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# **Measuring trade efficiency**

by

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## **Abstract**

*In this paper we use the Data Envelopment Analysis (DEA) window method to compare trade efficiency for 16 OECD countries and for the time period 1996–2000. From the analysis we obtained the efficiency scores and the optimal output levels for inefficient countries for all years under consideration. Results drawn from the broadly used ratio analysis were also compared to those derived from the DEA model. It seems that trade efficient countries have clear characteristics. These are the low exchange rates for exports, low R&D intensity, high value intra industry trade, and with positive effect of trade on their GDP.*

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**JEL Classification:** F1, O1

**Keywords:** DEA, development, OECD countries, trade efficiency, window analysis

## I. Introduction

In this paper we use Data Envelopment Analysis (hereafter DEA) window method to compare trade efficiency for 16 OECD countries and for the time period 1996–2000. For this reason we use for the first time in this type of formulation a number of ratios. Namely, we use and construct indicators for the Research and Development intensity of each country in terms of production, the value added shares from the manufacturing sector relative to the total economy, the intra industry trade, the net trade to GDP and the exchange rates. From the analysis we obtained the efficiency scores and the optimal output (ratios) levels for inefficient countries for all the five years under consideration. Results drawn from the broadly used ratio analysis were also compared to the results derived from the DEA window model.

The paper is organized as follows. In section II the technique adopted both in its theoretical and mathematical formulation is presented. Section III discusses the ratios used in the formulation of the proposed model. In section IV the empirical findings of our study are presented. The final section concludes the paper discussing the derived results and the implied policy implications.

## II. The proposed model

Consider  $N$  DMUs (in our case 16 OECD countries), each producing  $m$  products using  $n$  inputs. Efficiency is measured as:

$$f_k = \frac{\sum_{i=1}^m b_{ik} y_{ik}}{\sum_{j=1}^n c_{jk} x_{jk}} \quad (1)$$

Where  $y_{ik}$  ( $>0$ ) is the amount of output  $i$  by the  $k$ th DMU,  $x_{jk}$  ( $>0$ ) is the amount of input  $j$  used by the  $k$ th DMUs,  $b_{ik}$  and  $c_{jk}$  are the output and the input respectively. The efficiency ratio (1) is maximised subject to the constraints:

$$\sum_{i=1}^m b_{ik} y_{ik} / \sum_{j=1}^n c_{jk} x_{jk} \leq 1 \quad \text{for } k = 1, \dots, N \quad (2)$$

and 
$$b_{ik}, c_{jk} \geq 0 \quad (3)$$

According to the first inequality the efficiency ratios cannot exceed one, while according to the second the weights are positive and are determined by DEA in such a way as each DMU maximises its own efficiency ratio.

The problem can be formulated as an ordinary linear program. That is:

$$\text{Maximize } f_k = \sum_{i=1}^m \left( \frac{1}{\sum_i c_{ik} x_{il}} b_{ik} \right) y_{ik} \quad (4)$$

subject to 
$$\sum_{i=1}^m \left( \frac{1}{\sum_i c_{ik} x_{il}} b_{ik} \right) y_{ik} - \sum_{j=1}^n \left( \frac{1}{\sum_j c_{jk} x_{jl}} c_{jk} \right) x_{jk} \leq 0 \quad (5)$$

$$\sum_{j=1}^n \left( \frac{1}{\sum_j c_{jk} x_{jl}} c_{jk} \right) x_{jk} = 1 \quad (6)$$

and 
$$\left( \frac{1}{\sum_i c_{ik} x_{il}} b_{ik} \right) \geq 0, \left( \frac{1}{\sum_j c_{jk} x_{jl}} c_{jk} \right) \geq 0 \quad (7)$$

The corresponding dual problem can be expressed as:

$$\text{Minimize } \theta_k - \tau \left( \sum_{i=1}^m s_{ik}^+ + \sum_{j=1}^n s_{jk}^- \right) \quad (8)$$

subject to 
$$\sum_l \lambda_{kl} y_{il} - y_{il} - s_{ik}^+ = 0 \quad i = 1, \dots, m \quad (9)$$

$$\theta_k x_{jk} - \sum_l \lambda_{kl} x_{jl} - s_{jk}^- = 0 \quad j = 1, \dots, n \quad (10)$$

$$\lambda_{kl}, s_{lk}^+, s_{jk}^- \geq 0 \quad (11)$$

By linear programming duality theory, the optimal value of  $\theta_k$  (the overall technical efficiency) equals the optimal value of  $f_k$  ( $\theta_k$  lies between zero and one). In (8),  $\tau$  represents an arbitrarily small positive number and ensures that the optimal solutions are at finite non-zero external points and that the optimal solutions are at finite non-zero extremal points. It also ensures that the slack in input  $j$  does not affect the optimal value of  $f_k$ .

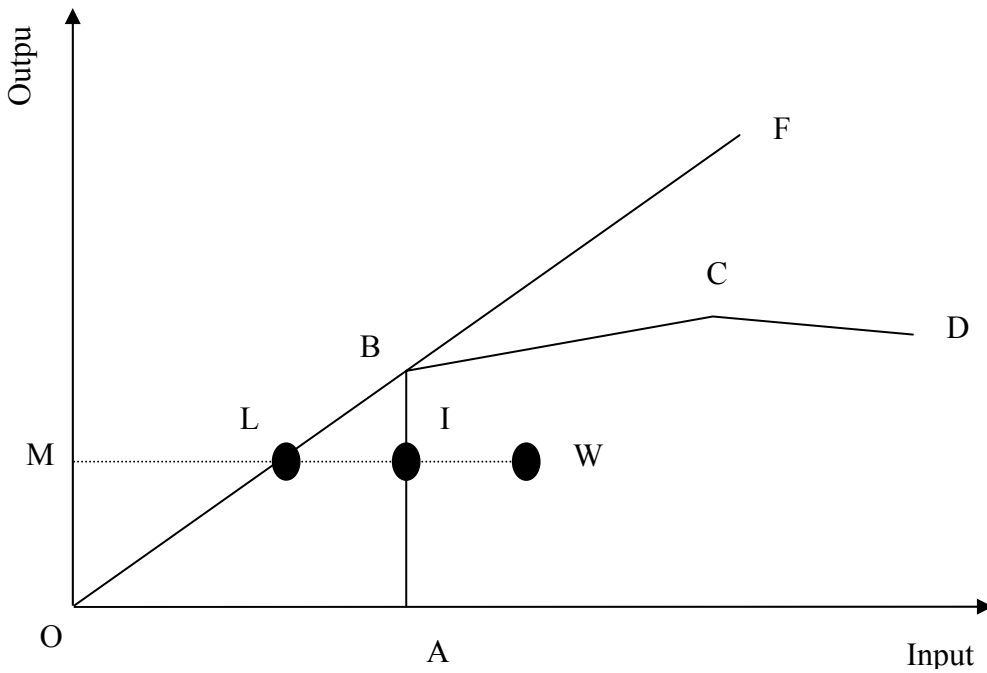
Technical efficiency is achieved only when  $\theta_k=1$  (ensuring that DMUs is on the frontier) and  $S_{lk}^+ = S_{jk}^- = 0$  (excluding external points). An inefficient DMU can become efficient by adjusting output and inputs as follows:

