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The logistic performance of Brazilian grains transportation

Desempenho logístico do transporte dos grãos brasileiros

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Abstract. Despite significant advances in the Brazilian agriculture, the logistics costs, especially with transport and storage, are still the main barriers that limit the potential of the Brazilian agribusiness. This study analyzes the logistics efficiency of the main flow routes for Brazil's corn exports from the major producing states to the main ports of Brazil. For this purpose, we develop a performance measurement system based on the Balanced Scorecard (BSC) using a model with four dimensions for efficiency analysis: financial, customer, internal business processes, and learning/growth. We calculate the efficiency of the main routes using the Data Envelopment Analysis (DEA). Our results suggest that the routes from Mato Grosso state to Santarem port using a road-waterway intermodal transport system were the most efficient on three of the four criteria. Thereafter, we analyze the relative efficiency of all main Brazilian routes based on the four criteria, establishing the efficiency ranking, and further, developing a standard model to evaluate other logistic systems for different agricultural commodities.

Key words: Performance Analysis, Logistics Index, Agribusiness.

Resumo. Apesar dos avanços significativos na agricultura brasileira, os custos logísticos, especialmente com transporte e armazenamento, ainda são as principais barreiras que limitam o potencial do agronegócio brasileiro. Este estudo analisa a eficiência logística das principais rotas de escoamento para exportação do milho brasileiro dos principais estados produtores aos principais portos do Brasil. Para isso, desenvolvemos um sistema de medição de desempenho baseado no Balanced Scorecard (BSC), usando modelo de quatro dimensões para análise de eficiência: financeira, cliente, processos internos do negócio e aprendizado/crescimento. Calculamos a eficiência das principais rotas usando a Análise de Envoltória de Dados (DEA). Nossos resultados sugerem que as rotas do Estado de Mato Grosso com destino ao o porto de Santarém no Estado do Pará, utilizando um sistema de transporte intermodal via hidrovia, foram as rotas mais eficientes em três dos quatro critérios avaliados. Posteriormente, analisamos a eficiência relativa de todas as principais rotas brasileiras com base nos quatro critérios, estabelecendo um ranking de eficiência, e ainda, desenvolvemos um modelo padrão capaz de para avaliar outros sistemas logísticos para diferentes commodities agrícolas.

Palavras-chave: Análise de Desempenho, Índice Logístico, Agronegócio.

Introduction

The spatial arrangement change of the Brazilian agricultural production is a recurring phenomenon and agricultural businesses were taking up new frontiers through activities that incorporate modern production technologies. This reconfiguration is causing changes in the agribusiness supply chain; thus, agricultural suppliers, storers and the processing industry are concentrated around these production areas in order to minimize logistics costs, especially in relation to transportation cost.

It should be noted that in the Brazilian case, logistics costs are a major component of the final product prices, due to the spatial dispersion of production, internal market distribution and long distances involved in intra and inter-regional. The improvement in the provision of logistics services would certainly increase various economic sectors competitiveness, a necessary condition for proper performance of any economy (OLIVEIRA, 2014).

Based on Bartolacci et al. (2012), only by directing investments and solving logistical barriers increased Brazilian competitiveness will be achieved. In the Brazilian case, overcoming problems such as: shortage of storage capacity, reducing bureaucracy and port organization, redistribution of cargo transportation matrix, increasing rail and waterway capacity and efficiency should increase products competitiveness.

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The Brazilian efficiency in some agricultural sectors is widely recognized, in particular: corn, soy, sugar and ethanol, orange juice, coffee and meat. However, some of the competitive gains are lost along the marketing and export process due to logistical obstacles. Therefore, the overall objective of the study was to develop a performance measurement system that makes it possible to evaluate the relative logistics process efficiency of the Brazilian corn export process through the Data Envelopment Analysis (DEA) method in the main practiced routes.

