Measurement 54 (2014) 166–177

Contents lists available at ScienceDirect

Measurement

journal homepage: www.elsevier.com/locate/measurement

Measuring efficiency improvement in Brazilian trucking: A Distance Friction Minimization approach with fixed factors

Peter Wanke [a,*], Carlos P. Barros [b,c,1], Otavio Figueiredo [d,2]

[a] Center for Studies in Logistics, Infrastructure and Management, COPPEAD Graduate Business School, Federal University of Rio de Janeiro, Rua Paschoal Lemme, 355, Rio de Janeiro CEP.: 21949-900, Brazil
[b] Instituto Superior de Economia e Gestão, Technical University of Lisbon Rua Miguel Lupi, 20, 1249-078 Lisbon, Portugal
[c] UECE (Research Unit on Complexity and Economics), Portugal
[d] COPPEAD Graduate Business School, Federal University of Rio de Janeiro, Rua Paschoal Lemme, 355, Rio de Janeiro CEP.: 21949-900, Brazil

ARTICLE INFO

Article history:
Received 30 December 2013
Received in revised form 5 March 2014
Accepted 18 April 2014
Available online 28 April 2014

Keywords:
Longitudinal study
Trucking industry
Brazil
DFM
Fixed factors
Efficiency drivers
Unbalanced panel

ABSTRACT

This paper investigates paths for improving efficiency in the Brazilian motor carrier industry, which has undergone significant transformations since the economy deregulation in the mid 1990s. The main research objective is to determine whether or not different types of cargoes and geographic regions serviced significantly impact trucking efficiency levels by applying a Distance Friction Minimization approach with fixed factors. Results support the evidence regarding a heterogeneous impact of cargo mix and route mix on input reducing and output increasing potentials. Managerial impacts in terms of fleet subcontracting and increased focus on specific transport demands are also addressed.

1. Introduction

The motor carrier industry occupies an important position in the movement of goods and services [43]. Given its advantages in the areas of accessibility to points of origin and final destination, and the relatively low capital requirements for industry entry, motor carriers have overshadowed other transportation modes in terms of market share, employment, and the number of firms [6]. Bolstered by the *Plano Real* economic plan and post-1994 economic stability [31], the trucking industry began to garner more attention in Brazil, one of the so-called "emerging countries" or "BRICs" [100], an acronym for Brazil, Russia, India, and China. Although Brazil has experienced significant changes in terms of market competitiveness since 1994, it is still a country strongly dependent on its motor carriers. Approximately two thirds of Brazilian firms' transport-related expenditure is spent on trucking services [21]. As such, motor carriers must continually be on the lookout for new ways to stay competitive [68], with efficiency evaluation techniques serving a fundamental role in this pursuit.

A powerful tool for measuring efficiency is Data Envelopment Analysis (DEA), developed over 30 years ago [23,49]. Its main characteristic is the capacity to simultaneously process multiple inputs and outputs, thereby aiding managers in decision-making [1,50]. The DEA frontier model remains widely used in transportation/logistics efficiency research in general, probably because it has been successfully applied to a wide number of different planning situations, such as third-party logistics

* Corresponding author. Tel.: +55 21 25989896.
E-mail addresses: peter@coppead.ufrj.br (P. Wanke), cbarros@iseg.utl.pt (C.P. Barros), otavio@ufrj.br (O. Figueiredo).
[1] Tel.: +351 213 016115; fax: +351 213 925 912.
[2] Tel.: +55 21 25989800.

http://dx.doi.org/10.1016/j.measurement.2014.04.013
0263-2241/

(e.g. [75,57,58,42,77,103,94], airline industry (e.g. [76,13,17,92], airports (e.g. [55,67,8,14,34,80,96,97], road passenger transport (e.g. [66,64], container terminals (e.g. [91,89,56,51,69,95].

The DEA Distance Friction Minimization (DFM) model, however, is one of the most recent solutions to face this major DEA drawback: there are, in principle, an infinite number of improvements paths a DMU could take in order to reach the efficient frontier [36]. The DFM model, which was developed by Suzuki et al. [85], serves to improve the performance of a DMU by identifying the most appropriate movement towards the efficiency frontier surface. In this approach, a generalized distance function, based on a Euclidean distance metric in weighted spaces, is proposed to assist a DMU to improve its performance by an appropriate movement towards the efficiency frontier surface. Such approach offers a refreshing perspective on efficiency enhancement by employing a weighted projection function. This can address both input reduction and output augmentation options. More recently, Suzuki and Nijkamp [86] extended the DFM approach to circumstances where decision makers are faced with fixed factors or non-discretionary variables, following the seminal ideas of Banker and Morey [11] model.

