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The evolution of container terminal productivity and efficiency under changing economic environments

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ABSTRACT

The paper analyzes the evolution of container terminal productivity and efficiency of 20 terminals in 10 countries in Latin America and the Caribbean and Spain for the period 2005–2011. The inclusion of data from the demand growth period, and the subsequent reduction of demand and recovery, allows evaluating the impact and repercussion of the financial crisis on terminal productivity and efficiency.

The aim of the empirical analysis in the paper is twofold: a) to document the harmonic mismatch in the evolution of port infra- and superstructure endowment, container demand in key Latin American and Caribbean container terminals and; b) to quantify the effect of the financial crisis and the posterior changing economic development on container port productivity applying non-parametric Data Envelopment Analysis (DEA). The panel data analysis allows for specifically identifying the effect of dynamic economic environments on productivity and efficiency on individual terminals.

1. Introduction

Inadequate and lack of physical infrastructure is often referred to as the main cause for countries to perform poorly in international trade (Lora & Pages, 2010). However, beyond the simple lack of infrastructure the actual performance of available infrastructure and superstructure in response to external pressures in its economic environment should be perceived as a key factor when determining the competitiveness of a country. Performance in the context is defined as the match between "organization's external operating environment, strategies and structures" (Baltazar & Brooks, 2007, p.384). Ports as key facilitators of international trade and their efficiency and productivity as a contribution to the overall performance therefore play a critical role.

Sustained positive market development in the past decade has made efficiency and productivity gains in ports relatively "*easy*" to achieve as demand was continuously outgrowing supply. Expansion of infrastructure and technology deployment was the preferred response in Latin America and the Caribbean (LAC) as in other regions. The recent results from port devolution processes and the influx of international and global container terminal operators were seen as a *panacea* to solve these challenges and to provide the necessary capital to rapidly expand infrastructure and deploy technology. Undoubtedly, port infrastructure development advanced, but nevertheless by 2005 it became obvious that the gap in infrastructure development, a condition that had also triggered port devolution processes in the 1990s, was rather increasing than decreasing (Sánchez & Perrotti, 2011). In this context it might also be argued that the appearance of the financial crisis was a relief to the industry, potentially allowing infra- and superstructure development to catch up.

Thus, in the current volatile economic climate it may be the adequate time to reflect on and analyze the evolution of container port productivity and efficiency in dynamic market conditions and over a longer period of time. Productivity and efficiency are related but different concepts. Productivity is the ratio between the obtained products and the factors used in its production. On the other hand, technical efficiency is the capacity of obtaining maximum amount of output from certain inputs (output orientation) or, alternatively, as the capacity of obtaining a given output level using the minimum amount of inputs (input orientation). Also, a company presents scale efficiency if it reaches the maximum productivity by means of the current technology. From the previous definitions it is possible to deduce that technical efficiency is only one of the determining factors of productivity (for further discussion see also Kao, Chen, Wang, & Kuo, 1995).

Measuring changes in productivity during a period of changing market conditions allows measuring the success or failure achieved by production units as well as getting a deeper understanding of the drivers and sources of efficiency and productivity differentials (Cullinane, Ji, & Wang, 2005; Lovell, 1993).

Most existing studies find advances in port efficiency and productivity independent of the region of study, but many of those were conducted during periods of uninterrupted sustained growth. Given the changing dynamics of economic development in 2008 and 2009 arising questions

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are: Do the production units allocate their inputs differently to maintain productivity? Does productivity simply decrease in correlation with reduced demand? Is the time lag of infra- and superstructure investment (and availability) so significant that in the crisis supply outgrows demand and thus actually reduces efficiency? Can we observe rebound effects after the abrupt changes in the economic environment in 2008–2009?

The evaluation of a set of container terminals in Latin America and the Caribbean, adds a spatial dimension so that the sample embraces an emerging region. The further inclusion of a developed country, Spain enables to test for spatial variations and to compare, if a set of terminals in a developed region responded differently to the crisis in terms of productivity changes than a set of terminals in a developing region.

In order to obtain the necessary data the authors engaged in an in-depth data search on the container terminals at the top 30 ports in Latin America and the Caribbean to find key output and input information. This search involved annual reports, government reports, and industry websites as well as personal phone interviews with some terminals. The goal was to gather information on terminal area, deployment of ship-to-shore cranes, employment and TEU throughput and was motivated by a previous port efficiency survey conducted in 2000 in the region (Sánchez et al., 2003). The authors were able to gather data for 16 terminals in LAC and additional sample data from four Spanish terminals. As a result the paper analyzes panel data for container terminal productivity during the period from 2005 to 2011, for 16 terminals in the top 30 ports in Latin America and the Caribbean, namely in Argentina, Bahamas, Brazil, Chile, Colombia, Dominican Republic, Ecuador, Mexico, Panama and a set of secondary ports in Spain that are included as external control (see Appendix A for the list of terminals included in the study).

Thus the aim of the empirical analysis in the paper is twofold: a) to document the harmonic mismatch in the evolution of port infra- and superstructure endowment, and container demand in key Latin American and Caribbean container terminals and; b) to quantify the effect of the financial crisis and the posterior changing economic development on container port productivity applying non-parametric Data Envelopment Analysis (DEA).

