EFFICENCY OF FREIGHT TRANSPORTATION INFRASTRUCTURE ON INTERNATIONAL TRADE THROUGH A DATA ENVELOPMENT ANALYSIS NETWORK

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Abstract - Trade logistics involve key steps to facilitate international trade. In this regard, freight transport infrastructure has an important role in international trade efficiency. The aim of this research is to calculate the efficiency levels of 27 countries. We implement a Dynamic DEA model (Data Envelopment Analysis Network) or non-parametric technique DEA Network for the year 2014. The results show that Germany, Argentina, Singapore, Hong Kong, China, the United Kingdom, Thailand, Brazil, Brunei and Costa Rica were the countries with the highest levels of efficiency in freight transportation infrastructure, while the least efficient country was India with 13%. The results also indicate that the great majority of the analyzed countries show inefficiency in the use of resources, and are not achieving maximum optimization revenue. These results also show the importance of implementing strategies that lead to progressive efficiency in international freight transportation infrastructure –with the aim of strengthening investment in infrastructure– and labor policies that contribute to better training of employed personnel.

Keywords - Dynamic, DEA, Freight transportation, logistics.

I. INTRODUCTION

It is well known that an efficient and reliable transport system forms the backbone for the development of any national or regional economy. Nowadays one of the issues regarding the economic development of a country is the need to have an infrastructure with quality to be able to compete in equal circumstances in the international trade environment and to have the ability to move products in an agile and efficient way. Logistics efficiency is an important part of the competitiveness that a country has to rank worldwide. Official data indicates that Mexico has multiplied seven times its rank in the foreign trade in the last two decades (OECD, 2015).

In this sense the transport infrastructure has a fundamental role. At present, the national road network has become the most important route in the country for the movement of goods, representing more than 60% of the exports. Because of this, an important question to answer is how efficient it is compared to the rest of the world.

The objective of this research is to determine how road transport infrastructure has affected international trade, considering several factors that affect the international load mobilization of each of the case study countries. For which it is intended to use the DEA model, which is a non-parametric model that measures efficiency. Specifically, a network model known as two-stage Network DEA, where the first stage corresponds to the technical and quality characteristics of road infrastructure as well as associated costs. And the second stage refers to international trade. The remainder of this inquire is structured in four main sections. In the first section we can find the introduction, the second one presents a brief review on the transport efficiency assessment. The third section proposes the methodology and describes the data collection for assessing regional integrated transport efficiency. The fourth section presents an analysis of the results of efficiency or the 27 countries. And finally, in the conclusions we present an overview of the most important findings and some avenues for further research.

II. METHODOLOGY

The method used in this study is the Data Envelopment Analysis, also known as DEA, a method developed by Charneset al (1978) and Banker et al (1989). DEA is a non-parametric mathematical programming technique that determines an efficient frontier of the most efficient decision-making units (DMUs), optimality regarding the notion of Pareto and calculating the efficiency of each DMU relative to this efficient frontier based on multiple observed inputs and outputs (Liu et al., 2000), (Mahammady, 2006)and (Weber, 1996). DEA defines the ratio between all weighted relevant outputs and inputs. Therefore, it can be represented by the following equation (Šegota, 2003):

$$\text{ef iciency} = \frac{\sum_{r=1}^{s} u_r y_r}{\sum_{i=1}^{m} v_i x_i} \qquad (1)$$

Where:
y_r= amount of output r,
u_r=weight assigned to output r,
s= total number of output r,
x_i=amount of input i,
v_i=weight assigned to input i,

m=total number of input i

2.1. Two-stage Network DEA

The current investigation is based on several other inquiries, among them we can find that of Charnes (1994), where he applies a two-stage DEA model to evaluate the management and policies within the American army recruiting system. Distinctly, Zhu (2000) applies a two-stage model to analyze the financial performance of the 500 best companies according to the Fortune magazine.

The model is output oriented; its inclusion in this investigation is the result of an attempt to increase the value and volume of the international trade by making use of the infrastructure present in the road transportation. The infrastructure input is measured through several indicators such as: the length of the road, its density, the freeways and the investment made in infrastructure, transport and storehouses. The first stage represents the technical variables of the road's infrastructure, as well as its investment. Meanwhile, the outputs represent the costs and logistic times. In the second stage, the outputs signify the value and volume of international trade that is made by means of roads.