This article aims to contribute to the construction of new parameters for performance evaluation of logistics processes in order to promote the establishment of new strategies for the transportation sector and the establishment of an additional tool for decision support for agents operating in the sector. Corn flow process is understood in an integrated context, assessing its broad supply chain and the transport logistics role. The originality of this research is demonstrated by using a DEA model, in addition to performance evaluation concept which incorporates not only economic variables, in this case there is the combination of three different dimensions: operational, economic and environmental.

Material and Methods

In the structuring process of the efficiency analysis system, we reviewed the main performance measurement systems. The Balanced Scorecard was developed by Kaplan and Norton, published in 1992 in the Harvard Business Review; the main objective of the methodology is to translate corporate strategy into performance indicators, unfolding it into four perspectives: financial; of the customer; of the internal business processes; and learning and growth, not restricting the analysis to financial criteria (KAPLAN; NORTON, 1997).

The Data Envelopment Analysis (DEA) methodology, which was originated by Farrel (1957) and was generalized by Charnes, Cooper and Rhodes (1978), is characterized as a non-parametric technique that allows to handle multiple outputs and inputs to measure comparatively the performance of independent units, that is, the efficiency of each unit. The data envelopment analysis (DEA), works in order to allow that several inputs and outputs can be used when analyzing the performance of various similar organizational units (DMUs).

The DEA technique occurs through a standard linear programming, which seeks to establish the maximum efficiency of a DMU, expressed in the rate between inputs and outputs, comparing the performance of a unit in relation to the group of similar units. The technique application allows us to observe which units have more efficient performance (TALLURI et al., 2015). According to Azambuja et al. (2015), DEA models can work with constant scale returns (CCR model – Charles, Cooper and Rhodes, also known as CRS) or variable returns to scale (BCC model – Banker, Charnes and Cooper, also known as VRS). In this study we used the BCC model oriented to output, which has its mathematical formulation defined as:

$$Max\ h_o \quad (1)$$

s.t

$$x_{jo} - \sum_{k=1}^{n} x_{ik} \cdot \lambda_k \geq 0, \forall i \quad (2)$$

$$-h_o \cdot y_{jo} + \sum_{k=1}^{n} y_{jk} \cdot \lambda_k \geq 0, \forall j \quad (3)$$

$$\sum_{k=1}^{n} \lambda_k = 1 \quad (4)$$

$$\lambda_k \geq 0, \forall k \quad (5)$$

The proposed model maximizes the outputs keeping the inputs unchanged. In (1), h_o is the efficiency and λ_k is the DMU contribution k in the formation of the DMU target o.

When developing the study we conducted a corn logistics process mapping, and the main routes of flow for export, which were defined as objects of study, the DMUs. We defined 17 routes, of these eight are unimodal, using only the road modal and nine are intermodal, using a combination of road/rail and road/waterway. Therefore, we have the origins of the routes in the States of Mato Grosso, Paraná and Goiás and destinations to the Ports of Santos (SP), Paranaguá (PR), São Francisco do Sul (SC), Vitória (ES), Santarém (PA) and Manaus (AM) (Figure 1). For example, the MT-SP-ROAD route (DMU01) is characterized by the corn flow between the producing State of Mato Grosso to the port of Santos (SP) using the exclusive road transport option. The MT-SP-ROAD-RAIL (DMU02)

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considers the route between the producing State of Mato Grosso to the port of Santos (SP) using the road-waterway intermodal transport. Corn travels about 600 km using the BR-163 and BR-364 highways to the intermodal terminal of Rondonópolis-MT, covering the rest of the way by rail for 1551 km. We considered the rail transshipment terminals Rondonópolis-MT, Araguari-MG, Maringá-PR and Roncador-GO. As for waterway terminals we considered the Miritituba-PA Terminal (DMU06) and the Porto Velho-RO Terminal (DMU07) (Figure 1).