$$y_{lk}^* = y_{lk} + s_{lk}^+ \quad (12)$$

and

$$x_{jk}^* = \theta_k x_{jk} - s_{jk}^- \quad (13)$$

Figure 1: DEA output-input frontier



The problem in (8) through (11) assumes constant returns to scale (CRS). Figure 1 illustrates the approach using one output and one input. The frontier OF is the solution of the formulated problem in (8)-(11). Countries on the frontier have an efficiency score of one. Countries located inside the frontier have an efficiency score of less than one. For example, country *s* located at point W is inefficient, and the overall technical efficiency is measured by the ratio  $ML/MW$ .

The overall technical efficiency can be broken into pure technical and scale efficiency. To do that we solve the above linear programming problem with the additional restriction that

$$\sum_l^N \lambda_{lk} = 1 \quad (14)$$

which allows for variable returns to scale (VRS). In figure 1, the VRS case is represented by the ABCD frontier. The pure technical efficiency of country *s* located at point W is given by the ratio  $MI/MW = \kappa_s$ . The degree of scale efficiency is computed as  $\zeta_s = \theta_s / \kappa_s$ . By construction  $\kappa_s$  exceeds  $\theta_s$ . If the value of  $\zeta_s$  is one the country is scale efficient. If scale inefficiency exists, it can be due to either increasing or decreasing returns to scale (IRS or DRS). To differentiate IRS from DRS, we solve again the same linear programming problem with the additional restriction of

$$\sum_l^N \lambda_{lk} \leq 1 \quad (15)$$

which allows for non-increasing returns to scale (NIRS). In figure 1, this case is represented by the OBCD frontier. For country *s* located at point W, the efficiency is given by  $\phi_s = ML/MW$ , which also equals  $\theta_s$ . By construction,  $\phi_s \geq \theta_s$  and  $\phi_s \leq \kappa_s$ , if  $\phi_s = \kappa_s$  and scale inefficiency exists, then it is due to decreasing returns to scale. If  $\kappa_s \neq \phi_s$ , then the scale inefficiency is due to increasing returns to scale (Halkos and Salamouris, 2004).

The DEA model illustrated above has been introduced by Charnes et al. (1978); however a variation of this model will be used based on moving averages introduced by Charnes et al. (1985). The use of this variation is due to its ability to handle multiple outputs and inputs and their efficiencies over time (Charnes et al. 1994). Asmid et al. (2004), highlight the fact that there are no technical changes within each of the windows because all DMUs in each window are measured (compared) against each other and suggest that in order for the results to be credible a narrow window width must be used. Adopting the formalization by Asmid et al. (2004) consider the  $N$  DMU's ( $n=1, \dots, N$ ) observed for  $T$  periods ( $t=1, \dots, T$ ) using  $r$  inputs and  $s$  outputs. So this will create a sample of  $N \times T$  observations where an observation  $n$  in period  $t$ , ( $DMU_t^n$ ) has an  $r$  dimensional input vector

$$x_t^n = (x_{1t}^n, x_{2t}^n, \dots, x_{rt}^n)' \text{ and an } s \text{ dimensional output vector } y_t^n = (y_{1t}^n, y_{2t}^n, \dots, y_{st}^n)'.$$

Then a window  $k_w$  with  $k \times w$  observations is denoted starting at time  $k$ ,  $1 \leq k \leq T$  with width  $w$ ,  $1 \leq w \leq T - k$ . So the matrix of inputs is given as:

$$X_{kw} = (x_k^1, x_k^2, \dots, x_k^N, x_{k+1}^1, x_{k+1}^2, \dots, x_{k+1}^N, x_{k+w}^1, x_{k+w}^2, \dots, x_{k+w}^N)$$

and the matrix of outputs will be:

$$y_{kw} = (y_k^1, y_k^2, \dots, y_k^N, y_{k+1}^1, y_{k+1}^2, \dots, y_{k+1}^N, y_{k+w}^1, y_{k+w}^2, \dots, y_{k+w}^N)$$

The output oriented DEA window problem for  $DMU_t'$  under the CRS assumption is given by solving the linear program illustrated below:

$$\begin{aligned} & \max_{\theta, \lambda} -\theta \\ & s.t. \\ & -X_{kw}\lambda + \theta x_t' \geq 0 \\ & Y_{kw}\lambda - y_t' \geq 0 \\ & \lambda_n \geq 0, (n = 1, \dots, N * w) \end{aligned} \tag{16}$$

### III. Data

Using data for 16 OECD countries (Table 1) from “Bilateral Trade Database”<sup>1</sup> and for a time span of five years (1996-2000) a number of ratios were constructed and are used in our empirical analysis.

Table 1: Description and variable codes.

Code	Country Name	Code	Country Name	Variables	Variable name
<i>AUS</i>	Australia	<i>ITA</i>	Italy	<i>IIT</i>	Intra Industry Trade
<i>BEL</i>	Belgium	<i>JPN</i>	Japan	<i>VASH</i>	Value Added Shares
<i>CAN</i>	Canada	<i>NLD</i>	Netherland	<i>RDIP</i>	R&D Intensity
<i>DEN</i>	Denmark	<i>NOR</i>	Norway	<i>EXCR</i>	Exchange rates for exports
<i>FIN</i>	Finland	<i>ESP</i>	Spain		
<i>FRA</i>	France	<i>SWE</i>	Sweden		
<i>DEU</i>	Deutschland	<i>GBR</i>	Great Britain	<i>NTGDP</i>	Net trade of total goods and services as a percentage of GDP
<i>IRL</i>	Ireland	<i>USA</i>	United States		

Specifically, the first ratio is an indicator showing the R&D intensity of each country in terms of production (**RDIP**). That is:

$$RDIP^k = \frac{ANBERD^k}{PROD^k} * 100 \quad (17)$$

Where *ANBERD* and *PROD* are business enterprise Research and Development and production at current prices respectively. For each country this indicator expresses the R&D expenditures by the total manufacturing sector relative to the production.

This ratio was constructed in order to approach the concern of a country to deal with technological developments and the speed with which the country adapts them.

