Economic and Environmental Perfomance in Coffee Supply Chains: A Brazilian Case Study

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Abstract. The concern to meet food needs of the world population and preserve the environment is frequent today. In this context, Brazil has a significant participation in world agriculture. For instance, the country is the largest producer and exporter of green coffee grain. Coffee, besides being part of cultural habits in many countries, still corresponds significantly in the Brazilian trade balance, in the generation of jobs and income in the food industry chain worldwide, having its consumption associated with meetings and socialization and also as food base of children in a situation of economic and social vulnerability. The aim of this work is to discuss the economic and environmental performance, through the analysis of different combinations of cargo vehicles in different paving and non-paving conditions for the flow of coffee grain production from Guaxup/MG to the Port of Santos/SP. It was observed that the best combination for load is "rodotrem" because it presents the best economic performance due to lower costs with diesel per ton of coffee grain transported and the best environmental performance which is maintained in all load combinations. It is clear that the Brazilian road network needs investments related to paving, technologies to improve fuel use and tire performance.

Keywords: Cargo Vehicle Combinations · Economic performance · Environmental performance · Coffee

1 Introduction

The projection of the world population for 2030 is 8.5 billion [1] and there is a concern to meet their needs, especially related to food production and environment. Thereby, Brazil plays a strategic role in global agribusiness, leading world grain production [2]. The country is favored by its edaphoclimatic [3,4], is the largest coffee producer and exporter [5,6], generates, by along the production chain, more than 400 thousand jobs [7], and in addition, it is the second-largest consumer of the beverage [5,6].

For many of children in the world, who are in vulnerable situation, the combination of coffee with flour or milk is the only source of food [8], and due to its stimulating and exotic properties, it has become, for decades, a very complex beverage and it is appreciated in almost all countries of the world [9].

The international market is a major consumer of Brazilian coffee and the blends prepared in the country are appreciated around the world [10].

Thus, it is possible to affirm that coffee is part of the cultural habits in many countries. Its consumption is associated with meetings and socializations [11,12].

Minas Gerais state, located in the southeast region of the country, is the main producer and exporter, with 82% of what is exported by the country [13]. The main port of exportation is Santos, located about 382 km far and the transportation is made by road [14].

One of the major barriers to the flow of coffee production is the availability of transport modes to efficiently meet production. Logistical inefficiency results in the raise of the costs and impacts negatively in the environment.

As transport activities are responsible for 14% of global anthropogenic emissions [15],the effects of environmental transport problems become critical, especially for food production chains in underdeveloped countries [16].

Regarding to the environment, there is a movement towards a change of habits and sustainable conditions are inserted in logistics processes for exports. The green seal is something which adds value to the grain. With these ideas in mind, this work seeks to answer questions related to the flow of coffee grain production and economic and environmental aspects inherent to the process.

The aim of this work is to discuss economic and environmental issues of different types of combinations of cargo vehicles related to the conditions of the roads for traffic, inherent to the process of flow of coffee grain production from Guaxupé, Minas Gerais, through highways to the Port of Santos, São Paulo.

2 Methodology

In order to discuss the economic and environmental issues of the processes of coffee production flow in Minas Gerais, an exploratory, bibliographic and descriptive research was carried out to contextualize the scenario [17].

When discussing these questions, some concepts were inserted to facilitate understanding and, to achieve the proposed methodology, it was organized in two stages:

2.1 Economic analysis

To pull the different types of semitrailer, it was used a tractor truck 420HP 6X4. The values for Fuel Consumption in Scale (km/L), Life of new tires (Km) and service life of retreaded tires (Km) were acquired by research with professional drivers (variable values for each type of driving). Diesel oil prices were defined based on the average price practiced in the State of Minas Gerais [18]. And values of cost of new tires and cost of retreaded tires were delimited by dividing the average tire value by the average kilometers driven in each proposed situation.

2.2 Environmental analysis

For calculations of greenhouse gas emissions, only one factor was taken into account, namely the emission factor related to combustion of diesel used [19].

$$Emission\, of\, Diesel : E_j k = (FE_i * Q_d iesel/Km * D_j k) \tag{1}$$

Where: Ejk corresponds to the total emission of CO_2 by municipality of origin j and port of destination k; The FE corresponds to the CO_2 emission factor of diesel, Q is diesel consumed per kilometer, and D is the distance traveled from origin j and destination port k in km.

A route was specified between the city of Guaxupé/MG and the Port of Santos/SP, an average distance of 382 km. As a functional unit in the environmental aspect, 1 kg of coffee grain was stipulated allowing comparisons with other studies (such as work-related to soybeans by [20]), since there is a scarcity in this type of study in the coffee area.

The data were compiled in a table to enable their discussion. The variables analyzed were extracted from the literature consulted [21,22,23,24,25,26,27,28,29,20] and pointed out in the research.

3 Results and Discussion

Three distinct situations were evaluated (highway with good and poor quality pavement and unpaved road) regarding the economic and environmental performance of vehicle combinations, data compiled in Table 1.