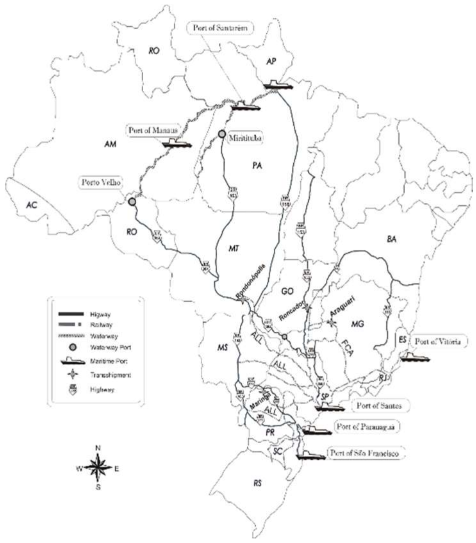

Figure 1 - Main Corn logistics routes in Brazil.

Variables

As variables organization we used as reference the Balanced Scorecard (BSC) based on four dimensions:

Financial Dimension: this dimension represents the costs and analyzes if all the indicators are contributing in order to minimize the final cost of the Brazilian corn in the international market. The strategic objective representing this dimension is the Logistics Costs (Figure 2), total cost of the Brazilian corn delivery in the port of Shanghai-China, since it is the largest port in activity in the world, and by the fact that the consumer market of the Brazil's grain is focused on Asia.

Customer Dimension: in the customer's perspective, we established the DMU Participation indicator (Figure 2), representing the total export concerning the route used (DMU) compared to the total of Brazilian corn exports.

Internal Business Processes Dimension: in this dimension we evaluated the activities that should be developed, taking into account history of bureaucratic procedures of customs and excessive time for delivery. The strategic objective that analyzes these factors is the Lead Time Delivery (Figure 2), considering the queue of ships in the port and transportation time to the port of Shanghai–China.

Learning and Growth Dimension: in the learning and growth perspective, we analyzed the factors which should be developed for the future business success. The objective adopted represented the adoption of clean practices; therefore, we adopted the Sustainable Development (Figure 2), which measures the flow impact of corn production in accordance with the modals and the route used. The estimate adopted in this case was the CO2 emission.

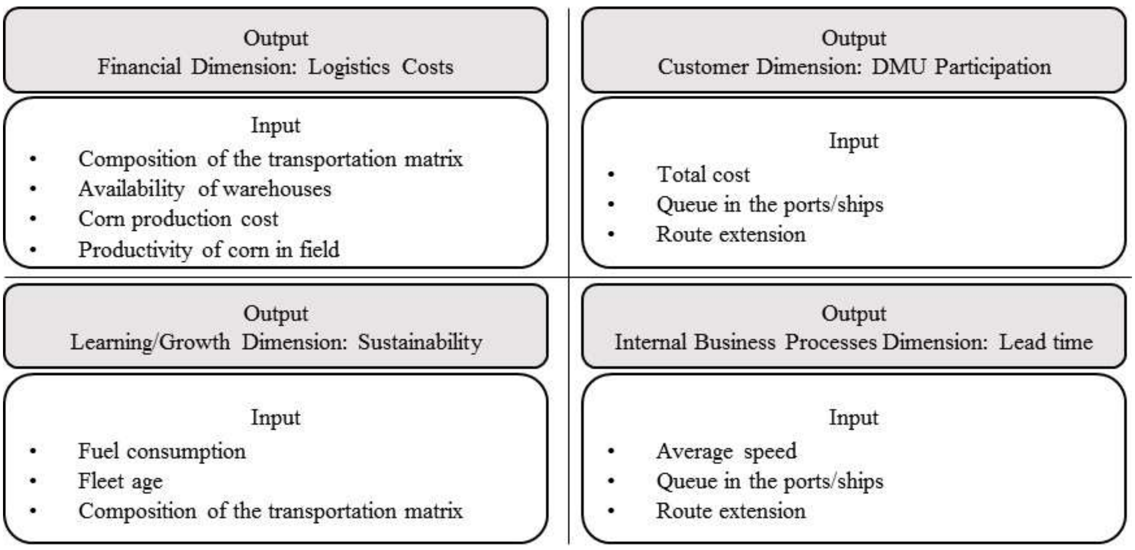

Figure 2 - Measuring efficiency model.