The second ratio shows the value added shares from manufacturing sector relative to the total economy (**VASH**). That is

$$VASH_i = \left[ \frac{VALU_i^K}{VALU_{total}^K} \right] * 100 \quad (18)$$

Where **VALU** is the value added at current prices. For a given country, this indicator shows the value added contributed by manufacturing sector relative to total value added for all



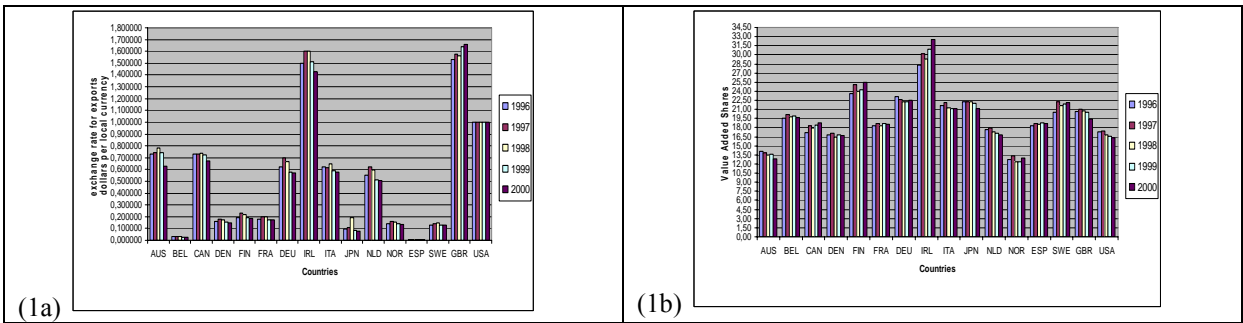
industries. The valuation of value added differs among countries and may therefore influence the interpretation of this indicator. Value added is measured at basic prices for all countries except JAPAN and the USA, which are used in producer or market prices.

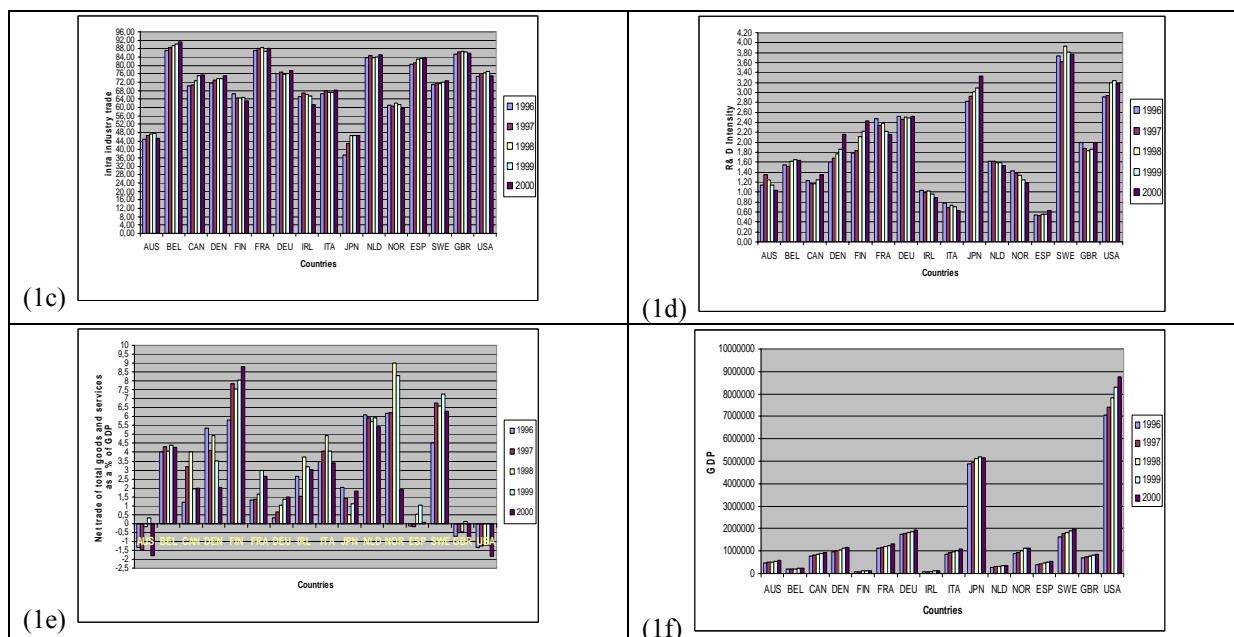
The third indicator shows the intra industry trade (**IIT**). This aspect of the structure of international trade has not received much attention in the existing trade performance literature. In our construction it is expressed as:

$$IIT_{tot.manuf.}^k = \left[ 1 - \frac{\sum_i (EXPO_i^k - IMPO_i^k)}{\sum_i (EXPO_i^k + IMPO_i^k)} \right] * 100 \tag{19}$$

where **EXPO** and **IMPO** are the total exports and imports of goods at current prices. Intra industry trade is the value of total trade remaining after subtraction of the absolute value of net exports and imports of manufacturing industry. For comparison, between countries this measure is expressed as a percentage of manufacturing industry’s combined exports and imports. This index ranges from 0 to 100. If a country exports and imports roughly equal quantities of certain products, the **IIT** index is high. If trade is mainly one-way (whether exporting or importing), the **IIT** index is low.

Figure 2: (a) Exchange rate for exports; (b) Value added shares; (c) Intra-Industry Trade; (d) R&D Intensity; (e) NTGDP; (f) GDP.





Furthermore, the ratio **NTGDP** has been constructed in order to indicate the contribution of net trade to GDP of each country. That is:

$$NTGDP = [(Exports\ of\ commodities - Imports\ of\ commodities) / GDP] * 100 \quad (20)$$

Finally, an indicator of the exchange rate for exports for each country (dollars per local currency) **EXCR** has been used.

#### IV. Empirical Results

Using a conventional ratio analysis as presented graphically in Figure 1a-f different conclusions can be derived looking at the countries from six different measurement perspectives. For instance looking at the performance of the exchange rate for exports and in the case of Great Britain (Figure 1a) an increase over the five years can be observed. Furthermore, the prices of the exchange rate for exports for Great Britain are significantly higher compared to other countries. The main reason behind this may be attributed to the fact that Great Britain has a “strong” currency.

Significantly different is the performance of the *EXCR* of Ireland compared to other countries. Additionally, Ireland has a significant higher index price (Figure 1b) in terms of the

value added contributed by manufacturing sector relative to total value added for all its industries, while Norway has the lowest compared to the other countries.