2.2. Variables Selection

In transportation, several investigations of the two-stage Network DEA exist, mainly in the railway and maritime systems. Where are considered as inputs; the physical infrastructure of the terminals, either ports or railways, and through intermediaries, such as the transport measured time frequency, we can obtain the exit variables that correspond to the transferred TEUs or the number of transported containers.

In the case of the two-stage model from Li, Cao and Yang (2015), applied to the transport, the considered inputs are the length of the network, the fleet capacity and the staff used in transportation. The outputs correspond to the passengers and the transported load.

In order to do the calculations, several indicators were selected from the representative inputs and outputs of the theoretical framework and the literary revision.

First Stage

Inputs

- Road network. Length of the roads in charge of the federal government and those that make up the federal highway corridor, providing access and communication to the main cities, frontiers and maritime ports of the country and, therefore, register the largest part of passengers and load transportation.
- Road density. It refers to the lineal kilometer proportion of the roads by square kilometer. This data point clarifies the infrastructure development or accessibility situation of each country.
- Highways. It refers to the highways in each country. This indicator includes the superhighways for traffic with high speeds.
- Investment in road, transportation and storehouse infrastructure. Represents the participation percentage of the transportation sector in the total national GDP. This indicator includes transportation and storage, as well as the construction and maintenance investment of the road network.

Intermediary Variables

- Execution term. Is the period between the initiation date and the expiration of the term for the execution of the contract, including the transportation term. The transportation term will be calculated with the total amount of traveled distance by the start and destinations stages.
- Delivery term. The delivery term is composed of:
  a) The expedition term, set in an evenly fashion for each transport, independently of the route's length and the number of participating networks.
  b) The transportation term, it differs according to the route's length.
  c) The supplementary terms, set or eventual.
- Cost by container. The cost calculates the applied rates to a 20 feet contained commonly known as TEU[1]. Every charge associated with the realization of the procedures to export or import the products is included. This influences the costs of documentation, the administrative rates by dispatch of the custom and technical control, dispatch fees, manipulating charges in the terminal and terrestrial transportation or the equivalent to an INCOTERM 2010 DDP.
- Terrestrial cost. The vehicle costs of terrestrial transportation can be grouped in: fixed and variable. Their fixed costs are the lowest of any transportation means, since they are not the owners of the roads they operate on; among the most representative fixed costs we have the following: insurance, amortization, driver's wages and depreciation.
- Quality in transportation. The quality in the transport implies the quality of the own load truck, as well as its load capacity, its antiquity and the operator's ability.

On the other hand, the variable costs tend to be high, since the construction and maintenance of the transit roads are charged to the users in the way of fuel taxes, tolls and taxes by the relation of weight-kilometer; the variable costs in the terrestrial transport must be calculated by kilometer traveled, among its most significant variable costs are the following: gasoline, oil, tires and tolls.

Second Stage

For the second stage of the model, those that were considered intermediary variables in the first stage will now be inputs. Moreover, the indicators of the outputs will be described ahead. (Chen, Li, Liang y Wu; 2015).

Outputs

- International trade value. It refers to the imports and exports of goods and services, representing the value of all the goods and other market services borrowed to the rest of the world. They include the value of merchandise, frets, insurance, transportation and other services.
- Volume of transported goods per road. It refers to the international transport of road merchandise.
- All recollected data was obtained from the World Bank, the OCDE, the OICA and the OMC.

III. RESULTS

The calculations of three types of efficiency were estimated as: Global Technical Efficiency (GTE), which makes reference to the constant scale performance, the Pure Technical Efficiency (PTE), which corresponds to the scale variables performance and the Efficiency Scale (ES) in an output oriented model. In other words, we are searching the maximization of exit variables that measure international trade.

