**A DEA-Logistic Performance Index**

**Leandro García1, Luisa Martí2, Juan Carlos Martín3, Rosa Puertas2**

1Universidad de Valencia

Instituto de Economía Internacional

46022 Valencia, Spain

leandro.garcia@uv.es

2Universidad Politécnica de Valencia

Grupo de Economía Internacional

46022 Valencia, Spain

mlmarti@esp.upv.es; rpuertas@esp.upv.es

3Universidad de Las Palmas de Gran Canaria

Institute of Tourism and Sustainable Economic Development

35017 Las Palmas de Gran Canaria, Spain

jcarlos.martin@ulpgc.es

**ABSTRACT**

Logistics and transport increasingly play a pivotal role in international trade relations. The Logistics Performance Index (LPI) measures the on-the-ground efficiency of trade supply chains, or logistics performance. Since the year 2007, the World Bank has produced it every two years. The LPI is built on the basis of a worldwide survey carried out on companies responsible for the transport of goods and for the facilitation of trade globally. The aggregate index is calculated by analysing six main components using the following indicators: (1) customs; (2) infrastructure; (3) international shipments; (4) logistics quality and competence; (5) tracking and tracing; and (6) timeliness. The 2014’s edition covers 160 countries. The aim of this paper is to propose a data envelopment analysis (DEA) approach to compute a synthetic index of overall logistic performance (DEA-LPI) and benchmark the logistic performance of the countries with LPI. Dealing with the six dimensions of LPI, the proposed approach uses DEA as a tool for multiple criteria decision making (MCDM). Since DEA measures the relative efficiency of decision making units (DMUs), in our case, one hundred forty one countries in the sample, and identifies a set of corresponding efficient DMUs called a reference set that can be used as benchmarks for improvement of inefficient DMUs, it is capable of providing clear guidelines for benchmarking of national logistic performance. Furthermore, the paper will also analyse the potential differences observed using different dimensions, name list income and geographical area.

Keywords: Logistic performance; Freight transport; Data envelopment analysis (DEA); LPI; LPI components.

# Introduction

International trade has recently been affected by globalization and increased competitiveness of lagged regions that in the past do not play such important role in the world. This trend has had an extreme impact on logistics as one of the key elements that facilitate the mobility of products, ensuring their safety and speed as well as providing cost reductions when international trade among countries is growing. De Souza et al. (2007) define logistics as part of the value chain that plans, implements and controls the efficient flow of goods, services and information from the source to the consumer. The importance of the key components of logistics – transport, inventory and warehousing – has been recognized as a vital element in the economy in the last 20 years although these elements have been fundamental in the industrial and economic life of nations for countless years (Rushton et al., 2014).

In late 2013, after more than 10 years of negotiation, the World Trade Organization (WTO) approved the Agreement on Trade Facilitation, providing crucial guidance on trade policies. This Ministerial Declaration deals with three key issues: trade facilitation, agriculture, and commercial impetus to help developing countries mitigate existing differences. Specifically, it contains provisions to speed up and improve the efficiency of customs procedures and border management (Sanz, 2014). However, as outlined by Arvis et al. (2014) it introduces only minimum common standards, and in no way guarantees success. Only if countries are truly prepared to implement the advances that commercial globalization requires, can they benefit from the advantages of improved logistics performance. Hence, a suitable quantitative instrument is clearly needed in order to measure and compare the role of logistics in different parts of the world.

The Logistics Performance Index (LPI) was established with a view to bridging this gap. Its main objective is to measure the efficiency of logistics supply chains based on survey feedback from export companies. The LPI was first published in 2007 and led to a global debate on the importance of logistics in world economic growth. At the same time it revealed the need to implement concrete policies to improve future performance. By comparing the results obtained by the LPI for the four years analysed, the enormous value of the trade facilitation policies (i.e. the international distribution of production) can be appreciated. This index and its components can help countries (governments and corporations) to get to know their business partners more closely and anticipate any possible adjustments that could harm their competitiveness.

LPI is sometimes compared to other indicators such as the Doing Businessranking. However they differ in a number of respects, and so are not interchangeable. Specifically, theDoing Business ranking makes use of data on regulations that are “on the books", while the LPI draws on surveys of logistics professionals who answer questions about their experiences in different countries. In this way it seeks to capture the day-to-day reality facing the private sector much more accurately. Moreover, the Global Competitiveness Index published by the World Economic Forum measures the ability of countries to provide high levels of prosperity to their citizens based on 12 pillars, and therefore only in the area of quality of transport infrastructure could it be considered comparable with one of the LPI components.

In this study, we propose another objective measure for the logistic of the countries. Therefore, the aim of this paper is fourfold: (1) to compute a synthetic index of overall logistic performance (DEA-LPI) using a DEA method that could be used to benchmark the logistic performance of the countries. Dealing with the six dimensions of LPI, the proposed approach uses DEA as a tool for multiple criteria decision making (MCDM). (2), since DEA measures the relative efficiency of Decision Making Units (DMUs), in our case, one hundred forty one countries in the sample, a set of corresponding efficient DMUs called a reference set will be identified. This group of countries can be used as benchmarks for improvement of inefficient DMUs, providing clear guidelines for benchmarking of national logistic performance. (3), a comparison of the results with both methods will be performed. And (4) furthermore, the paper will also analyse the potential differences observed using income and geographical area as determinants of logistics performance.

The remainder of the paper is organized as follows: Section 2 offers some insights from the literature, section 3 details the methodology, section 4 describes the data section, section 5 presents and discusses the results, and section 6 offers some concluding remarks.