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In the resolution process of the models we used the variable returns to scale method (BCC). As a way of dealing with *undesirable outputs*, we treated the data in order to adjust them through the multiplicative inverse method, which transforms undesirable outputs indicators (Logistics Costs, Lead Time Delivery and Sustainable Development) as inputs through the formula $F_{(u)} = -u$.

In order to highlight the efficient DMUs, we used the Inverted Frontier method:

$$Inverted\ Frontier\ Efficency = \frac{Standard\ Efficency + (1 - Inef}{2} \quad (6)$$

The final efficiency was obtained through calculating the inverted frontier, giving maximum efficiency for the DMUs with the best result and other proportional efficiencies DMUs compared to the best DMU.

Results and Discussion

We initially analyzed the results obtained by the routes in each of the four proposed models: logistics costs/financial dimension, DMU participation/customer dimension, delivery lead time/dimension of internal processes and sustainable development/growth dimension. Secondly, at the discussion, we analyzed the routes as a whole.

Financial Dimension

Following the financial model resolution, we verified as reference the road and waterway intermodal route through the Miritituba terminal for obtaining an overall efficiency rate of 76%, being the most efficient route studied. From this route we calculated the relative efficiency of other routes, highlighting the road and waterway intermodal route to export corn from the State of Goiás to the port of Santos through the Roncador terminal, using the FCA and ALL railways which reached a relative efficiency rate of 90.7%. Table 1 shows the financial model results.

Table 1 - Final Efficiency of DMUs, financial/logistics cost model.

DMU/Indicator	DMU	Efficienc y	Inefficienc y	Inverted Border Efficiency	Final Efficienc
MT-PA/AM-ROAD-	DMU06	1.000	0.479	0.760	1.000
GO-SP-ROAD-RAIL	DMU15	1.000	0.620	0.690	0.908
MT-PA/AM-ROAD	DMU05	0.819	0.585	0.617	0.812
MT-SP-ROAD-RAIL	DMU02	1.000	0.774	0.613	0.806
PR - PR - ROAD-RAIL	DMU11	1.000	0.799	0.601	0.790
GO-SP-ROAD	DMU14	0.891	0.748	0.572	0.752
MT-PA/AM-ROAD-	DMU07	0.768	0.764	0.502	0.660
GO-ES-ROAD-RAIL	DMU17	1.000	1.000	0.500	0.658
PR - SC - ROAD-RAIL	DMU13	0.893	0.894	0.499	0.657
PR - PR - ROAD	DMU10	0.880	0.907	0.486	0.640
PR - SC - ROAD	DMU12	0.799	1.000	0.399	0.525
MT-SP-ROAD	DMU01	0.572	0.838	0.367	0.483
GO-ES-ROAD	DMU16	0.666	1.000	0.333	0.438
MT-ES-ROAD-RAIL	DMU09	0.638	0.994	0.322	0.424
MT-PR-ROAD	DMU03	0.529	0.906	0.311	0.410
MT-PR-ROAD-RAIL	DMU04	0.532	0.944	0.294	0.387
MT-ES-ROAD	DMU08	0.479	1.000	0.240	0.315

Customer Dimension

As main references in the participation of routes model we verified the logistics process of corn flow between the producing State of Mato Grosso and the port of Santos via road, which obtained a rate of 98% efficiency, an expected result since it is the largest exporter state and the largest Brazilian port in export volume, with the distribution of 74% of the total transported according to the Brazilian transportation matrix of CNT (2014).

This result demonstrates that the route is at the limit of its capacity, with the need for distribution by other routes; the main alternative is using the port of Santarém and Manaus, with relative efficiency rate of 96.3%, followed by

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alternatives using the highway for transport between the State of Paraná and the ports of Paranaguá and São Francisco do Sul with relative efficiency rates of 94.4% and 87.9%, respectively, as detailed by the available results in Table 2.

Table 2 - Final Efficiency of DMUs, customer/DMU participation model.