Figure 1c, illustrates the intra industry trade of manufacturing for each country over the years. Australia and Japan have the lowest performance in terms of exports and imports at current prices. The highest price is observed for Belgium, France, Great Britain, the Netherlands and Spain. Moderate, trade performance has been noticed for the USA, Canada, Denmark and Sweden.

Looking at figure 1d the performance of countries in terms of their R&D expenditure over the five years time period can be observed. We notice that Sweden, Japan and the USA have a significant higher performance in terms of R&D expenditure compared to the other countries. A medium performance is highlighted for Germany, France, Finland and Great Britain. The lowest performance has been noticed for Spain and Italy. Figure 1e indicates the net trade of commodities as a percentage of GDP. Observing the performance of countries we realize that Finland, Norway, Sweden and the Netherlands have the highest contribution to their GDP from trade, whereas Australia, Great Britain and the USA have a negative contribution. In the case of Norway the first 4 years present a tremendous increase of trade as its economy was based mainly on exports, while an even greater reduction for net trade performance for the last year under consideration can be noticed.

Finally, all the above conventional analysis must be viewed and compared along with the last graph illustrated in figure 1f in order to have a clear view of trade efficiency and its impact on economic development for the countries examined. That is, Figure 1f illustrates GDP at current prices over the years.

Using conventional ratio analysis shows us the performance of the countries under review but from (in our case) six different angles. However, it is difficult to have a clear view of countries' trade efficiency, even though the observations through the ratios give us detailed

insights of the factors that affect trade efficiency. In order to overcome the problem of “multiple views” we use DEA modeling to observe trade efficiency in terms of a number of inputs and outputs, which will provide us with a unified and simultaneous picture of trade efficiency among the countries considered.

To perform an analysis focusing interest on changes in efficiency over time DEA window analysis may be used. In such a case moving average analogue can be applied in order to perform DEA overtime. DMUs in each period are treated as if they were different DMU. A DMU’s performance in a particular period is contrasted with its performance in other periods in addition to the performance of the other DMUs.

In our case the DMUs are the OECD countries ( $n=16$ ) over five years period ( $p=5$ ) and we proceed our analysis by using a three –year ( $w=3$ ) window. Each DMU (country) is represented as if it was a different DMU for each of the three years in the first window (Years 1, 2 and 3). An analysis of the 48 ( $nw = 3 \times 16$ ) DMUs is taking place. The window is then moved one period by replacing Year 1 with Year 4, and an analysis is performed on the second three year set (Years 2, 3 and 4) of these 48 DMUs. The process continues moving the window one period and concluding with the final (third) analysis of 48 DMUs for the last three years (Years 3, 4 and 5). This procedure implies  $p-w+1$  separate analyses, where each analysis examines  $n*w$  DMUs.

Table 2a illustrates the results of the analysis in the form of overall efficiency and pure technical efficiency while Table 2b presents the scale efficiency scores for the performance of the 16 OECD countries considering the VASH, RDIP and EXCR as inputs and the IIT and NTGDP ratios as outputs. The underlying framework of the window analysis is illustrated on this table. For the first window, Australia (AUS) is represented in the constrains of the DEA model as if it was a different DMU in years 1, 2 and 3. Therefore, when Australia is evaluated for its Year 1 efficiency, its own performance data for Year 2 and Year 3 are included in the

constraint sets along with similar performance data of the other OECD countries for Years 1, 2 and 3. Concluding, the results of the first window analysis include all the 48 efficiency scores under the column headings for Years 1 to 3 in the first row of each OECD country.

Scale efficiency scores are calculated by dividing overall efficiency by pure efficiency as can be found in Coelli et al. (2001). If the overall efficiency and pure technical efficiency of a DMU (country) are equal then the scale efficiency is 1. If, however, the DMU has lower overall efficiency compared to pure technical efficiency its scale efficiency will be below 1 (Thanassoulis, 2001). A lower overall efficiency score compared to pure technical efficiency score suggests that a country is efficient in trade terms in the former case and less efficient when we control for scale size (in trade terms). This means that scale operation does impact the trade efficiency of the country. Therefore, the larger the divergence between overall and pure technical efficiency scores the lower the value of scale efficiency (in trade terms) and the more adverse the impact of scale size on trade efficiency. Scale scores results are presented in Table 2 (a): Window Analysis; Overall Efficiency, Pure Technical Efficiency.

DMUs/Years	Overall Efficiency					Pure Technical Efficiency				
	Year 1	Year 2	Year 3	Year 4	Year 5	Year 1	Year 2	Year 3	Year 4	Year 5
AUS	65,579	67,711	71,333			65,624	68,04	71,419		
		67,711	71,333	72,355			67,714	71,334	72,496	
			69,651	70,692	71,067			71,177	72,493	100
BEL	100	100	100			100	100	100		
		98,572	99,929	100			100	99,977	100	
			96,981	100	100			97,9	100	100
CAN	86,21	81,49	85,636			87,063	84,571	90,636		
		81,49	85,636	86,447			83,633	89,602	88,283	
			84,913	85,017	82,917			89,602	87,018	85,937
DEN	87,248	86,614	90,678			90,545	90,158	93,457		
		86,609	90,667	89,695			89,848	93,158	91,03	
			90,176	88,848	91,486			92,295	90,419	92,927
FIN	58,583	66,817	58,373			87,056	95,285	94,007		
		66,139	57,768	65,333			95,277	93,9	96,921	
			57,768	65,333	70,44			93,872	96,894	99,442
FRA	96,759	94,97	97,637			98,874	99,175	100		
		94,959	97,626	95,599			99,04	100	98,576	
			97,146	94,754	96,32			100	97,514	98,922
DEU	65,296	67,39	67,666			85,109	85,946	84,83		
		67,39	67,666	67,82			85,371	84,263	84,664	
			67,657	67,813	68,061			83,019	83,415	84,691

<b>IRL</b>	58,723	53,521	64,938			79,51	78,108	85,895		
		51,242	64,144	62,625			77,677	84,975	82,89	
			64,144	62,593	63,288			84,975	82,89	79,192
<b>ITA</b>	84,819	100	100			90,816	100	100		
		99,061	100	95,867			100	100	95,924	
			100	95,855	100			100	95,865	100
<b>JPN</b>	33,422	38,176	41,741			42,741	47,876	52,267		
		38,176	41,741	42,038			47,556	51,918	51,948	
			41,736	42,033	43,508			51,151	51,182	50,889
<b>NLD</b>	96,065	96,27	98,307			100	100	100		
		96,27	98,307	99,984			100	98,923	100	
			95,96	97,7	100			98,829	100	100
<b>NOR</b>	96,121	91,231	100			100	92,027	100		
		91,231	100	100			91,97	100	100	
			100	100	93,24			100	100	93,565
<b>ESP</b>	100	100	100			100	100	100		
		100	100	100			100	100	100	
			100	100	100			100	100	100
<b>SWE</b>	72,94	69,763	69,107			84,995	96,422	95,565		
		68,074	69,082	77,055			95,745	94,892	99,145	
			68,035	77,055	68,452			94,752	99,014	94,508
<b>GBR</b>	83,228	83,688	85,226			95,442	96,624	96,865		
		83,688	85,226	85,586			95,978	96,217	95,92	
			83,136	83,404	87,425			94,797	94,504	94,267
<b>USA</b>	85,457	86,658	90,121			88,684	89,968	93,269		
		86,658	90,121	92,038			89,202	92,161	94,031	
			90,11	92,026	91,499			90,142	92,026	91,5

Table 2 (b): Window Analysis; Scale Efficiency.

