970-1990 were Australia, Austria, Belgium, Canada, Denmark, Finland, France, West Germany, Greece, Iceland Ireland, Italy, Republic of Korea, Luxemburg, Mexico, Netherlands, New Zealand, Norway, Portugal, Spain, Sweden, Switzerland, Turkey, U.K., and USA. Additionally we include Poland for the period 1980-1990 only. The data are obtained from the Penn World Tables (mark 5.6). The procedures used to construct the data are discussed in Summers and Heston (1991). We use gross domestic output (GDP) as our measure of aggregate output, employment (L) and capital stock (K) as our aggregate inputs, and the openness indicator is exports plus imports as percentage of real GDP. GDP and capital stock are measured in constant 1985 international prices. GDP is obtained using the per capita real GDP, employment is calculated from the real GDP per worker and capital stock is obtained form the capital stock per worker.

4. Results and Discussion

Obtaining technical efficiency scores for our sample countries is the first step of our analysis. The next step is to consider how technical efficiency is influenced by the external-operating environment, i.e., how openness affects efficiency. That is we adopt a “two-stage” approach that uses data on outputs and inputs in the first stage, and data on observable environmental variables in the second stage to determine their impact on efficiency. The regression analysis in the second step allows capturing the systematic effect of the operating environment on efficiency in terms of both sign and significance. It should be noted that a frequently used alternative approach is an “all-in-one-stage” model that includes environmental variables along with data on outputs and inputs. In our case, however, this would require to classify openness as an input or an output prior to the analysis and thus it is unsuitable since we want to test whether a particular feature of the operating environment is conducive to productive efficiency or not.

We first provide some summary results from the DEA analysis. Table 1 shows the technical efficiency score for each country averaged for the period 1970-1990 as well as average openness for the same period. As is typical with DEA the extremely small units tend to be among the highly efficient ones, thus the high scores of Iceland and Luxembourg. The US emerges as a “benchmark” country, which is again a typical result for the relative large-output units in efficiency analysis studies. The low degree of openness of the US is not a surprise either, but what is interesting is that this combination of high efficiency and relatively closed economy is an outlier to the regression results that we obtain.

Table 2 shows the cross-sectional average technical efficiency score and average openness, of all the countries considered, for each year in our sample. In addition, we provide the correlation coefficient between the two variables, which reveals an interesting pattern. In particular, the correlation coefficient falls from 1973 to 1976, as compared to the earlier yeas. After then, however, there is a strong rising pattern until the end of period considered.

The basic results that correspond to the second stage of our analysis, i.e., from regressions of the aggregate productive efficiency on the degree of trade openness, are provided in Table 3. This Table shows the cross-country regression results for each year. The coefficient of openness is almost always statistically significant (with the exception of the period 1974-1976) and displays the hypothesized positive sign. The only exceptions to this general picture are the regressions for the years 1975 and 1976, where the openness coefficients display negative signs, but they are not statistically significant. Moreover the magnitude of the openness coefficient displays an increasing trend over time. That is, the effect of trade openness on productive efficiency becomes increasingly important. On the contrary the magnitude of the constant, which captures other factors that affect productive efficiency, seems to be at lower levels in the 1980s as compared to the 1970s. Finally, the last row of Table 3 shows the results when we run all our data as a panel and they corroborate the basic result of the cross-country regressions. That is, the openness coefficient is positive and statistically significant. The magnitude of the openness coefficient is in general lower than that emerging from the cross-country regressions during the 1980s, but this may be because of the variability of those coefficients during the 1970s. The fit of the regression is always very high.

How do those results to fit the current state of the inquiry in the effects of trade openness on countries’ economic performance? Of course, the dependant variable in the existing literature is usually growth, or total factor productivity, rather than technical efficiency, but technical efficiency is itself a ratio of two total factor productivity measures, one being the actual and the other being the optimal benchmark. One could classify the existing studies into three strands, an “optimistic, a “sceptical”, and an “agnostic”. The optimistic camp finds evidence for a positive relationship between trade openness (defined either as trade intensities or trade policies) and economic growth and to a great extend constitutes the conventional wisdom. Such studies include Sachs and Warner (1995), Frankel and Romer (1999), Edwards (1998), and so on. Sachs and Warner (1995) suggest that trade openness is a sufficient condition for achieving higher-than-average growth by poorer countries. Frankel and Romer (1999) after correcting for the possibility of simultaneity between growth and trade, by using instruments that reflect geographical features, find that the effect of openness on growth is even stronger than in the traditional

OLS regressions. More recently, however, this conventional wisdom has been scrutinized both in terms of data quality and in terms of cross-country regressions robustness. Rodriguez and Rodrik (1999) conclude that the systematic evidence in favor of trade openness has been overstated. Finally, a number of studies, such as Dollar and Kraay (2002) take a slightly agnostic view suggesting that either the current tools of analysis or the measures of openness at hand are far from adequate for providing a confident answer to the question of how trade openness affects growth.

The results of our analysis tend to be more consistent with the optimistic camp, since we are able to uncover a statistically significant relationship between the degree of trade intensity and the aggregate level of technical efficiency in the OECD countries. On should be careful, however, in interpreting those results for policy purposes. Our results, for example, may not be directly comparable with those of studies that focus on the openness-total factor productivity relationship. Here we consider technical efficiency, which is practically the ratio of total factor productivity to an optimum total factor productivity benchmark. Thus when we test for the effects of openness we don't explicitly distinguish how it affects the numerator and the denominator. In addition, it would be misleading to suggest that that growth and technical efficiency should necessarily be expected to move the same direction. One should rather expect changes in technical efficiency to do so.