# Literature review

Major trade reforms have been successfully implemented all over the world. These range from trade liberalization policies that have fostered bilateral and multilateral international trade agreements to more ambitious international integration treaties. As a result, tariffs have been decreasing in recent years in comparison with other trade facilitations that have been improving. Nevertheless these reforms do not always compensate the myriad of non-tariff barriers that are often more important on trade than actual tariffs. As Blyde and Iberty (2012) contended, even though the underlying theoretical models do not make a distinction between developed and developing countries when it comes to the predictions of decreasing trade costs, it is possible that the effects could differ for various reasons. For instance, developing countries tend to exhibit additional non-tariff barriers associated with trading goods, like higher transport costs, less efficient port infrastructures or more cumbersome custom procedures, than developed countries. The existence of such additional barriers might detain the full effects of a trade liberalization process.

Trade facilitation measures have been a central issue in the WTO negotiations on trade facilitation since 2005 when the OECD Trade Committee analysed the costs of introducing and implementing trade facilitation measures, based on the experience of fifteen developing countries. The WTO defines trade facilitation measures as: ‘the simplification and harmonisation of international trade procedures in collecting, presenting, communications and processing data required for the movement of goods in international trade’. Wilson et al. (2005) define trade facilitation using four indicators: port efficiency, customs, regulations and use of e-commerce. Soloaga et al. (2006) apply the same definition to analyse the impact of changes in the trade facilitation of Mexican industrial goods flows, suggesting that trade reform could boost total Mexican exports by 22.4%.

Möisé (2013) analyse the three main areas of trade facilitation measures — transparency and predictability; procedural simplification and streamlining; and coordination and cooperation between border agencies — finding that equipment and infrastructure seem to be the most expensive elements of trade facilitation, in particular the introduction and use of information technologies and the establishment of single window mechanisms. However, countries themselves reported that the most important area was training, given its fundamental role in bringing about sustained change in the business practices of border agencies.

Notwithstanding, other studies have proposed a sole indicator to estimate trade facilitation and ascertain its impact on exports (UNDP 2001, OECD 2003, Dennis 2006, Decreux and Fontagne 2006). In the same vein, Behar and Manners (2008) and Puertas et al. (2014) use the LPI published by the World Bank to explore the relationships that exist between bilateral exports and logistics. Hoekman and Nicita (2011) and Korinek and Sourdin (2011) include the LPI using a gravity equation for exports as an indicator of trade costs, together with others such as Doing Business Costs, concluding that domestic costs are quantitatively important and that the LPI has the largest effect on trade.

The literature includes research on synthetic index in technological and social capabilities of countries (Mahlberg and Obersteiner, 2001; Osberg and Sharpe, 2002; Filippetti and Peyrache, 2011). Following OECD ‘a composite indicator is formed when individual indicators are compiled into a single index on the basis of an underlying model of the multidimensional concept that is being measured’. It is a mathematical aggregation of a set of sub-indicators for measuring multi-dimension concepts that cannot be captured by a single indicator (OECD, 2008). Synthetic index has been accepted as a useful tool for performance comparisons, benchmarking, policy analysis and public communication in various fields such as economy, environment and society. In this context, the paper proposes this type of index to measure the logistic performance of the countries.

# Methodology

Many organizations such as the United Nations, the European Commission, and the OECD have developed and used an ample panoply of composite indicators (CIs) in different areas such as energy, environment, logistics, and quality of life, among others, in which sub-indicators are transformed mathematically into one synthetic indicator, with a view to provide comparisons of countries in complex policy issues. These measures are gaining more acceptance as a tool for policy making and, especially, benchmarking analysis on countries' relative performance (Cherchye et al., 2008).

The construction methodology that is used in the present study is based on Data Envelopment Analysis (DEA). DEA was originally designed to measure the performance of a firm on a context of production economics. This methodology was initially proposed by Charnes et al. (1978) to evaluate the performance of different DMUs *–*a set of some decision-making units. The authors described the DEA methodology as a "mathematical programming model applied to observed data that provides a new way of obtaining empirical estimates of extremal relationships such as the production functions and/or efficiency production possibility surfaces that are the cornerstones of modern economics". This was the origin of a discipline that deals with how one could measure each decision-making unit's relative efficiency, given observations on input and output quantities in a sample of peers (Charnes and Cooper, 1985). Mathematically, we will see below that DEA is a linear programming-based methodology whose main advantage is that it does not require any assumption on the shape of the frontier surface.

A well-known feature of DEA is that it looks for endogenous weights that can be constrained, which maximize the overall score for each DMU given a set of other observations. For this reason, it gained its acceptance in real policy-related settings in different fields, such as education, health care, banking, armed forces, sports, transportation, agriculture, and electricity among others, and there has been a continuous explosion of sectorial studies using conventional or more sophisticated DEA models. There exist a number of papers that analyze under different perspective the previous research that have appeared in the DEA literature (Seiford, 1996; Emrouznejad et al., 2008; Cook and Seiford, 2009).

These reviews show that the applications which deal directly with DEA evaluation of countries’ logistics performance are inexistent. In a posterior search we could only find some studies that analyze the logistics performance of cities (Jiang, 2010) or regions (Jiang and Fu, 2009). To our knowledge there is only one study which deals with the countries’ logistic performance (Markovits-Somogyi and Bokor, 2014). In this paper, the authors analyzed the logistics efficiency of 29 European countries using a methodology where DEA is combined with analytic hierarchy process to fully rank all the countries included in the analysis. The authors compared also the results with a DEA-PC (pairwise comparison) methodology and with the ‘Logistics quality and competence’ index of the LPI.