DMUs/Years	Scale Efficiency				
	Year 1	Year 2	Year 3	Year 4	Year 5
<b>AUS</b>	0,999 (DRS)	0,995 (DRS) 1 (CRS)	0,998 (DRS) 1 (CRS)	0,998 (DRS)	0,710 (IRS)
<b>BEL</b>	1 (CRS)	1 (CRS) 0,985 (IRS)	1 (CRS) 1 (CRS)	1 (CRS) 1 (CRS)	1 (CRS)
<b>CAN</b>	0,990 (DRS)	0,963 (DRS) 0,974 (DRS)	0,944 (DRS) 0,955 (DRS)	0,979 (DRS)	0,964 (DRS)
<b>DEN</b>	0,963 (DRS)	0,960 (DRS) 0,963 (DRS)	0,970 (DRS) 0,973 (DRS)	0,985 (DRS)	0,984 (DRS)
<b>FIN</b>	0,672 (DRS)	0,701 (DRS) 0,694 (DRS)	0,620 (DRS) 0,615 (DRS)	0,674 (DRS)	0,708 (DRS)
<b>FRA</b>	0,978 (DRS)	0,957 (DRS) 0,958 (DRS)	0,976 (DRS) 0,976 (DRS)	0,969 (DRS)	0,973 (DRS)
<b>DEU</b>	0,767 (DRS)	0,784 (DRS) 0,789 (DRS)	0,797 (DRS) 0,803 (DRS)	0,801 (DRS)	0,803 (DRS)
<b>IRL</b>	0,738 (DRS)	0,685 (DRS) 0,659 (DRS)	0,756 (DRS) 0,754 (DRS)	0,755 (DRS)	0,799 (DRS)
<b>ITA</b>	0,933 (DRS)	1 (CRS) 0,990 (IRS)	1 (CRS) 1 (CRS)	0,999 (IRS)	1 (CRS)
<b>JPN</b>	0,781 (DRS)	0,797 (DRS) 0,802 (DRS)	0,798 (DRS) 0,803 (DRS)	0,809 (DRS)	0,854 (DRS)
<b>NLD</b>	0,960 (DRS)	0,962 (DRS) 0,962 (DRS)	0,983 (DRS) 0,993 (DRS)	1 (CRS)	1 (CRS)
<b>NOR</b>	0,961 (IRS)	0,991 (DRS) 0,991 (DRS)	1 (CRS) 1 (CRS)	1 (CRS)	0,996 (IRS)
<b>ESP</b>	1 (CRS)	1 (CRS) 1 (CRS)	1 (CRS) 1 (CRS)	1 (CRS)	1 (CRS)
<b>SWE</b>	0,858 (DRS)	0,723 (DRS) 0,710 (DRS)	0,723 (DRS) 0,728 (DRS)	0,777 (DRS)	0,724 (DRS)
<b>GBR</b>	0,872 (DRS)	0,866 (DRS) 0,871 (DRS)	0,879 (DRS) 0,885 (DRS)	0,892 (DRS)	0,927 (DRS)
<b>USA</b>	0,963 (DRS)	0,963 (DRS) 0,971 (DRS)	0,966 (DRS) 0,977 (DRS)	0,978 (DRS)	1 (CRS)

Table 2b. As it can be observed, for instance Canada has a low pure technical efficiency score in year 5 of 0.8594 or 85.94% and relatively high scale efficiency (0.964). This means that the overall trade inefficiency of that country in the overall efficiency model (0.8292 or 82.92%) is attributed mainly to inefficient trade policies and comparative disadvantages. The same holds also for other countries such as Denmark, Japan and Norway.

On the other hand, if a country has an optimal pure technical efficiency score (100) and low scale efficiency score this may imply that the trade overall inefficiency is attributed to comparative disadvantages conditions. Australia may be viewed as an example of this case, where it has an optimal pure technical efficiency (year 5) and a relative scale efficiency score of 0.71. Finally, our results show that Australia and Norway display increasing returns to scale, while Belgium, Italy, the Netherlands, and Spain exhibit constant returns to scale and the rest of the countries decreasing returns to scale.

Table 3 decomposes overall average efficiency scores for each country in each window, clarifying trends of trade efficiencies over the years. Moreover, in the same lines, pure technical efficiency has been decomposed. Countries can be distinguished into three different groups. Namely, countries with an overall efficiency over 90% (Group 1), with an overall efficiency between 80% and 90% (Group 2) and with overall trade efficiency below 80% (Group 3). The first group includes Belgium, France, Italy, Netherlands, Norway, and Spain. It is worth mentioning that in the case of Belgium and France we observe a tendency of decrease over the three windows of 1.01% and 0.4% respectively, whereas for the other countries of the group there is an increasing trend of overall trade efficiency. Group 2 consists of Canada, Denmark, Great Britain and the USA. From these countries only Canada indicates a decrease on its efficiency (0.19%) over the three windows, whereas the USA has the highest increase of 4.35%. Finally, the third group includes Australia, Finland, Germany, Ireland, Japan, and Sweden. All the countries forming the third group have an increase in their overall



trade efficiency with the highest increase observed in Japan (12.3%) and the lowest for Sweden (0.82%). However, it is worthy mentioning that Finland and Ireland although they have low overall efficiency scores, they have extremely high scores of pure technical efficiency. This is due to the fact that Finland and Ireland are trading only goods and/or services, which are specialized on producing them and therefore have a comparative advantage in comparison with other countries.