DMU/Indicator	DMU	Efficiency	Inefficiency	Inverted Border	Final Efficienc
MT-SP-ROAD	DMU01	1.000	0.039	0.981	1.000
MT-PA/AM-ROAD	DMU05	1.000	0.109	0.945	0.964
PR - PR - ROAD	DMU10	1.000	0.148	0.926	0.944
PR - SC - ROAD	DMU12	1.000	0.275	0.862	0.879
PR - PR - ROAD-RAIL	DMU11	1.000	0.430	0.785	0.800
GO-SP-ROAD	DMU14	0.480	0.181	0.647	0.660
MT-SP-ROAD-RAIL	DMU02	0,38	0.112	0.633	0.645
PR - SC - ROAD-RAIL	DMU13	1.000	0.801	0.599	0.611
MT-PA/AM-ROAD-	DMU06	1.000	1.000	0.500	0.510
GO-ES-ROAD	DMU16	0.190	0.330	0.431	0.439
MT-PR-ROAD	DMU03	0.110	0.344	0.385	0.393
GO-SP-ROAD-RAIL	DMU15	0.190	0.527	0.333	0.339
MT-ES-ROAD	DMU08	0.270	1.000	0.136	0.138
MT-PA/AM-ROAD-	DMU07	0.110	1.000	0.055	0.056
GO-ES-ROAD-RAIL	DMU17	0.060	0.961	0.049	0.050
MT-ES-ROAD-RAIL	DMU09	0.090	1.000	0.047	0.048
MT-PR-ROAD-RAIL	DMU04	0.040	1.000	0.020	0.020

Internal Business Processes Dimension

As a result of the internal business processes efficiency model, all routes had partial efficiency rate above 93% due to the representativeness of the transshipment time between the Brazilian ports and the port of Shanghai–China, which influences directly the total Lead Time process. After application of the inverted frontier method, the analyzed routes had a very high inefficiency rate (above 90%), thus, the inverted frontier efficiency had rates below 60%. The highlighted routes of this model were the State of Mato Grosso to the ports of Santarém/Manaus, using the road and waterway intermodal route through the Miritituba terminal, and the Paraná route – Port of São Francisco do Sul using the ALL railway, with a relative efficiency rate of 98%. The data on internal business processes model are available in Table 3.

Table 3 - Final Efficiency of DMUs, internal processes/delivery lead time model.

DMU/Indicator	DMU	Efficiency	Inefficiency	Inverted Border Efficiency	Final Efficienc
MT-PA/AM-ROAD-	DMU06	1.000	0.895	0.552	1.000
PR - SC - ROAD-RAIL	DMU13	1.000	0.910	0.545	0.987
MT-PA/AM-ROAD	DMU05	1.000	0.936	0.532	0.963
MT-PA/AM-ROAD-	DMU07	1.000	0.939	0.531	0.961
PR - SC - ROAD	DMU12	1.000	0.955	0.523	0.946
PR - PR - ROAD-RAIL	DMU11	1.000	0.965	0.518	0.937
PR - PR - ROAD	DMU10	1.000	0.965	0.518	0.937
GO-ES-ROAD	DMU16	0.980	0.955	0.512	0.927
GO-ES-ROAD-RAIL	DMU17	1.000	0.980	0.510	0.923

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GO-SP-ROAD	DMU14	0.978	0.966	0.506	0.916
GO-SP-ROAD-RAIL	DMU15	1.000	1.000	0.500	0.905
MT-SP-ROAD	DMU01	0.948	0.987	0.480	0.870
MT-SP-ROAD-RAIL	DMU02	0.942	0.983	0.480	0.868
MT-ES-ROAD	DMU08	0.957	1.000	0.478	0.866
MT-PR-ROAD	DMU03	0.936	1.000	0.468	0.847
MT-PR-ROAD-RAIL	DMU04	0.933	1.000	0.466	0.844
MT-ES-ROAD-RAIL	DMU09	0.914	1.000	0.457	0.827

Learning and growth Dimension

The highlighted routes were from the State of Paraná, which is the closest producing state of export routes. The reference is the railway route to the port of Paranaguá – PR with final efficiency of 97.5%, followed by the road route by the BR – 376 to the port of Paranaguá – PR (91.7% relative efficiency), and routes to the port of São Francisco do Sul – SC (89.4% relative efficiency). The results details of all routes are shown in Table 4.