3.1. Efficiency analysis

The following table shows that, according to the values of the GTE in transport road infrastructure, the most efficient countries are: Germany, Argentine, Brazil, Brunei, China, Costa Rica, Hong Kong, United Kingdom, Singapore and Thailand. Meanwhile, the PTE results show that there were 13 efficient countries (Germany, Argentine, Brazil, Brunei, Canada, China, Costa Rica, Hong Kong, Italy, Peru, Singapore and Thailand) under variable returns. For its part, the Efficiency Scale pointed out 10 efficient countries, which are: Germany, Argentina, Brazil, Brunei, China, Costa Rica, Hong Kong, United Kingdom, Singapore and Thailand.

NO	DMU	ETG	ETP	EE	RTS
1	ALEMANIA	1	1	1	Constante
2	ARGENTINA	1	1	1	Constante
3	AUSTRALIA	0.63275	0.915604	0.691074	Creciente
4	BRASIL	1	1	1	Constante
5	BRUNEI	1	1	1	Constante
6	CANADA	0.736349	1	0.736349	Creciente
7	CHILE	0.867229	0.920569	0.942058	Decreciente
8	CHINA	1	1	1	Constante
9	COREA DEL SUR	0.28716	0.298606	0.961668	Creciente
10	COSTA RICA	1	1	1	Constante
11	DINAMARCA	0.561352	0.601997	0.932483	Decreciente
12	ESPAÑA	0.462181	0.623117	0.741724	Creciente
13	EUA	0.222329	0.303528	0.732483	Decreciente
14	FRANCIA	0.48016	0.543516	0.883434	Creciente
15	HONG KONG	1	1	1	Constante
16	INDIA	0.130178	0.157442	0.82683	Decreciente
17	INDONESIA	0.588224	0.666632	0.882383	Creciente
18	ITALIA	0.777296	1	0.777296	Creciente
19	JAPON	0.304804	0.46319	0.658055	Decreciente
20	MÉXICO	0.679531	0.788089	0.862252	Decreciente
21	NUEVA ZELANDA	0.306331	0.681288	0.449636	Creciente
22	PERU	0.451183	1	0.451183	Creciente
23	REINO UNIDO	1	1	1	Constante
24	RUSIA	0.901277	0.922238	0.977272	Decreciente
25	SINGAPORE	1	1	1	Constante
26	TAILANDIA	1	1	1	Constante
27	VIETNAM	0.71319	0.821932	0.8677	Creciente

Table 1.International load transport efficiency results: GTE, PTE and ES
Source: Author´s calculation base on DEA and bootstrap analysis, 2016.

In spite of there being a great amount of countries that did not present efficiency values, they can be classified according to their scale performance: countries with constant performances, countries with increasing performance and countries with decreasing performances. The first classification corresponds to the countries with constant performances, such as: Germany, Argentina, Brazil, Brunei, China, Costa Rica, Hong Kong, United Kingdom, Singapore and Thailand. The countries that belong to the increasing performance are: Australia, Canada, South Korea, Spain, France, Indonesia, Italy, New Zealand, Peru and Vietnam. Finally, Chile, Denmark, USA, India, Mexico and Russia belong to the group of countries that have a decreasing performance scale.

CONCLUSIONS

There is a variety of researches using the same technique in logistics, particularly in transportation, where the authors conclude that investment is important since it increases the quality and network, as well as reducing costs and time, creating greater coverage and connectivity.In this paper we present the DEA methodology, the measurement of the technical, scale and pure efficiency of a model output orientation. We analyze for the year 2014, variables from 27 countries with greater flow of international trade.

Based on the input and output data used to calculate the efficiency levels for each country, it can be observed and concluded that the countries receiving more capital to continue improving and increasing their infrastructure are: Mexico, China, Japan, Russia, Singapore, Thailand and Argentina, which means that these countries have a greater surface used in roads, which facilitates the movement of goods.

Regarding the results, the countries: Germany, Argentina, Brazil, Brunei D, China, Costa Rica, Hong Kong, United Kingdom, Singapore and Thailand show overall technical efficiency; Germany, Argentina, Brunei, Canada, China, Costa Rica, Hong Kong, Italy, Peru, Singapore and Thailand have pure technical efficiency and the countries of Brazil, Germany, Argentina, Brunei D., China, Costa Rica, Hong Kong, United Kingdom, Singapore and Thailand have scale efficiency.

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