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# A DEA-LOGISTICS PERFORMANCE INDEX

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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. The aim of this paper is to propose a data envelopment analysis (DEA) approach to compute a synthetic index of overall logistics performance (DEA-LPI) and benchmark the logistics 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). Furthermore, the paper also analyses the potential differences observed when using different variables, namely income and geographical area. Our findings suggest that the logistics performance depends largely on income and geographical area. High income countries are in the group of best performers, which is highly dominated by the EU.

*JEL classification codes*: C5, F1, O52, R4
*Key words*: logistics performance, freight transport, data envelopment analysis, logistics performance index

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## I. Introduction

International trade has recently been affected by globalization and increased competitiveness of lagged regions that in the past did not play such an important role in the world. This trend has had an extreme impact on logistics as one of the key elements facilitating 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 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 Business* ranking. However they differ in a number of respects, and so are not interchangeable.

Specifically, the *Doing 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.

A 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 logistics performance of the countries. According to the 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'.[1] 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).The literature includes research on synthetic indexes in technological and social capabilities of countries (Mahlberg and Obersteiner 2001; Osberg and Sharpe 2002; Filippetti and Peyrache 2011). Nevertheless, the literature on countries' logistics performance is certainly scant with the exception of Markovits-Somogyi and Bokor (2014). Thus, this paper contributes with a second empirical application to this understudied research field providing a new synthetic logistics performance index based on DEA and using the LPI database.

In this study, we propose another objective measure for countries´ logistics. Therefore, the aim of this paper is fourfold: (1) to compute a synthetic index of overall logistics performance (DEA-LPI) using a DEA method that could be used to benchmark the logistics 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) under three different scenarios considering a different selection of inputs and outputs; (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

[1] OECD, *Glossary of Statistical Te*rms.

logistics performance; (3) a comparison of the results with the different methods will be performed analysing to what extent there exists a positive association between all the methods; furthermore, (4) 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 II offers some insights from the literature, Section III details the methodology, Section IV describes the data section, Section V presents and discusses the results, and Section VI concludes.

## II. 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. Nevertheless these reforms do not always compensate the myriad of non-tariff barriers that are often more important for 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 traded 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 harmonization of international trade procedures, including the activities, practices and formalities involved in collecting, presenting, communicating and processing data and other information 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) analyses 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.

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. Some authors remark that there are inherent benefits of applying DEA in the context of countries' performance analysis as the method is based on the most favorable and country-specific weights (Atkinson et al. 2002; Cherchye et al. 2008). Thus, the controversy on the subjective judgments regarding the weights for the sub-indicators that are needed in other methodologies does not exist. There exist a number of papers that analyze under different perspective the previous research that have appeared in the DEA literature (Charnes et al. 1994; Emrouznejad et al. 2008; Cook and Seiford 2009; Cooper et al. 2011; Zhu 2014).

These reviews show that the applications which deal directly with DEA evaluations of countries' logistics performance are inexistent. To our best knowledge, there are only two studies that analyze the logistics performance of cities (Jiang 2010) or regions (Jiang and Fu 2009), and there is only one study which deals with the countries' logistics performance (Markovits-Somogyi and Bokor 2014). In this last paper, the authors analyzed the logistics efficiency of 29 European countries using a methodology where DEA is combined with an 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.

## III. Methodology

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 $x_{io}$ units of input $i$ ($I$ = 1 to $m$) and produces $y_{ro}$ units of output $r$ ($r$ =1 to $s$). The $o$'th production unit can be described more compactly with the vector $(X_o,Y_o)$, which denote, respectively, the vectors of input and output values for $DMU_o$.

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.[2] 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. In the same way, it is dominated in terms of 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.[3]

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 actions 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 Returns to Scale (CRS) input orientation model. In this sense, the problem is resolved for each country through the following linear programming specification:

$$\begin{aligned} &\max_{v\mu} \sum_{r=1}^{s} \mu_r y_{r0} \quad ; \\ &\text{s.t. } \sum_{i=1}^{m} v_i x_{ij} - \sum_{r=1}^{s} \mu_r y_{rj} \geq 0 \quad (j = 1 \cdots n), \sum_{i=1}^{m} v_i x_{i0} = 1, \text{where } v_i, \mu_r \geq 0. \end{aligned} \tag{1}$$

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[2] Different envelopment surfaces may be obtained considering additional constraints about the scalars. For example, VRS models are obtained imposing convexity constraint N1´λ=1; and non-increasing return to scale models (NIRS) are characterized by the restriction of the sum of scalars being less or equal to one.