Ali and Seiford (1993), Charnes et al. (1994), Coelli et al. (1998), Cooper et al. (2011) and Zhu(2014) are good references to cover the basic aspects of DEA models, DEA notation, formulation and geometric interpretation. There are three basic conventional DEA models: variable returns to scale (VRS), constant returns to scale (CRS) and additive models. These models separate the DMUs into two different sets: the firms that lie on the frontier of the envelopment surface, and are considered efficient units and those who are inefficient because they do not lie on the frontier.

Researchers are usually confronted with the selection of a suitable DEA model that could help to explain the different performance of a group of DMUs. The selection of a particular model is constrained by the characteristics of the problem that researchers are analyzing. In particular, as in our case, if researchers are interested in obtaining a fully rank of all the units under analysis, then conventional DEA models might not be appropriate, and then a refined DEA method should be applied. In some circumstances, obtaining good quality data might be even more problematic than choosing a proper method to analyze the industry. Data availability is a natural premise that affects the success of the research, and it is well-known that some market structure might favor or deter the data availability.

In DEA analysis, it is generally assumed that there are *n* production units to be evaluated, using amounts of *m* different inputs to produce quantities of *s* different outputs. Specifically, the *o'th* production unit consumes *xio* units of input *i (i= 1 to m)* and produces *yro* units of output *r (r=1 to s)*. The *o'th* production unit can now be described more compactly with the vector *(Xo,Yo)*, which denote, respectively, the vectors of input and output values for DMUo.

Next, it is necessary to determine a potential set of possible dominant or non-dominant comparisons for each production unit considered in the analysis. DEA usually considers the dominance of all the possible linear combinations of the *n* DMUs, i.e. , with the scalar restricted to be non-negative[[1]](#footnote-1). The production unit *o* is dominated, in terms of inputs, if at least one linear combination of production units shows that some input can be decreased without worsening off the rest of inputs and outputs. If at least one linear combination of production units shows that some output can be increased without worsening off the rest of inputs and outputs[[2]](#footnote-2), it is dominated in terms of outputs.

In our case, policy makers can affect the logistics performance of their country making policies that improve some of the dimensions considered in the LPI such as the efficiency of customs and border clearance, the quality of trade and transport infrastructure, the ease of arranging competitively priced shipments, the competence and quality of logistics services—trucking, forwarding, and customs brokerage, the ability to track and trace consignments or the frequency with which shipments reach consignees within scheduled or expected delivery times. It is out of the scope of the present paper to give some guidelines about what trade facilitation measures should be implemented as we do not have the costs of such policies. Möisé (2013) contended that some measures need to be evaluated taking a long term perspective as these may be expensive to introduce but not costly to operate. Other measures require political commitment rather than funds, and some institutional barriers act as real impediments to achieve any gain. In any case, the author concluded saying that an increasing amount of technical and financial assistance to implement some trade facilitation measures has been made available to developing countries over the last decade.

In this paper, countries’ logistics performance is going to be based on a constant return to scale (CRS) input orientation model. Formally, the multiplier-DEA CRS output efficiency for the unit *o* is calculated through the following linear programming problem:

 

The set of constraints requires that the same weights, when applied to all the countries, do not provide any country with efficiency greater than one. The solution to this maximization problem is not unique. It can be shown that if there exists a solution to the above problem, then there exist an infinite number of solutions because () is also a solution to the problem (Coelli, 1996). Since, there are an infinite number of solutions for the dual variables (multipliers), it is necessary to formulate an equivalent linear programming program which avoids this problem. In this sense, the following problem is derived from (1) and it is resolved for each country:

 

A country is in the frontier if and only if  in optimality. The constraint  is known as a normalization constraint, and the weighted input and output are called virtual input and virtual output, respectively. See Seiford and Thrall (1990) for a detailed discussion of these models. The efficiency ratio ranges from 0 to 1. Thus, for each country under analysis the weights will be chosen so as to maximize self-efficiency, given the constraints. This intrinsic characteristic of the model explains partly the appeal of DEA-based CIs in real policy-related exercises. It is unarguable that several policy issues should balance adequately different regional interests taking into account supranational, regional or country-specific policy priorities. For this reason, a fixed set of weights to compare the multidimensional performance of countries may prevent the acceptance of the evaluation.

# Data

The LPI is a good indicator of trade facilitation for a broad group of countries. The logistics index values differ between countries and provide a general picture of customs procedures, logistics costs and the quality of the infrastructure necessary for overland and maritime transport.

The World Bank has published this index for 4 years (Arvis et al., 2007, 2010, 2012 and 2014), ranking 150 countries and providing an extensive explanation of logistic performance in these countries (43 from Africa, 42 from Europe, 41 from Asia, 22 from South America, 5 from the Pacific, and 2 from North America). The first edition contains data compiled in 2005 and was published in 2007; the second edition contains data processed between 2008 and 2009 and was published in 2010; the third edition contains information for the year 2010 and was subsequently published in 2012, following the same sequence in 2014. The index makes an important statistical contribution by establishing a harmonized scale for all countries to identify the difficulties faced by bilateral trade, together with their requirements in terms of logistics associated with existing facilities. From the information obtained the LPI is constructed using Principal Component Analysis (PCA), a statistical technique used to reduce the dimensionality of a dataset. Thus, using inputs corresponding to each of the six components, and then averaging out scores for each country, the PCA ultimately provides a single indicator - the LPI - thereby establishing a logistics ranking for the countries analysed.