Table 3: Average efficiency scores for each country in each window

DMUs/ windows' averages	<i>Overall efficiency</i>				<i>Pure Technical Efficiency</i>			
	window 1	window 2	window 3	% Difference w1-w3	window 1	window 2	window 3	% Difference w1-w3
<b>AUS</b>	68,21	70,47	70,47	3,32	68,36	70,51	81,22	18,82
<b>BEL</b>	100,00	99,50	98,99	-1,01	100,00	99,99	99,30	-0,70
<b>CAN</b>	84,45	84,52	84,28	-0,19	87,42	87,17	87,52	0,11
<b>DEN</b>	88,18	88,99	90,17	2,26	91,39	91,35	91,88	0,54
<b>FIN</b>	61,26	63,08	64,51	5,32	92,12	95,37	96,74	5,02
<b>FRA</b>	96,46	96,06	96,07	-0,40	99,35	99,21	98,81	-0,54
<b>DEU</b>	66,78	67,63	67,84	1,59	85,30	84,77	83,71	-1,86
<b>IRL</b>	59,06	59,34	63,34	7,25	81,17	81,85	82,35	1,46
<b>ITA</b>	94,94	98,31	98,62	3,87	96,94	98,64	98,62	1,74
<b>JPN</b>	37,78	40,65	42,43	12,30	47,63	50,47	51,07	7,24
<b>NLD</b>	96,88	98,19	97,89	1,04	100,00	99,64	99,61	-0,39
<b>NOR</b>	95,78	97,08	97,75	2,05	97,34	97,32	97,86	0,53
<b>ESP</b>	100,00	100,00	100,00	0,00	100,00	100,00	100,00	0,00
<b>SWE</b>	70,60	71,40	71,18	0,82	92,33	96,59	96,09	4,08
<b>GBR</b>	84,05	84,83	84,66	0,72	96,31	96,04	94,52	-1,86
<b>USA</b>	87,41	89,61	91,21	4,35	90,64	91,80	91,22	0,64

Table 4 corroborates the results shown in table 3 by reporting rankings, means and variances across all windows, the greatest differences by window and by year. It illustrates the relative stability of each country's overall trade efficiency results and its further indication of the trade efficiency and stability of Spain. Given the fact that Spain reports an overall efficiency (in trade terms), no variability is a strong indication of healthy and strong trade performance. Stability in performance is further observed by the greatest difference scores being the lowest whether measured by window (GDW) or by year (GDY). Moreover, Belgium has the second best performance with an overall mean efficiency of 99.49 and with a

variance of 1.1. Observing Italy we notice that even though is fourth in terms of its trade efficiency (with a mean of 97.28) it seems that it hasn't a stable performance with a variance of its efficiency of 24.9 and with a greatest window difference of 15.1. Table 4 indicates also a low trade performance for Sweden, Australia, Germany, Finland, Ireland and Japan. Generally, the most consistent trade performers are Spain, Belgium and the Netherlands with very high trade efficiency means and low variances.

Table 4: Window analysis –Rankings, means, variances, greatest difference within window (GDW) and greatest difference in the same year but different window (GDY)

<i>DMUs</i>	<i>GDW</i>	<i>GDY</i>	<i>Mean</i>	<i>Variance</i>	<i>Ranking</i>
<b>ESP</b>	0	0	100	0	1
<b>BEL</b>	3,019	2,948	99,498	1,11131875	2
<b>NLD</b>	2,3	2,347	97,6514444	2,62662003	3
<b>ITA</b>	15,181	0,939	97,2891111	24,9333661	4
<b>NOR</b>	8,769	0	96,8692222	15,7898797	5
<b>FRA</b>	2,667	0,845	96,1966667	1,353155	6
<b>USA</b>	3,463	0,012	89,4097778	6,29850244	7
<b>DEN</b>	4,058	0,847	89,1134444	3,50342853	8
<b>GBR</b>	4,021	2,182	84,5118889	2,09828561	9
<b>CAN</b>	-4,72	1,43	84,4173333	3,787293	10
<b>SWE</b>	9,02	1,689	71,0625556	13,7114723	11
<b>AUS</b>	3,622	1,682	69,7146667	5,016313	12
<b>DEU</b>	2,094	0,009	67,4176667	0,67695725	13
<b>FIN</b>	-8,444	0,678	62,9504444	23,288344	14
<b>IRL</b>	12,902	2,279	60,5797778	25,0549984	15
<b>JPN</b>	4,754	0,005	40,2856667	9,85725525	16

Table 5 provides us with the rankings of all the countries according to highest scores obtained from conventional ratio and window analyses. Furthermore, looking at the rankings according to the value added shares from manufacturing sector relative to the total economy of the countries (VASH) we realize that Ireland and Finland have the highest performances even though when looking at the window analysis ranking they are in the 14<sup>th</sup> (Finland) and 15<sup>th</sup> (Ireland) place. The fact that they are so high in the ranking of VASH explains the fact that they have so high scores in terms of pure technical efficiency (Table 3).

Looking at the rankings for R&D expenditures by the total manufacturing sector relative to the total economy (RDIP) we realize that Japan lies on the 3<sup>rd</sup> place compared to

the trade efficiency ranking which has the worst trade performance. Countries, which are the last in the ranking of RDIP ratio are the most trade efficient according in the DEA window analysis (Spain)<sup>2</sup>.

Table 5: Rankings and average values according to the ratios used and the DEA window analysis.