[3] 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).

A country is in the frontier only if $\sum_{r=1}^{s} \mu_r y_{ro} = 1$ , this is optimality. The constraint $\sum_{i=1}^{m} v_i x_{io} = 1$ 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.

## IV. 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 logistics 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; the second edition contains data processed between 2008 and 2009; the third edition contains information for the year 2010, following the same sequence for 2012. 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 the 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.[4] Each respondent of 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.[5] 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. 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

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[4] The questionnaire is available at www.worldbank.org/lpi

[5] The LPI published in 2010, 2012 and 2014 only take six indicators into consideration (they exclude the domestic logistics costs included in 2007).

the efficiency of the service. Each component is key to determining competitiveness in international trade within each country. Any changes to these components has 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.[6]

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 (Arvis et al., 2014), higher-income countries occupy the top 10 positions in the 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 ranking 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 has narrowed progressively. The LPI expressed as a percentage of the highest country in the ranking reveals that the LPI for Somalia represents 25% 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 infrastructure 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, three different DEA scenarios are proposed (Table 1). The first scenario is characterized by considering customs, infrastructure, and international shipments as inputs, applying a monotone decreasing transformation (five minus

[6] For example see, Boske (2001) and Herrera (2005)

the original values). This first scenario is based on the first category proposed by Arvis et al (2007). The authors claimed that this category contains mainly inputs to the supply chain such as customs, infrastructure, and ease of arrangement for international shipments. The rest of components that belong to the second category are left as outputs with their original values. The second scenario is based on the DEA method in which all the LPI components are considered as outputs jointly with a single constant input variable. In the third scenario, the role of inputs and outputs between the original LPI components is reversed. These three scenarios are used to perform a sensitivity analysis as a way to assess the robustness of the final results.[7]

Table 2 shows the descriptive statistics for the inputs and outputs of the LPI components that were included in our analysis under the first scenario. As it can be observed, there are great differences between the minimum and maximum values of almost all variables. However, the standard deviation and average figures do not

**Table 1. Inputs and outputs used in the study under three different scenarios**

**A. First scenario (base)**

| Inputs | Outputs |
|---|---|
| Customs | Logistics quality and competence |
| Infrastructure | Tracking and tracing |
| Ease of arrangement shipments | Timeliness |

**B. Second scenario**

| Inputs | Outputs |
|---|---|
| A single constant variable (1) | Customs |
| | Infrastructure |
| | Ease of arrangement shipments |
| | Logistics quality and competence |
| | Tracking and tracing |
| | Timeliness |

**C. Third scenario**

| Inputs | Outputs |
|---|---|
| Logistics quality and competence | Customs |
| Tracking and tracing | Infrastructure |
| Timeliness | Ease of arrangement shipments |

Source: Own elaboration.

[7] The robustness analysis was suggested by two anonymous reviewers.

show any particular pattern with the exception that timeliness is the only variable that presents an average figure higher than three. This means that timeliness 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 (Norway, Germany and Luxembourg) are Western European countries. Regarding the worst performers, there are only two countries (Somalia and Yemen) that present the lowest figures in the whole set of dimensions.

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 a consequence of 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, even in the absence of a significant number of attacks, pirates would have increased cargo tariffs affecting international trade.

**Table 2. Descriptive statistics**

| Variables | Mean | SD | Min | Country | Max | Country |
|---|---|---|---|---|---|---|
| Inputs | | | | | | |
| Customs | 2.24 | 0.60 | 0.79 | Norway | 3.38 | Yemen |
| Infrastructure | 2.19 | 0.67 | 0.68 | Germany | 3.50 | Somalia |
| International shipments | 2.10 | 0.49 | 1.18 | Luxembourg | 3.25 | Somalia |
| Outputs | | | | | | |
| Logistics quality and competence | 2.90 | 0.58 | 1.75 | Somalia | 4.19 | Norway |
| Tracking and tracing | 2.94 | 0.59 | 1.75 | Somalia | 4.17 | Germany |
| Timeliness | 3.30 | 0.59 | 1.88 | Somalia | 4.71 | Luxembourg |

Source: Own elaboration.