The LPI is built on the basis of a worldwide survey carried out on companies responsible for the transport of goods and for the facilitation of trade globally. Specifically, it was developed with the assistance of over 800 professionals involved across the different areas of the sector’s lines of activity[[3]](#footnote-3). Each respondent to the survey was asked for data pertaining to the eight countries they most traded with at the international level.

The aggregate index is calculated by analysing six main components using the following indicators: customs, infrastructure, international shipments, logistics quality and competence, tracking and tracing, and timeliness[[4]](#footnote-4). None of these independently guarantee a good level of logistics performance, and their inclusion is conditioned to empirical studies and extensive interviews carried out with specialists in international freight transport. All the indicators have been aggregated and duly weighted and scores range from 1 to 5, the highest score representing the best logistics performance. Each component is defined as follows:

* Customs: Measures agility clearance processes, in terms of speed, simplicity and predictability of formal issues conducted by customs control bodies.
* Infrastructure: Evaluates the quality of maritime, land, rail and air transport infrastructure. The perception held by respondents about this infrastructure is valuated in terms of the modes of transport together with storage and moving goods.
* International shipments: Measures the ease of negotiating competitive prices for sending.
* Logistics quality and competence: Indicates the quality of logistical services, such as transport operators or customs agents.
* Tracking and tracing: Measures the follow-up and location of shipments. Identifying the exact location and route followed by each good is relevant up to the moment of delivery to the final client. In this component, all agents of the good’s supply chain are involved; therefore, traceability is the result of global action.
* Timeliness: Refers to the exact time of shipment delivery. It is important to consider this factor because due to the high degree of existing competition, not meeting the established times is unacceptable.

These indicators can be divided into two main areas: (1) regulatory policies (customs, infrastructure and logistic quality and competence), and (2) service delivery performance outcomes (timeliness, international shipments, and tracking and tracing). The first concerns the distribution chain, while the second determines the efficiency of the service. Each component is key to determining competitiveness in international trade within each country. Any changes to these components will have important repercussions. For example, an improvement in *customs* and *infrastructure* would lead to an increase of 4.7% and 14.5% of GDP and global trade respectively. If tariffs were completely eliminated worldwide, GDP would increase by 0.7% and trade by 10.1% (400 billion and 1.1 trillion dollars), or at any rate would improve the efficiency of the international transport of goods. In the literature studies tend to follow this approach, concluding that frequency, time flexibility, development of infrastructure, and on-time delivery are all key factors in international competitiveness variables[[5]](#footnote-5).

In general, low-income countries, with little development or geographical impediments as far as market access goes, occupy the last places of the ranking (countries from Africa and Central Asia). However, it should be clarified that when trade has been a factor in accelerating their growth, logistical performance is also significantly better than in other locations with similar income levels (India and Vietnam, both low income, are ranked 46 and 53, respectively, in 2010).

According to the index published in 2014, higher-income countries occupy the top 10 positions in ranking (Germany, Netherlands, Belgium, United Kingdom, Singapore, Sweden, Norway, Luxembourg, USA and Japan). These countries are well positioned logistically, and play a key role in supply chains at both global and regional levels. In a similar way, at the bottom of the rankings lie lower income countries, mainly African nations or countries where conflicts have undermined their development.

On the other hand, the distance between the highest and lowest countries in the ranking has narrowed progressively. The LPI expressed as a percentage of the highest country in the ranking reveals that the LPI for Somalia represents 25% that of the highest performer (Germany), while previously it was 19% in 2012, 11% in 2010 and 7% in 2007. At the same time, the gap between countries at the top of the ranking is narrowing. This might be explained by the improvement in infrastructures to foster trade in low and middle-income countries, and to a lesser extent by their logistics performance and customs clearance. Hence, the same progressive strategies clearly cannot be applied equally to all countries.

In this paper, it has been considered as inputs some LPI components (Customs, Infrastructure, and International shipments). They have been transformed as 5 minus the original value (Table 1).

(Insert Table 1 here)

The selection of the variables to be transformed as inputs in the DEA model was made because these variables were mainly classified in the first category by Arvis et al (2007) developing the LPI as areas for policy regulations that contain main inputs to the supply chain such as customs, infrastructure, and ease of arrangement for international shipments. We have preferred to leave the original values of those dimensions that mainly belong to the second category which is characterized by those service delivery performance outcomes such as timeliness, tracking and tracing, and quality of logistics services

Table 2 shows the descriptive statistics for the inputs and outputs of the LPI components that were included in our analysis. As it can be observed, great differences are appreciated between the minimum and maximum values on almost all the variables. However, the standard deviation and average figures do not show any particular pattern with the exception that timeliness is the only variable that presents an average figure higher than three, so this dimension is the most positively valued by the logistics professionals from the companies responsible for moving goods around the world who answered the structured online survey administered by the World Bank. Looking at those countries which present the best and worst performance values, it can be seen that good performers are characterized by being Western European countries as this set includes Norway, Germany and Luxembourg. Regarding the worst performers, it can be seen that there are only two countries, Somalia and Yemen, which present the worst figures in the whole set of dimensions.