Finally, we should discuss the openness measure we employ. Typically, empirical studies that examine the role of openness in affecting growth typically employ two different types of openness measures. The first type represents trade intensities and the most typical of those measures is the ratio of imports and exports to the GDP. The second type of measures includes various "policy openness" measures (e.g., as in Sachs and Warner, 1995). The survey on openness and growth by Edwards (1993), for example, covers studies that use this kind of measure. We use a trade-volume or trade-intensity based index of openness for many reasons. First, while the use of a trade intensity openness measure may be questionable when one focuses on its effect on growth because of the potential endogeneity problem (that is, exports and imports are components of GDP), our approach is immune to such an endogeneity problem because we focus on efficiency ratios. Second, the choice of one or another index of policy openness is highly subjective. Third, since all the countries we consider are OECD members there is relatively little variation in the degree of policy openness that characterises them.[3]

5. Conclusion

We examine a relatively unexplored issue, namely the relationship between openness and the overall productive efficiency performance. In particular, we consider whether greater openness in the form of trade intensities affects the technical efficiency of economies, as measured by a linear programming technique --Data Envelopment Analysis (DEA). We focus on the OECD countries for the period 1970-1990. Our results indicate that countries that are more open to the international economy tend to operate closer to their maximum potential output as

[3] For example in the binary openness measure of Sachs and Warner (1995) all our sample countries are defined as open.

this emerges from assessing the relative efficiency performance of the economies in our sample.

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Table 1

Country	Average TE	Average OPEN
Australia	84.28	32.14
Austria	77.71	70.51
Belgium	82.31	126.81
Canada	90.09	49.67
Switzerland	89.68	69.90
Germany West	79.60	50.95
Denmark	70.31	64.00
Spain	89.74	34.87
Finland	66.49	55.32
France	82.78	41.08
Greece	61.68	45.48
Ireland	78.56	104.03
Iceland	100.00	75.18
Italy	84.62	41.95
Japan	64.75	23.25
Korea Rep.	67.73	64.51
Luxembourg	100.00	182.11
Mexico	94.74	22.87
Netherlands	88.97	98.20
Norway	76.53	84.63
New Zealand	80.43	56.44
Poland	52.91	40.33
Portugal	97.78	66.40
Sweden	78.42	59.32
Turkey	83.64	28.05

U.K.	99.70	52.54
U.S.A.	100.00	17.51

Table 2

Year	Average TE	Average OPEN	Correlation (TE, OPEN)
1970	84.72	53.14	0.0886
1971	84.62	52.66	0.0841
1972	83.62	51.63	0.0728
1973	83.04	55.53	0.0442
1974	84.65	62.63	0.0473
1975	85.74	58.11	0.0311
1976	85.06	59.11	0.0472
1977	83.24	59.46	0.1198
1978	82.14	58.16	0.1750
1979	82.84	62.22	0.2002
1980	83.48	65.05	0.1556
1981	81.28	65.92	0.1690
1982	84.18	64.72	0.2129
1983	82.58	65.35	0.2655
1984	80.91	69.29	0.2562
1985	81.14	69.85	0.2497
1986	81.14	63.66	0.2636
1987	81.09	63.59	0.2302
1988	80.89	64.47	0.2273
1989	81.61	66.09	0.2550
1990	82.90	65.24	0.2654

Table 3

	Constant	Std. Error	Openness	Std. Error	R^2
1970	0.8294 *	0.0090	0.0190 *	0.0258	0.998792
1971	0.8071 *	0.0080	0.0833 *	0.0178	0.999965
1972	0.8077 *	0.0061	0.0707 *	0.0149	0.999539
1973	0.8142 *	0.0014	0.0260 *	0.0024	0.999935
1974	0.8420 *	0.0037	-0.0009	0.0086	0.999946
1975	0.8660 *	0.0079	-0.0240	0.0189	0.99698
1976	0.8499 *	0.0019	0.0009	0.0047	0.999458
1977	0.8103 *	0.0028	0.0222 *	0.0080	0.999686
1978	0.7878 *	0.0034	0.0499 *	0.0072	0.99938
1979	0.7837 *	0.0032	0.0728 *	0.0078	0.999932
1980	0.8075 *	0.0095	0.0546 *	0.0075	0.998199
1981	0.7836 *	0.0035	0.0418 *	0.0056	0.999971
1982	0.8043 *	0.0028	0.0593 *	0.0045	0.999949
1983	0.7791 *	0.0036	0.0717 *	0.0057	0.999978
1984	0.7502 *	0.0012	0.0874 *	0.0020	0.999526
1985	0.7594 *	0.0008	0.0779 *	0.0016	0.999952
1986	0.7677 *	0.0060	0.0807 *	0.0129	0.998736
1987	0.7576 *	0.0028	0.0901 *	0.0065	0.999953
1988	0.7685 *	0.0039	0.0655 *	0.0053	0.999352
1989	0.7668 *	0.5674	0.0800 *	0.0072	0.996754
1990	0.7774 *	0.5296	0.0930 *	0.0063	0.995098
Pooled Data: 1970-1990	0.8165 *	0.0034	0.0267 *	0.0056	0.97857

* significant at 5% level of significance.