## V. 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 under the first scenario. We find 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.[8]

**Table 3. The 20 best and worst countries in the world according to the DEA-LPI. 1st scenario.**

| Rank | Country | VDEA | Rank | Country | VDEA |
|---|---|---|---|---|---|
| 20 Best Countries | | | | | |
| 1 | Belgium | 1.00000 | 11 | Denmark | 0.85666 |
| 2 | Germany | 1.00000 | 12 | USA | 0.82392 |
| 3 | Norway | 1.00000 | 13 | Japan | 0.81430 |
| 4 | Luxembourg | 1.00000 | 14 | Switzerland | 0.80654 |
| 5 | Sweden | 0.94133 | 15 | China. Hong Kong SAR | 0.80531 |
| 6 | Singapore | 0.93740 | 16 | New Zealand | 0.80391 |
| 7 | Netherlands | 0.91997 | 17 | Ireland | 0.79227 |
| 8 | United Kingdom | 0.89631 | 18 | Malaysia | 0.78170 |
| 9 | France | 0.86466 | 19 | Australia | 0.77113 |
| 10 | Taiwan, China | 0.85707 | 20 | Canada | 0.76995 |
| 20 Worst Countries | | | | | |
| 122 | Bhutan | 0.27736 | 132 | Haiti | 0.25536 |
| 123 | Lesotho | 0.27704 | 133 | Sudan | 0.25501 |
| 124 | Zimbabwe | 0.27650 | 134 | Kyrgyz Republic | 0.25125 |
| 125 | Azerbaijan | 0.27380 | 135 | Mozambique | 0.24209 |
| 126 | Zambia | 0.27243 | 136 | Mauritania | 0.23931 |
| 127 | Gabon | 0.27225 | 137 | Djibouti | 0.22814 |
| 128 | Tanzania | 0.27083 | 138 | Eritrea | 0.22584 |
| 129 | Cameroon | 0.26782 | 139 | Syrian Arab Republic | 0.22284 |
| 130 | Yemen, Rep. | 0.26521 | 140 | Afghanistan | 0.21587 |
| 131 | Myanmar | 0.25619 | 141 | Somalia | 0.15952 |

Source: Own elaboration.

[8] We note here that all the DEA-LPI 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.

An examination of the Table 3 reveals that, according to the efficiency DEA-LPI 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[9] 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. The majority of the countries in the lower end of the ranking are located in Africa. The freight logistics systems in Afghanistan are exploited for a variety of illicit activities, in particular for trafficking of prohibited and restricted goods.[10] 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).

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[9] 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.

[10] 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.

Focusing on the logistics performance of the ten best countries according to these two methodologies, we observe that there are four main mismatches in the following set: Taiwan (10, 12, 17, 19), France (9, 13, 14, 13), United States (12, 6, 6, 9) and Japan (13, 14, 11, 10) (Table 4). The first three figures in parenthesis show the rank obtained by our DEA-LPI method under the three different scenarios and the last figure gives the rank obtained by the LPI methodologym.[11] Regarding the other extreme, the five worst performers according to our methodology are also located in the set of the seven worst performers of the LPI method. There are only three mismatches looking at the group of the ten worst performers using both methods, namely Yemen (131, 132, 131, 136), Mozambique (136, 138, 136, 132), and Haiti (133, 135, 134, 129). Using a Spearman correlation coefficient to estimate a rank-based measure of association between these four ranking methods, we can conclude that there is a positive association between all the four methods (ϱ lies in