(Insert Table 2 here)

The poor results of Somalia and Yemen can be partly explained by the thousands of attacks on cargo ships perpetrated in the Somalian coast during the last decade that have caused a significant burden to maritime trade in the area. Burlando et al. (2015) found that cargo passing through pirate waters has been reduced by 4.1% per year in the period 2000-2010 and that this reduction is not evenly distributed in all the groups of goods that are shipped by sea. They also found that five countries and the EU shouldered 70% of the total costs. The Somalian and Yemeni results are incardinated with a combination of sources such as weak governmental institutions, a natural bottleneck in the area, and a significant flow of merchant ships through the Gulf as more than a 10% of the cargo use the Suez Canal and is potentially affected by this threat. Recent reports indicate that piracy is on the decline in Somalia (Saul, 2013). The ongoing slowdown in attacks might be due to the presence of navy patrols and enhanced on-board security (World Bank, 2013). In any case, these methods of protection and security are quite costly, so even in the absence of a significant number of attacks, pirates would have increased cargo tariffs affecting international trade.

# Results

As discussed earlier, we use a multiplier DEA input model to analyze the logistics performance for a group of 141 countries. Table 3 shows the results for the twenty best and worst countries in the world included in our analysis. It can be seen that the group of best performers are mainly characterized by high-income countries that belong to Europe and Asia together with the US and Canada. However, the list of the twenty worst countries is highly biased to the Africa continent and some other low-income countries of other regions like Bhutan, Myanmar, Haiti and Afghanistan[[6]](#footnote-6).

(Insert Table 3 here)

An examination of the Table 3 reveals that, according to the efficiency LPI-DEA score, Belgium, Germany, Norway and Luxembourg are the most competitive countries in the world regarding their logistics performance. In fact, they form the peers in the frontier according to DEA parlance. It is interesting to remark that these countries are all located in the European continent and although Norway is not a member of the European Union (EU), the country has a long established good relationship through the Agreement on the European Economic Area (EEA) which facilitates that Norway takes part in the EU internal market. Norway also signed the Schengen Agreement and cooperates with the EU on foreign and security policy issues. Regarding the ten best performers, all the countries are considered as high income according to the PPP-GNI[[7]](#footnote-7) index for the year 2011 elaborated by the World Bank. Most of them belong to the OECD and only Taiwan and Singapore are non-OECD countries. On the other hand, it can be seen that Djibouti, Eritrea, Syrian Arab Republic, Afghanistan and Somalia are the least competitive countries of the world. At this respect, it can be seen now that the majority of the countries are located in Africa with the only exception of Afghanistan that is located in Asia. In this respect, freight logistics systems in Afghanistan are exploited for a variety of illicit activities, in particular for trafficking of prohibited and restricted goods[[8]](#footnote-8). For example, the heroin annual flows into the global market are assessed to be between 430-450 tons, and Afghanistan is the main source followed by Myanmar and Laos (UNODC, 2010). Djibouti and Eritrea share part of the coast of the Red Sea but very near to Somali routes where the pirates’ conflicts of the last decade have reduced the cargo trade passing through the Gulf of Aden. All the countries belong to the groups of low or lower middle income.

Comparing the groups of worst and best performers countries according to the DEA-LPI and the LPI, it can be seen that the four countries that belong to the frontier using our empirical results are ranked as the first (Germany), the third (Belgium), the seventh (Norway) and the eighth (Luxembourg).

(Insert Table 4 here)

Focusing on the logistics performance of the ten best countries according to these two methodologies, we can observe that there are four main mismatches in the following set: Taiwan (10,19), France (9,13), United States (12,9) and Japan (13,10) (Table 4). The first figure in parenthesis shows the rank obtained by our LPI-DEA method and the second figure gives the rank obtained by the LPI methodology[[9]](#footnote-9). Regarding the other extreme of the worst performers, it can be seen that the five worst performers according to our methodology are also located in the set of the seven worst performers of the LPI method. It can also be highlighted that in this case there are only three mismatches looking at the group of the ten worst performers using both methods, name list: Yemen (12,7), Mozambique (7,11), and Haiti (10,14). Using a spearman’s correlation coefficient to estimate a rank-based measure of association between these two methods, we conclude that there is a positive association between the two methods (ρ=0.9816). The value of rho shows that these two methods do not obtain the same ranking logistics performance as discussed above.

It seems that income and geographical area might influence the DEA-LPI score by analyzing the group of worst and best performers. For this reason, one-way analysis of variance is going to be used in order to examine whether there are significant differences that can be accrued to these particular factors. Table 5 shows the standard anova table, which divides the variability of the DEA-LPI performance into two parts: variability due to the differences among the factor groups means (variability between groups); and variability due to the differences between the individual country performance in each group and the group mean (variability within groups).

(Insert Table 5)

The results of the anova show that the null hypothesis, i.e., the average performance of the DEA-LPI is equal, independently of the geographical area location or income, may be rejected. The p-value, shown in the sixth column, casts doubt on the null hypothesis and suggests that at least the logistics performance on some group of countries is significantly different from other groups. We compare the performance of the groups of the countries according to their geographical area and income and we test the hypothesis that the average DEA-LPI score is the same, against the general alternative that some significant differences exist. However, as we accept the alternative hypothesis and it is too general, we would like to obtain more particular information about which pairs of means are significantly different, and which are not. For this reason, we study pair wise mean differences to assess in what sense a group can be characterized by its better or lower performance.

To do this, we need to use some multiple comparison procedure. In our case, we use the Tukey-Kramer test in order to determine whether the DEA-LPI performance is significantly different according to each of the factors under analysis. As we want to compare every group to each other, we can form ten and twenty-one different pairwise comparisons to obtain their mean differences attending their income and geographical area, respectively. Differences and 95% confidence interval for these differences are presented in Table 6.