The paper is structured as follows: Section 2 presents the context of port infrastructure development in Latin America. Section 3 discusses the theoretical concepts for measuring port productivity and efficiency and identifies the methodology for the empirical analysis. This section explains the Malmquist total factor productivity (TFP) index as the methodology used to measure temporal productivity changes applying non-parametric DEA. Section 4 describes the data base and discusses the empirical findings, Section 5 presents implications for managerial practice and Section 6 gives an outlook for future research.

2. The context

Exponential growth in trade volumes paired with continuous increases in ship size and advances in the technological evolution of handling have constantly altered the environment for port development (UNCTAD, 2012) and thus the framework for achieving port performance.

Ports have been required to respond to these changes through investment in infra- and superstructures, leading the governing institutions to search for and implement new strategies to attract investment. This has triggered devolution processes, leading also to a shift in the responsibility and management of productivity and efficiency of port infra- and superstructure. Changes in the port system occur in an almost completely discrete manner, since variations in port infrastructure and superstructure, as well as organizational changes, appear to be rather abrupt and are neither implemented nor do they 'grow' in a continuous fashion; investment in the port sector is often characterized as being 'lumpy' (Cullinane & Wilmsmeier, 2011; Sánchez & Wilmsmeier, 2010).

The discrete characteristics of advances and the port's adjustment to the continuous evolution of freight transport demand will inevitably lead to alternating situations of either infrastructural insufficiency and scarcity of supply on the one hand (i.e. excess demand), or to a surfeit of port infrastructure (i.e. surplus supply) on the other. Thus, an interesting question is how this natural characteristic of a virtually constant harmonic mismatch of port infrastructure supply and demand is reflected in port productivity and port efficiency in dynamic market conditions. Consequently, it might be expected that demand excess as well as supply surplus will negatively affect the efficiency and performance of a port (Sánchez & Wilmsmeier, 2010).

As the Latin American economies have become increasingly integrated with the global economy their ports are the interfaces and facilitators of trade, key elements to further facilitate this integration and to strengthen the countries' economic development. Recent figures show that over 8% of global GDP growth will take place in Latin America and the Caribbean in the period between 2011 and 2017 (ECLAC, 2012). Hence, productivity and efficiency of ports in changing environments (i.e. strong changes in demand) are a key factor to strengthening economic development. The period under study is particularly interesting as port reform and private sector participation led to significant changes in port operation in the region during the 1990s and the first decade of this millennium. Efficiency gains from port reform in the Latin American Caribbean port system have been widely studied (Barros, Felicio, & Fernandes, 2012; Estache, Tovar, & Trujillo, 2004; Rios & Maçada, 2006; Wilmsmeier, Hoffmann, & Sanchez, 2006). While these studies identify advances and improvements in port efficiency through private sector involvement, results in the global literature on the relationship between port efficiency and private sector involvement vary and are sometimes even contradictory as recently discussed by Gong, Cullinane, and Firth (2012) and Bichou (2013). The results of port devolution are clearly associated with the influx of international and global terminal operators in the region (see figure below). The number of terminals in the region operated by international and global terminal operators increased from 28 to 40 between 2006 and 2012 (see Figs. 1 and 2). During the same period the number of terminals operated by leading global terminal operators (e.g. DP World, Hutchison Port Holdings, APM Terminals) grew from 15 to 22, which has contributed to fundamental changes in the Latin American port system (Wilmsmeier, Monios, & Perez, 2013) and undoubtedly has also driven the deployment of new port technology.

Beyond changes in the operational and institutional environment, ports in LAC had to respond to continued double digit annual growth rates, the impact and repercussions of the financial crisis as well as altering strategies and concentration in the liner shipping industry (Wilmsmeier & Notteboom, 2011; Wilmsmeier & Sánchez, 2010, 2011).

Overall container port throughput (TEU) in LAC increased 186% since the turn of the millennium (ECLAC, 2012). In the 16 terminals under study throughput expanded from 10 to 16.6 million TEU between 2005 and 2011 a growth in demand of 60%, despite the recent repercussions of the financial and economic crisis in other parts of the world.

Fig. 3 depicts the annual changes in container throughput in the terminals (For list of terminals see Appendix A) under study to illustrate the impact of the changing economic environment. Two patterns can be observed a) terminals with growth between 2005 and 2008 and decline of activity in 2009 (e.g. PA_1, CH_3, MX_5); b) terminals with continued container throughput growth throughout the crisis years (e.g. MX_2, EC_1, CH_2). It is also remarkable that most of the terminals affected by crisis in terms of container throughput reduction show a strong rebound in growth during 2010 and 2011 that overcompensates previous losses.

The overall sustained positive development of demand, even in the crisis years has put a significant challenge to the provision of infrastructure services calling for greater investments in infra- and superstructure and also improving levels of productivity and efficiency in order to respond to the increases in demand.

The container port industry responded with an increase in terminal areas and in particular technological change in terminal superstructures was speeded up. This led to changes in the equipment of terminals and application of new container management systems to increase the quayside efficiency and productivity (see Fig. 4).