**Table 4. Mismatches between DEA-LPI ranks and LPI rank. Spearman correlation coefficients**

| | DEA-LPI | | | LPI-Rank |
|---|---|---|---|---|
| | 1st scenario | 2nd scenario | 3rd scenario | |
| Best dountries | | | | |
| Taiwan | 10 | 12 | 17 | 19 |
| France | 9 | 13 | 14 | 13 |
| USA | 12 | 6 | 6 | 9 |
| Japan | 13 | 14 | 11 | 10 |
| Worst countries | | | | |
| Yemen | 131 | 132 | 131 | 136 |
| Mozambique | 136 | 138 | 136 | 132 |
| Haiti | 133 | 135 | 134 | 129 |

| | Spearman correlation coefficients | | |
|---|---|---|---|
| | DEA-LPI (1) | DEA-LPI (2) | DEA-LPI (3) |
| LPI-Rank | 0.9819 | 0.9655 | 0.9870 |
| DEA-LPI (2) | | 0.9891 | 0.9907 |
| DEA-LPI (3) | | | 0.9821 |

Source: Own elaboration.

[11] The LPI is constructed using 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.

the range between 0.9655 and 0.9907). The values of ϱ show that these four methods do not obtain the same ranking logistics performance as discussed above. Nevertheless, the robustness of DEA results to different selection of inputs and outputs has been proven. Thus for the rest of the paper, DEA-LPI results are referred to the first scenario under consideration.

By analyzing the group of worst and best performers, it seems that income and geographical area might influence the DEA-LPI score. 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).

The results of the ANOVA analysis 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 in some group of countries is significantly different from other groups. We compare the

**Table 5. One-way analysis of variance. TTCI performance by income and geographical area**

| | Df | SumSq | MeanSq | Fvalue | Pr(>F) | |
|---|---|---|---|---|---|---|
| Income | 4 | 4.140 | 1.034 | 66.6 | <2e-16 | *** |
| Residuals | 136 | 2.113 | 0.015 | | | |
| Geographical Area | 6 | 2.362 | 0.3926 | 13.55 | 5.54e-12 | *** |
| Residuals | 134 | 3.891 | 0.029 | | | |
| Grand mean: 0.4747 | | | | | | |
| Income factor means | | | | | | |
| Low Income | Lower Middle Income | | Upper Middle Income | High Income Non OECD | High Income OECD | |
| 0.308 (29)* | 0.351 (36) | | 0.447 (32) | 0.574 (15) | 0.774 (29) | |
| Geographical area factor means | | | | | | |
| East Asia & Pacific | Europe & Central Asia | | Latin America & Caribbean | | Middle East & North Africa | |
| 0.58 (19) | 0.61 (41) | | 0.39 (21) | | 0.42 (15) | |
| North America | South Asia | | Sub-Saharan Africa | | | |
| 0.79 (2) | 0.35 (7) | | 0.32 (36) | | | |

Notes: *** 1% significance codes.* The number of countries appears between parentheses for each of the factor means.
Source: Own elaboration.

performance of the groups of 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.

As shown in Table 6, we find that 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,[12] 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.

**Table 6. Tukey multiple comparisons of means. 95% family-wise confidence level**

| Comparison (Income) | Difference | Lower | Upper | Probability |
|---|---|---|---|---|
| High income OECD/High income non OECD | 0.2004 | 0.0908 | 0.3100 | 0.0000134 s |
| Low income/High income non OECD | -0.2663 | -0.3759 | -0.1567 | 0.0000000 s |
| Lower middle income/High income non OECD | -0.2232 | -0.3291 | -0.1173 | 0.0000004 s |
| Upper middle income/High income non OECD | -0.1266 | -0.2345 | -0.0188 | 0.0125630 s |
| Low income/High income OECD | -0.4667 | -0.5572 | -0.3762 | 0.0000000 s |
| Lower middle income/High income OECD | -0.4236 | -0.5096 | -0.3377 | 0.0000000 s |
| Upper middle income/High incom OECD | -0.3270 | -0.4154 | -0.2387 | 0.0000000 s |
| Lower middle income/Low income | 0.0430 | -0.0429 | 0.1290 | 0.6381660 |
| Upper middle income/Low income | 0.1397 | 0.0513 | 0.2280 | 0.0002335 s |
| Upper middle income/Lower middle income | 0.0966 | 0.0128 | 0.1803 | 0.0149684 s |

Notes: s Differences are statistically significant for the comparison between the groups under consideration at least at 95 per cent of confidence level. Source: Own elaboration.