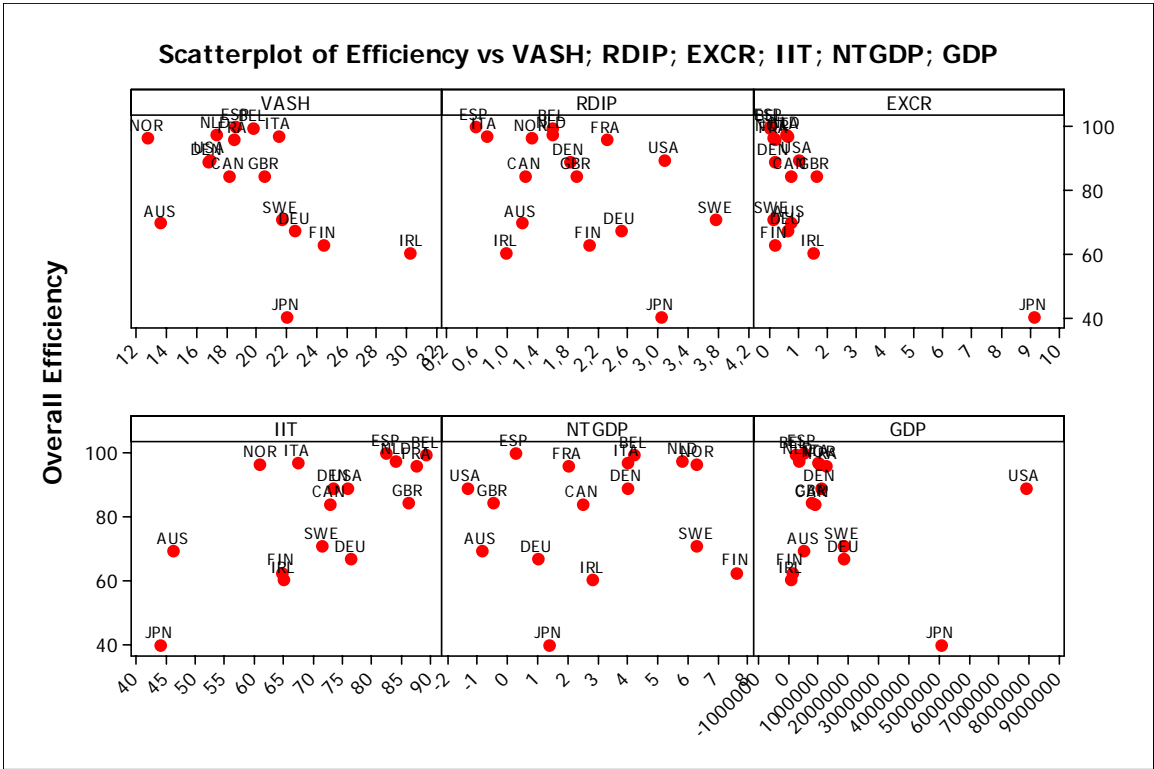
<b>VASH /Rank</b>	<b>DMUs</b>	<b>Average value of Years 95-00</b>	<b>RDIP/ Rank</b>	<b>DMUs</b>	<b>Average value of Years 95-00</b>	<b>NTGDP/ Rank</b>	<b>DMUs</b>	<b>Average value of Years 95-00</b>
1	IRL	30,2443289	1	SWE	3,76734542	1	FIN	7,616704
2	FIN	24,4871573	2	USA	3,09521077	2	NOR	6,325158
3	DEU	22,5550636	3	JPN	3,0364985	3	SWE	6,28069
4	JPN	21,9856671	4	DEU	2,5006202	4	NLD	5,827938
5	SWE	21,6603509	5	FRA	2,3152444	5	BEL	4,213006
6	ITA	21,49262	6	FIN	2,07312906	6	ITA	3,988228
7	GBR	20,5156603	7	GBR	1,90891696	7	DEN	3,977936
8	BEL	19,7921173	8	DEN	1,81608936	8	IRL	2,82598
9	ESP	18,6007695	9	BEL	1,59154751	9	CAN	2,473358
10	FRA	18,4975284	10	NLD	1,58890337	10	FRA	2,00105
11	CAN	18,1106355	11	NOR	1,31297721	11	JPN	1,37107
12	NLD	17,3460502	12	CAN	1,23108328	12	DEU	0,974004
13	USA	16,8977581	13	AUS	1,18116865	13	ESP	0,252354
14	DEN	16,7656618	14	IRL	0,97939034	14	GBR	-0,5001392
15	AUS	13,5770863	15	ITA	0,70466916	15	AUS	-0,881146
16	NOR	12,7616214	16	ESP	0,55962193	16	USA	-1,36823
<b>EXCR /Rank</b>	<b>DMUs</b>	<b>Average value of Years 95-00</b>	<b>IIT/ Rank</b>	<b>DMUs</b>	<b>Average value of Years 95-00</b>	<b>Window Analysis Rank</b>	<b>DMUs</b>	<b>Averages scores/ window analysis</b>
1	GBR	1,593832	1	BEL	89,2362129	1	ESP	100
2	IRL	1,529264	2	FRA	87,7038911	2	BEL	99,498
3	USA	1	3	GBR	86,1009596	3	NLD	97,65144444
4	AUS	0,725403	4	NLD	84,1171103	4	ITA	97,28911111
5	CAN	0,7181632	5	ESP	82,3567296	5	NOR	96,86922222
6	DEU	0,6256474	6	DEU	76,4748752	6	FRA	96,19666667
7	ITA	0,609308	7	USA	75,919439	7	USA	89,40977778
8	NLD	0,5563836	8	DEN	73,4269361	8	DEN	89,11344444
9	FIN	0,2040604	9	CAN	72,8600179	9	GBR	84,51188889
10	FRA	0,1836148	10	SWE	71,6184693	10	CAN	84,41733333
11	DEN	0,162012	11	ITA	67,428486	11	SWE	71,06255556
12	NOR	0,145913	12	IRL	64,9667409	12	AUS	69,71466667
13	SWE	0,1353584	13	FIN	64,6119426	13	DEU	67,41766667
14	JPN	0,11200894	14	NOR	61,022402	14	FIN	62,95044444
15	BEL	0,0302406	15	AUS	46,3137573	15	IRL	60,57977778
16	ESP	0,0073672	16	JPN	44,0572182	16	JPN	40,28566667

In the same lines, when we observe the exchange rate for exports for each country we realize that countries with higher exchange rates are the ones which are in the lower places of

our DEA ranking and therefore they are less trade efficient compared to Belgium and Spain, which have the lowest average exchange rate prices for exports.

Figure 2 provide us with essential information comparing overall efficiency and ratios. More analytically we realize graphically that countries, which are more trade efficient, have, as expected, lower exchange rates for exports. Moreover, countries with lower research and development expenditure are more trade efficient. This is justified by the fact that most of the goods, which are tradable, are agricultural products. Furthermore, high technology goods and services are costly to be traded due to tariffs and taxes, which are imposed from the importing countries. As expected countries with higher value of IIT are trade efficient.

Figure 3: Overall efficiency versus VASH; RDIP; EXCR; IIT; NTGDP and GDP



These results are supported by the derived targeted values presented in table 6. These values are obtained for the trade inefficient countries in order to become efficient. It is noticeable that the targeted values for VASH and RDIP ratios require moderate changes for inefficient countries in order to become trade efficient. On the other hand, looking at the

targeted values for EXCR these are quite high. Taking Japan as an example, we realize that in order for Japan to become trade efficient it has to reduce its exchange rates for exports (probably making its commodities more competitive), increasing significantly the intra industry trade and enhancing policies for trade to contribute to the country's growth. A similar picture is valid in the case of Australia, Canada and Great Britain while Germany, Ireland and Italy have to reduce their exchange rates for exports, increasing their IIT ratio.