(Insert Table 6)

It can be seen that the difference between the High Income OECD countries and High Income non OECD countries is 0.2004 and a 95% confidence interval for the true mean is [0.0908, 0.3100]. In this example the confidence interval does not contain 0, so the difference is significant at the 0.05 level[[10]](#footnote-10), and we can conclude that the performance of logistics of High Income OECD countries is better than those that belong to the group of High income non OECD countries.

If the confidence interval contains the zero value, then we conclude that the difference is not statistically significant at the 0.05 level (see, for example, the eighth row in Table 6). In this case, we can conclude that the performance of the Lower Middle Income countries is not significantly different from the Low Income countries. However, it can be seen that the rest of the rows show a statistical significant difference between the countries that belong to different income groups. In all the cases, the expected conclusion that says that higher income countries are better logistic performers is observed.

In a similar way, Table 7 shows the relative performance of the countries focusing now in the geographical area. In this case, it can be seen that the differences can be accrued to different areas that include Latin American & Caribbean, South Asia, Sub-Saharan Africa, Middle East & North Africa as low performance regions; and East Asia & Pacific, Europe & Central Asia and North America as high performers.

(Insert Table 7)

Sub-Saharan Africa region presents the lowest DEA-LPI performance of the world in spite of receiving a lot of funding and attention in the last years for potential infrastructure development that addressed this area’s massive deficiencies in transport provision (Gwilliam, 2010; Gwilliam et al., 2010). Foster and Briceño-Garmendia (2010) found the following Decalogue: (1) infrastructure has been responsible for more than half of Africa’s recent improved growth performance and has the potential to contribute even more in the future; (2) Africa’s infrastructure networks increasingly lag behind those of other developing countries and are characterized by missing regional links; (3) Africa’s economic geography presents a particular challenge for the region’s infrastructure development; (4) Africa’s infrastructure services are twice as expensive as elsewhere, and lack of competition is one of the main causes; (5) Power is by far Africa’s largest infrastructure challenge; (6) The costs of addressing Africa’s infrastructure needs is around $ 93 billion a year; (7) The infrastructure challenges are very heterogeneous among different countries; (8) A large share of Africa’s infrastructure is still domestically financed mainly by the central government budget; (9) Africa would still face an infrastructure funding gap of $ 31 billion a year; and (10) Africa’s institutional, regulatory, and administrative reforms are only halfway along.

# Concluding remarks

Our DEA-LPI has aimed to contribute to the literature strand on the ranking of countries regarding the performance on logistics. To our knowledge, there are only two studies with a similar aim: the DEA-PC method proposed by Markovits-Somogyi and Bokor (2014) and the LPI method proposed by Arvis et al. (2014). The approach adopted in the present study is an hybrid of both of the methods as it used DEA as the methodological approach and the LPI database in terms of the variables and the countries included in the analysis. Our method is based on an input orientation DEA efficiency model which presents some major advantages over other traditional ranking and benchmarking models. In particular, it could be used to rank all the countries unambiguously except the four countries that were part of the frontier.

This paper has offered interesting insights into the benchmark position of the countries regarding the logistics performance. Our findings reveal striking differences among the best and the worst performers, as well as among different geographical areas. We have also compared our results with those provided by the original LPI, finding that there is a significant positive association between these two methods. Nevertheless, as it was discussed the methods did not give the same results.

We have also found that the logistic performance depends largely on income and geographical area. On one hand, our findings suggest that high income countries are in the group of best performers. In particular, we found that the group of the ten best performers is highly dominated by the EU. It is difficult to predict additional related strategic re-location of logistics and production platforms in specific industries that would result in a deterioration of Europe’s role as a main production/industrial world region. However, the recent financial crisis that has affected the euro zone and the Greek situation could affect this leadership in the near future. On the other hand, in spite of all the efforts that have been made in the recent past there is still a big gap between this developed region and the Sub-Saharan region. More innovative logistics programs need to be developed in the lagged regions of the world.

This new method maximizes the radial distance for those variables considered as outputs taking into account that all the countries are relatively dominated by those countries that form the technological frontier. Furthermore, the new model could be adapted to reflect realistic conditions in an efficiency-improvement projection taking into account different layers of projection conformed by a different set of countries. Thus, the stepwise projection allows all the countries to incorporate more realistic levels of potential improvement than take into account their own characteristics and those from the area where they are located. To summarize, this stepwise DEA-LPI model would be able to present a more realistic direction and intensity for efficiency-improvement regarding logistics performance, and may thus provide a valid tool for planners and policy makers for implementing adequate logistic programs.

# References

Ali, A., and Seiford, L.M. (1993) The Mathematical Programming Approach to Efficiency Analysis. In: The Measurement of Productive Efficiency: Techniques and Applications, eds, Fried, H.O., Lovell, C.A.K and Schmidt, S.S. Oxford University Press, New York.

Arvis, J.F., Mustra, M., Ojala, L., Shepherd, B., and Saslavsky, D. (2012) *Connecting to compete: Trade logistics in the global economy*. Washington DC: The World Bank.

Arvis, J.F., Mustra, M., Panzer, J., Ojala, L., and Naula, T. (2007) *Connecting to compete: Trade logistics in the global economy*. Washington DC: The World Bank.

Arvis, J.F., Mustra. M., Ojala, L., Shepherd, B., and Saslavsky, D. (2010) *Connecting to compete: Trade logistics in the global economy*. Washington DC: The World Bank.