[12] In fact, the probability shown in the last column of the table can be used to obtain the exact p-confidence value.

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 logistics 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,

**Table 7. Tukey multiple comparisons of means. 95% family-wise confidence level**

| Comparison (geographical area) | Difference | Lower | Upper | Probability |
|---|---|---|---|---|
| Europe & Central Asia/East Asia & Pacific | 0.03565 | -0.10592 | 0.17723 | 0.98872 |
| Latin America & Caribbean/East Asia & Pacific | -0.18551 | -0.34703 | -0.02399 | 0.01344 s |
| Middle East & North Africa/East Asia & Pacific | -0.15567 | -0.33187 | 0.02052 | 0.12105 |
| North America/East Asia & Pacific | 0.21386 | -0.16537 | 0.59309 | 0.62508 |
| South Asia/East Asia & Pacific | -0.22528 | -0.45083 | 0.00028 | 0.05050 s |
| Sub-Saharan Africa/East Asia & Pacific | -0.25987 | -0.40453 | -0.11522 | 0.00001 s |
| Latin America & Caribbean/Europe & Central Asia | -0.22116 | -0.35806 | -0.08427 | 0.00007 s |
| Middle East & North Africa/Europe & Central Asia | -0.19133 | -0.34527 | -0.03739 | 0.00529 s |
| North America/Europe & Central Asia | 0.17821 | -0.19121 | 0.54762 | 0.77675 |
| South Asia/Europe & Central Asia | -0.26093 | -0.46956 | -0.05231 | 0.00488 s |
| Sub-Saharan Africa/Europe & Central Asia | -0.29553 | -0.41204 | -0.17901 | 0.00000 s |
| Middle East & North Africa/Latin America & Caribbean | 0.02984 | -0.14262 | 0.20229 | 0.99856 |
| North America/Latin America & Caribbean | 0.39937 | 0.02186 | 0.77688 | 0.03067 s |
| South Asia/Latin America & Caribbean | -0.03977 | -0.26241 | 0.18287 | 0.99828 |
| Sub-Saharan Africa/Latin America & Caribbean | -0.07436 | -0.21444 | 0.06571 | 0.68938 |
| North America/Middle East & North Africa | 0.36954 | -0.01448 | 0.75355 | 0.06757 |
| South Asia/Middle East & North Africa | -0.06960 | -0.30311 | 0.16391 | 0.97318 |
| Sub-Saharan Africa/Middle East & North Africa | -0.10420 | -0.26097 | 0.05257 | 0.42604 |
| South Asia/North America | -0.43914 | -0.84816 | -0.03012 | 0.02671 s |
| Sub-Saharan Africa/North America | -0.47374 | -0.84434 | -0.10313 | 0.00366 s |
| Sub-Saharan Africa/South Asia | -0.03460 | -0.24532 | 0.17613 | 0.99893 |

Notes: s Differences are statistically significant for the comparison between the groups under consideration at least at 95 per cent of confidence level. Source: Own elaboration.

Sub-Saharan Africa, Middle East & North Africa as low performance regions; and East Asia & Pacific, Europe & Central Asia and North America as high performers.

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.

## VI. Concluding remarks

Our DEA-LPI has aimed to contribute to the literature strand on the ranking of countries regarding the performance in 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 under three different scenarios 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 shown that the DEA-LPI results are robust to different input and output selection. We have also compared our results with those provided by the original LPI, finding that there is a significant positive association between all the four analyzed methods. Nevertheless, as it was discussed, the methods did not give the same results.

We have also found that the logistics 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 that 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 logistics programs.

We consider that DEA-LPI is a promising tool for ranking countries logistics performance. In this paper, the analysis has been focused on the tool properties and the effects of income and geographical area. However, an interesting area for future research that needs to be addressed could be based on the individual country performance regarding the relative efficiency progress or regress in two different periods of time. Thus, a policy analysis of some specific actions could be analyzed to obtain important practical implications for different stakeholders.

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