Table 6: Targeted values for the trade inefficient countries to become trade efficient

Dmus/ratios	VASH	RDIP	EXCR	IIT	NTGDP
<b>AUS</b> <i>(targeted)</i>	12,9000 <b>12,8980</b>	1,0318 <b>1,0313</b>	0,6282 <b>0,3166</b>	45,2704 <b>63,6522</b>	-1,8017 <b>3,3598</b>
<b>BEL</b> <i>(targeted)</i>	19,6071 <b>19,6071</b>	1,6294 <b>1,6294</b>	0,0276 <b>0,0276</b>	91,3616 <b>91,3616</b>	4,2639 <b>4,2639</b>
<b>CAN</b> <i>(targeted)</i>	18,7393 <b>18,7362</b>	1,3475 <b>1,3478</b>	0,6742 <b>0,3808</b>	75,5266 <b>90,9671</b>	2,0036 <b>4,0349</b>
<b>DEN</b> <i>(targeted)</i>	16,6914 <b>16,6926</b>	2,1607 <b>1,4218</b>	0,1496 <b>0,1524</b>	75,1113 <b>79,4656</b>	2,0172 <b>4,0882</b>
<b>FIN</b> <i>(targeted)</i>	25,4403 <b>25,4423</b>	2,4296 <b>2,1561</b>	0,1874 <b>0,1914</b>	62,9306 <b>120,5730</b>	8,8126 <b>6,0826</b>
<b>FRA</b> <i>(targeted)</i>	18,5611 <b>17,1893</b>	2,1580 <b>1,2474</b>	0,1698 <b>0,3551</b>	88,0536 <b>83,5652</b>	2,6523 <b>3,7629</b>
<b>DEU</b> <i>(targeted)</i>	22,5416 <b>24,0527</b>	2,5200 <b>1,0068</b>	0,5694 <b>0,1085</b>	77,3750 <b>109,5830</b>	1,4948 <b>1,1127</b>
<b>IRL</b> <i>(targeted)</i>	32,4701 <b>26,1745</b>	0,8916 <b>0,8977</b>	1,4285 <b>0,0140</b>	61,3953 <b>117,2800</b>	3,0235 <b>0,0982</b>
<b>ITA</b> <i>(targeted)</i>	21,2019 <b>18,4952</b>	0,6300 <b>0,6343</b>	0,5761 <b>0,0099</b>	68,1938 <b>82,8715</b>	3,4049 <b>0,0694</b>
<b>JPN</b> <i>(targeted)</i>	21,1880 <b>21,1852</b>	3,3273 <b>1,9259</b>	7,6639 <b>0,6420</b>	46,4932 <b>106,8580</b>	1,8352 <b>6,8226</b>
<b>NLD</b> <i>(targeted)</i>	16,8322 <b>16,8322</b>	1,5316 <b>1,5316</b>	0,5051 <b>0,5051</b>	84,8929 <b>84,8929</b>	5,4151 <b>5,4151</b>
<b>NOR</b> <i>(targeted)</i>	13,0402 <b>13,0410</b>	1,1802 <b>1,1151</b>	0,1326 <b>0,1349</b>	59,7283 <b>62,2946</b>	1,8959 <b>3,2517</b>
<b>ESP</b> <i>(targeted)</i>	18,6643 <b>18,6643</b>	0,6356 <b>0,6356</b>	0,0067 <b>0,0067</b>	83,6107 <b>83,6107</b>	0,0672 <b>0,0672</b>
<b>SWE</b> <i>(targeted)</i>	22,1579 <b>22,1603</b>	3,7589 <b>1,8678</b>	0,1259 <b>0,1292</b>	72,7133 <b>104,5160</b>	6,2853 <b>5,1610</b>
<b>GBR</b> <i>(targeted)</i>	19,4651 <b>19,4626</b>	1,9974 <b>1,7693</b>	1,6570 <b>0,5898</b>	85,8265 <b>98,1685</b>	-0,9904 <b>6,2678</b>
<b>USA</b> <i>(targeted)</i>	16,3013 <b>16,2991</b>	3,1813 <b>1,4817</b>	1,0000 <b>0,4939</b>	75,2260 <b>82,2121</b>	-1,8286 <b>5,2490</b>

## V. Conclusions and Policy Implications

In this study we performed an application of DEA window analysis in order to compare international trade efficiency, by using conventional ratio measures in the suggested model and for the time period 1996–2000. The efficiency scores and the optimal ratio levels for inefficient countries for all the five years of the study were obtained. Results drawn from the broadly used ratio analysis were also compared to the results derived from the DEA window model. The advantage of using DEA compared to economic ratios is that DEA provides us with an overall objective numerical score, ranking, and efficiency potential improvement targets for each one of the inefficient units.

Specifically, DEA assists in efficiency comparisons with the simultaneous use of multiple criteria, which determine efficiency for each DMU, forming a rounded judgment on DMU efficiency taking into consideration a variety of efficiency dimensions and combining them into a single performance measure. Looking at the results of the conventional ratio analysis and our DEA window analysis we may conclude that even though DEA analysis provide us with a ranking taking into account all the variables, it needs conventional ratio analysis in order to clarify different aspects, which cannot be explained through input/output analysis.

In our case, it seems that the trade efficient countries have clear characteristics. Specifically, these are

- Low exchange rates. As expected, looking at the exchange rate for exports for each country we realize that countries with higher exchange rates are the ones, which are in the lower places of our DEA ranking, and therefore they are less trade efficient.
- Low R&D intensity. Countries with low ranking according to their RDIP ratio are the most trade efficient in the DEA window analysis.

- High value intra industry trade.
- The combination of the above mentioned factors have positive effect on the contribution of net trade to GDP of each country.
- Countries with high ranking according to their VASH ratio have high scores in terms of pure technical efficiency
- Scale operation does affect the trade efficiency of the country. The larger the divergence between overall and pure technical efficiency scores the lower the value of scale efficiency (in trade terms) and the more adverse the impact of scale size on trade efficiency.

From the above, it can be concluded that through long-term relationships with firms from more advanced countries, the companies from less developed countries can get access to foreign technology, management skills and organizational expertise. Advanced countries mainly attract efficiency- and market-seeking and asset-augmenting Foreign Direct Investment while less developed countries are mostly attractive for resource- and market-seeking investors.

Finally the results need to be treated with discretion and caution taking into accounts all the economic parameters affecting trade efficiency and economic development along with individual country's economic and trade history.

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## Notes:

<sup>1</sup> [http://www.oecd.org/document/48/0,2340,en\\_2649\\_201185\\_33762800\\_1\\_1\\_1\\_1,00.html](http://www.oecd.org/document/48/0,2340,en_2649_201185_33762800_1_1_1_1,00.html)



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<sup>2</sup> An economic interpretation may rely on that a country has to decide if it will be a technological leader or a technological follower. The former case requires the involvement in expensive R and D activities. This may lead to new inventions through patents or even to nowhere. On the other hand the technological follower has to search for access to the technology developed by the leader. This may be achieved either by developing a similar version but having to bear a lower R and D cost compared to the leader or by licensing the new technology from the leader (Blake, 1993).