The most important in this state is the fact that Minas Gerais presents a good railway network and has important railway transfer terminals located in the cities of Uberaba, Uberlândia, and Araguari, all part of the region of the mining triangle, that transfers cargo from the road network to the railway network, for shipping to the next destination, which generally is the port of Vitória in the state of Espírito Santo. Further, the rule establishes that the move between MT and the intermodal terminals of MG, occurred with higher intensity in 2015.

Table 4 - Final Efficiency of DMUs, growth/sustainable development model.

DMU/Indicator	DMU	Efficiency	Inefficiency	Inverted Border	Final Efficienc
PR - PR - ROAD-RAIL	DMU11	1.000	0.049	0.976	1.000
PR - PR - ROAD	DMU10	1.000	0.210	0.895	0.918
PR - SC - ROAD-RAIL	DMU13	0.805	0.061	0.872	0.894
PR - SC - ROAD	DMU12	0.732	0.240	0.746	0.765
GO-SP-ROAD-RAIL	DMU15	0.250	0.195	0.527	0.540
GO-ES-ROAD-RAIL	DMU17	0.201	0.287	0.457	0.469
GO-SP-ROAD	DMU14	0.233	0.401	0.416	0.426
MT-PA/AM-ROAD-	DMU06	0.137	0.479	0.329	0.337
MT-SP-ROAD-RAIL	DMU02	0.132	0.494	0.319	0.327
MT-PA/AM-ROAD	DMU05	0.118	0.552	0.283	0.290
GO-ES-ROAD	DMU16	0.114	0.562	0.276	0.283
MT-PA/AM-ROAD-	DMU07	0.063	0.789	0.137	0.141
MT-PR-ROAD-RAIL	DMU04	0.067	0.808	0.129	0.133
MT-SP-ROAD	DMU01	0.061	0.803	0.129	0.132
MT-PR-ROAD	DMU03	0.055	0.882	0.087	0.089
MT-ES-ROAD-RAIL	DMU09	0.069	1.000	0.035	0.036
MT-ES-ROAD	DMU08	0.049	1.000	0.024	0.025

Conclusion

This research analyzed the efficiency of the main flow routes of the Brazilian corn production for export among the major producing states and the main Brazilian ports. In the evaluation process we defined the input and output indicators which represented influence on the final process outcome.

By analyzing the four proposed models: financial, customer, internal business processes and learning/growth, we can highlight the corn export route DMU06, which represents the flow of Mato Grosso to the ports of Santarém/Manaus using the road and waterway intermodal route through the waterway terminal Miritituba in the Tapajós-Amazonas Waterway (MT-PA/AM-

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Road-Waterway-DMU06), which was featured in the financial models (1st place - 100% efficiency) and internal business processes (1st place - 100% efficiency), in the sustainable development model it was the best alternative when the origin of corn was the State of Mato Grosso - the largest producing state. When the reference is the State of Paraná, we can highlight the road and rail route to the port of Paranaguá, and when corn comes from the State of Goiás, the road and waterway intermodal route through the port of Santos is the reference.

Through the financial efficiency evaluation model, we observed the influence of the participation of rail and waterway modes in the process of defining efficient routes; four of the five best results were part of that intermodality. It is also important to note that the flow to the ports of Santarém and Manaus were the best alternatives to the already overloaded port of Santos. In the efficiency analysis model in sustainable development, the routes with lower extension between the producer state and the export port were privileged, such as the State of Paraná route to the port of Paranaguá through intermodal road-rail. The results of this study allow the analysis of each route level development and the targeting of investments on routes which had unsatisfactory results, that is, low levels of efficiency. The proposed models become relevant due to their replication potential in other logistics process efficiency analysis to other agricultural commodities, as well as in comparison with competing countries in the corn chain.

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