Arvis, J.F., Saslavsky, D., Ojala, L., Shepherd, B., Busch, C., and Raj, A. (2014) *Connecting to Compete 2014: Trade Logistics in the Global Economy--The Logistics Performance Index and Its Indicators*. Washington DC: The World Bank.

Behar, A., and Manner, P. (2008) Logistics and Exports, *African Economics Working* Paper Series 293.

Blyde, J.,and Gonzalo Iberti, G. (2012) [Trade Costs, Resource Reallocation and Productivity in Developing Countries](https://ideas.repec.org/a/bla/reviec/v20y2012i5p909-923.html), [Review of International Economics](https://ideas.repec.org/s/bla/reviec.html), 20(5) 909-923.

Boske, L. (2001) Maritime transportation in Latin America and Caribbena, *Policy Research Project Report No. 138, School of Public Affairs*. The University of Texas at Austin

Bulando, A., Cristea, A., and Lee, L.M. (2015) The Trade Consequences of Maritime Insecurity: Evidence from Somali Piracy**,** Review of International Economics. doi:10.1111/roie.12183

Charnes, A., and Cooper, W.W. (1985) Preface to topics in data envelopment analysis, Annals of Operations Research, 2(1) 59-94.

Charnes, A., Cooper, W., Lewin, A.Y., and Seiford, L.M. (1994) *Data Envelopment Analysis. Theory, Methodology and Applications*. Kluwer Academic. Boston.

Charnes, A., Cooper, W.W., and Rhodes, E. (1978) Measuring the Efficiency of Decision Making Units, European Journal of Operational Research, 2(6) 429-444.

Cherchye, L., Moesen, W., Rogge, N., Van Puyenbroeck, T., Saisana, M., Saltelli, A., and Tarantola, S. (2008) Creating composite indicators with DEA and robustness analysis: the case of the Technology Achievement Index, Journal of the Operational Research Society, 59(2) 239-251.

Coelli, T. (1996) A guide to DEAP version 2.1: a data envelopment analysis (computer) program, *CEPA Working Paper 96/08. Centre for Efficiency and Productivity Analysis*, University of New England, Armidale.

Coelli, T., Rao, D.S.P., and Battese, G.E. (1998) *An Introduction to Efficiency and Productivity Analysis*, Kluwer Academic, Boston.

Cook, W.D., Seiford, L.M. (2009) Data envelopment analysis (DEA) – Thirty years on. European, Journal of Operational Research, 192 (1) 1–17.

Cooper, W. W., Seiford, L. M., and Zhu, J. (2011) Handbook on data envelopment analysis, 164, Springer Science & Business Media.

De Souza, R., Goh, M., and Gupta, S. (2007) An investigation into the measures affecting the integration of ASEAN’s priority sectors: phase 2: the case of logistics, *REPSF Project No. 06/001d Regional Economic Policy Support Facility*, Association of Southeast Asian Nations, Manila.

Decreux, I., and Fontagne, L. (2006) A quantitative assessment of the outcome of the Doha development agenda, *CEPII working paper* 2006-10.

Dennis, A. (2006) The impact of regional trade agreements and trade facilitation in the Middle East and North Africa region, *World Bank Policy Research Working Paper* 3837.

Emrouznejad, A., Parker, B.R., and Tavares, G. (2008) Evaluation of research in efficiency and productivity: a survey and analysis of the first 30 years of scholarly literature in DEA, Socio-Economic Planning Sciences 42 (3), 151–157.

Farrel, M.J. (1957) The Measurement of Productive Efficiency, Journal of the Royal Statistical Society A120, 253-290.

Filippetti, A., and Peyrache, A. (2011) The patterns of technological capabilities of countries: a dual approach using composite indicators and data envelopment analysis, World Development, 39(7) 1108-1121.

Foster, V., and Briceno-Garmendia, C. (2010) *Africa’s Infrastructure: A time for transformation*. Washington, DC: World Bank.

Gwilliam, K. (2010) Transport: More than the sum of its parts. In V. Foster & C. Briceno- Garmendia (Eds.), Africa’s Infrastructure: A time for transformation, 203–210, Washington, DC: World Bank.

Gwilliam, K., Sethi, K., Nogales, A., and Foster, V. (2010) Roads: Broadening the Agenda. In V. Foster & C. Briceno-Garmendia (Eds.), Africa’s Infrastructure: A time for transformation, 211–228, Washington, DC: World Bank.

Herrera A (2005) Equipment for intermodal transportation. U.S. Commercial Service

Hintsa, J., and Mohanty, S. (2014) A Literature-Based Qualitative Framework for Assessment of Socio-Economic Negative Impacts of Common Illicit Cross-border Freight Logistics Flows. In T. Blecker, W. Kersten & C. M. Ringle (Eds.), Innovative Methods in Logistics and Supply Chain Management. Current Issues and emerging practices, 317, 319-340, Berlin: epubli GmbH.

Hoekman, B., and Nicita, A. (2011) Trade Policy, trade costs, and developing country trade, World Development, 39, 2069-2079.

Jiang, C. (2010) Research on logistics network infrastructure based on HCA and DEA-PCA approach, Journal of Computers, 5(4) 533–540.

Jiang, C., and Fu, P. (2009) Evaluating efficiency and effectiveness of logistics infrastructure based on PCA-DEA approach in China. In Second International Conference on Intelligent Computation Technology and Automation, 2009. ICICTA'09, (3) 62-66, IEEE.