The Brazilian trucking industry is the focus of this paper. Its objective is to identify the major drivers for increasing outputs and reducing inputs from 2002 to 2011, assessing whether or not different types of cargoes and geographic regions serviced present significant impact. To this end, a review of the literature was carried out, both to provide some background to the sector and to support the DFM approach adopted. More precisely, the determination of input/output improvement potentials under the presence of non-discretionary variables was followed by a generalized least-squares models using unbalanced panel, thus allowing the effect of different types of cargoes and geographic regions serviced on sector managerial efficiency to be estimated.

The remainder of the article comprises six sections. Section 2 presents a brief background on the Brazilian trucking industry; also presented are the scant previous studies that applied DEA to the motor carrier industry in other countries, as well as the major research proposition considered here. Section 3 supports the most fundamental methodological issues concerning data analysis, providing not only a background on DFM, but also giving more detailed insights on fixed factors within the ambit of the motor carrier industry. In Section 4, the data are analyzed and the results discussed in the context of several relevant issues, such as, the selection of variables and the possibility of variable reduction. Section 5 addresses managerial implications, especially in terms of opportunities of fleet subcontracting and increased focus on specific transport demands. Lastly, Section 6 presents the conclusions of the study.

2. Literature review

2.1. Background on the Brazilian trucking industry

Historically, the integration of Brazil was based on the construction of highways, while the construction of railroads and development of waterways was instead aimed at meeting specific projects for out flowing cargo, particularly exports from the ports. Currently, the paved highway network is around five times larger than the railroad network. When considering all types of highways, the size is over 50 times as large as the rail system. The waterway system, on the other hand, is underused due to a lack of needed investment to improve navigability [30].

The highway system is responsible for about 56% of the total tonnage-per-mile moved in Brazil, according to ANTT [62] surveys. The enduring market share held by road transportation in Brazil is due to low price and a lack of comparable, equally reliable modes of transportation, particularly rail and waterborne services. Evidence collected by Wanke and Fleury [93] indicate that there are 2926 registered motor carrier companies with more than 20 employees operating in Brazil, and more than 100,000 self-employed drivers and single-driver trucking companies. In a country where the minimum monthly wage is only about US$300, highway transportation is often linked to certain aggressive and potentially unfair business practices, including excessive/uninterrupted driving hours, excessive speed, and uncontrolled vehicle/cargo weight [32].

2.2. Efficiency in the trucking industry

Although efficiency studies in the trucking industry are scarce, differently from other applications in logistics and transportation, a number of methods to evaluate motor carrier efficiency have been tested and used over the course of time [98]. Basically, these methods can be divided in two major groups, following Bogetoft and Otto [18]: parametric and non-parametric. They are discussed next.

Parametric models are characterized by prior definition except for a finite set of unknown parameters that are estimated from data. This group highlights the technique known as Stochastic Frontier Analysis (SFA), directly linked to econometric theory. It is worth commenting that international, peer-reviewed papers dealing with the application of SFA in the trucking industry are even scarcer. A search at **Proquest Database** with the terms "trucking industry" or "motor carrier" and "stochastic frontier" returned only one paper [53]. This paper compared cost efficiency in the US motor carrier industry, both before and after deregulation in 1980. Unionization was found to be the most important determinant of inefficiency in both periods, with its negative impact being stronger in the deregulated industry.

On the other hand, non-parametric models are characterized by being much less restricted, since there is no need for prior parameter definition. DEA, which has its roots in mathematical programming, is an example of a technique for this group. Specifically concerning the trucking industry, only few papers were found after performing a search at **Proquest Database** with the terms "trucking industry" or "motor carrier" and "data envelopment analysis". Odeck and Hjalmarsson [65] and Hjalmarsson and Odeck [41] initially demonstrated the usefulness of DEA as a tool for evaluating the efficiency of trucks involved