Korinek, J., and Sourdin, P. (2011) To what extent are high-quality logistics services trade facilitating?, OECD Trade Policy Working Papers 108. OECD Publishing.

Mahlberg, B., and Obersteiner, M. (2001) Remeasuring the HDI by data envelopment analysis, *International Institute For Applied Systems Analysis Intering Report*, 01-069.

Markovits-Somogyi, R., and Bokor, Z. (2014) Assessing the logistics efficiency of European countries by using the DEA-PC methodology, Transport 29(2), 137–145.

Moïsé, E. (2013) The costs and challenges of implementing trade facilitation measures, *OECD Trade Policy Papers*, 157, OECD Publishing

OECD. (2003) Quantitative Assessment of the Benefits of Trade Facilitation, *TD/TC/WP31*,OECD, Paris.

OECD. (2008) *Handbook on Constructing composite indicators. Methodology and user guide*, OECD Publications, Paris.

Osberg, L., and Sharpe, A. (2002) An index of economic well-being for selected OECD countries, Review of income and wealth, 48 (3) 291-316.

Puertas, R., Martí, L., and García, L. (2014) Logistic performance and export competitiveness: European experience, Empirica, 41, 467-80.

Rushton, A., Croucher, P., and Baker, P. (2014) *The handbook of logistics and distribution management: Understanding the supply chain*, London: Kogan Page Publishers.

Sanz, A. (2014) IX Conferencia Ministerial de la Organización Mundial de Comercio, Boletín Económico del ICE, 3.047, 3-9.

Saul, J. (2013) Sea Piracy Falls to 5-year Low as Somali Gangs Retreat. Reuters, 16 January.

Seiford, L.M. (1996) Data envelopment analysis: the evolution of the state of the art (1978–1995), The Journal of Productivity Analysis 7, 99–137.

Seiford, L.M., and Thrall, R.M. (1990) Recent developments in data envelopment analysis: The mathematical programming approach to frontier analysis, Journal of Econometrics 46, 7-38.

Soloaga, I., Wilson, J.S., and Mejía, A. (2006) Trade facilitation reform and Mexican competitiveness, *World Bank Policy Research Working Paper* 3953, June.

UNDP. (2001) *Human development report*, New York Oxford University Press

UNODC. (2010) *World Drug Report*, United Nations Publication.

Wilson, J.S, Mann, C.L., and Otsuki. T. (2005) Assessing the potential benefit of trade facilitation: a global perspective. in P. Dee and M. Ferrantino (Eds), *Quantitative Methods For Assessing the Effects of Non-tariff Measures and Trade Facilitation* APEC Secretariat and World Scientific, Singapore: 121-60

World Bank (2013) Pirates of Somalia: Ending the Threat, Rebuilding the Nation, Regional Vice-Presidency for Africa, World Bank, Washington, DC.

Zhu, J. (2014) Quantitative models for performance evaluation and benchmarking: data envelopment analysis with spreadsheet, 213, Springer.

1. Different envelopment surfaces may be obtained considering additional constraints about the scalars. For example, variable returns to scale models (VRS) are obtained imposing that the sum of scalars is equal to one; and non-increasing return to scale models (NIRS) are characterized by the restriction of the sum of scalars being less or equal to one. [↑](#footnote-ref-1)
2. This discussion is very close to the definition of Pareto-Koopmans efficiency. The unit *o* is considered fully efficient if and only if the performance of other DMUs does not provide evidence that some of the inputs or outputs of the unit *o* could have been improved without worsening off some of its other inputs or outputs. This definition of relative performance has its origin in Farrell (1957). [↑](#footnote-ref-2)
3. The questionnaire is available at www.worldbank.org/lpi [↑](#footnote-ref-3)
4. The LPI published in 2010, 2012 and 2014 only take six indicators into consideration (they exclude the domestic logistics costs included in 2007). [↑](#footnote-ref-4)
5. For example see, Boske (2001) and Herrera (2005) [↑](#footnote-ref-5)
6. We note here that all the LPI-DEA figures are lower than or equal to one. 1. The values have been calculated according to the formulation of DEA-LP program described by equation 2. [↑](#footnote-ref-6)
7. GNI per capita based on purchasing power parity (PPP). PPP GNI is gross national income (GNI) converted to international dollars using purchasing power parity rates. An international dollar has the same purchasing power over GNI as a U.S. dollar has in the United States. GNI is the sum of value added by all resident producers plus any product taxes (less subsidies) not included in the valuation of output plus net receipts of primary income (compensation of employees and property income) from abroad. [↑](#footnote-ref-7)
8. It is out of the scope of the current paper to analyze to what extent there exist a negative relationship between this illicit trade and the logistics performance. Hintsa and Mohanty (2014) prepared a literature-based qualitative framework for the assessment of socio-economic negative impacts on six commonly occurring illegal trade flows: (1) trafficking in cocaine and heroin; (2) counterfeit products; (3) ozone depleting substances; (4) firearms; (5) stolen cultural products; and (6) endangered species. [↑](#footnote-ref-8)
9. The LPI is constructed using principal component analysis (PCA) in which the normalized scores for each of the six original indicators are multiplied by their component loadings and then summed. The component loadings represent the weight given to each original indicator in constructing the international LPI. Since the loadings are similar for all six, the international LPI is close to a simple average of the Indicators. [↑](#footnote-ref-9)
10. In fact, the probability shown in the last column of the table can be used to obtain the exact p-confidence value. [↑](#footnote-ref-10)