For better understanding, some information is relevant in the context of the proposed situation. Cargo transport in Brazil is predominantly carried out through the road modal [30,31], corresponding to 61.1% of the amount carried out with about 485 million tons per useful kilometer [27].

In this perspective, coffee is transported by road modal to the Port of Santos. Among the combinations of vehicles for transport, the usual is the use of a tractor truck and a semitrailer, which can vary from 5 to 9 axles, and its maximum transport capacity varies between 41.5 and 74 tons [28]. These different combinations have different fuel and tire consumption, being directly linked to economic and environmental issues [22,23]. With a focus on the environmental issue, transport modes are required to have lower consumption of fossil fuels with consequent lower CO_2 emissions and longer life of tires (which are manufactured from rubber) [23]. On the other hand, Brazil has 1,720,756 km of highways, has poor quality infrastructure with about 12.3% of the paved highways and of this total 58.2% are poorly maintained [22,32].

Table 1. Behavior of combinations of cargo vehicles in pavement modalities.

Grain Body Type (pulled by 420 hp tractor with 6x4	Good quality paved highway				Low quality paved highway				Unpaved highway			
	Rodotrem 9 axes 25 meters	Bitrem Articulate 7 axes (up to 30 meters)	Truck	Stump	Rodotrem 9 axes 25 meters	Bitrem Articulate 7 axes (up to 30 meters)	Truck	Stump	Rodotrem 9 axes 25 meters	Bitrem Articulate 7 axes (up to 30 meters)	Truck	Stump
Total Gross Cargo Weight (PBTC) (tons)	74	57	48.5	41.5	74	57	48.5	41.5	74	57	48.5	41.5
Net weight (tons)	50	38	30	25	50	38	30	25	50	38	30	25
Fuel Consumption with Scale Load (Km/L)	1.7	1.9	2.5	2.8	1.45	1.62	1.92	2.21	1.23	1.38	1.67	1.88
Diesel Oil Cost (BRL/km)	2.22	1.99	1.51	1.35	2.61	2.33	1.97	1.71	3.07	2.74	2.26	2.01
Tire Quantity	34	26	22	18	34	26	22	18	34	26	22	18
New Tire Life (Km)	250 000	280 000	290 000	290 000	212 500	238 000	246 500	246 500	180 625	202 300	209 525	209 525
Cost with new tires (BRL/km)	BRL 0.20	BRL 0.14	BRL 0.11	BRL 0.09	BRL 0.24	BRL 0.16	BRL 0.13	BRL 0.11	BRL 0.28	BRL 0.19	BRL 0.16	BRL 0.13
Unit cost of new tire (BRL/ton of coffee grain)	BRL 1.56	BRL 1.40	BRL 1.45	BRL 1.42	BRL 1.83	BRL 1.65	BRL 1.70	BRL 1.67	BRL 2.16	BRL 1.94	BRL 2.01	BRL 1.97
Retreaded Tire Life (Km)	140000	150000	150000	160000	119000	127500	127500	136000	101150	108375	108375	115600
Cost of retreaded tires (BRL/km)	R$0,15	R$0,10	R$0,09	R$0,07	R$0,17	R$0,12	R$0,10	R$0,08	R$0,20	R$0,14	R$0,12	R$0,09
Unit cost of retreaded tire (BRL/ton of coffee grain)	BRL 1.11	BRL 1.05	BRL 1.12	BRL 1.03	BRL 1.31	BRL 1.23	BRL 1.32	BRL 1.21	BRL 1.54	BRL 1.45	BRL 1.55	BRL 1.43
Consumption in liters of diesel to cover average distance from Guaxupé/MG to the Port of Santos (382 km)	224.71	201.05	152.80	136.43	263.45	235.80	198.96	172.85	310.57	276.81	228.74	203.19
Unit cost of diesel (BRL/ton of coffee grain)	BRL 16.99	BRL 20.00	BRL 19.25	BRL 20.63	BRL 19.92	BRL 23.46	BRL 25.07	BRL 26.14	BRL 23.48	BRL 27.54	BRL 28.82	BRL 30.72
CO_2 emission	602.22	538.81	409.51	365.63	706.05	631.95	533.21	463.24	832.33	741.85	613.03	544.55
CO_2 emission per kg of coffee grain	0.012	0.014	0.014	0.015	0.014	0.017	0.018	0.019	0.017	0.019	0.020	0.022

The use of the road modal is deeply linked to anthropogenic CO_2 emissions. There is a projection indicating that in 2020 emissions will be 270 million tons of CO_2, about 60% higher than in 2009 [21,33].

After a brief contextualization of the Brazilian scenario in relation to the most used transport modal and the concern about it being the largest CO_2 emitter, an analysis will be presented regarding the different types of combinations of cargo vehicles in relation to paving conditions of the roads.

3.1 Economic and environmental efficiency analysis

It is observed that, in general, from an economic point of view, the use of retreaded tires for any type of vehicle is better. The expenses (BRL/ton of coffee grains) on retreaded tires are on average 26% lower than with new tires. The average for new tires is BRL 1.46 and for retreads are BRL 1.08 per ton of coffee grains transported.

Regarding the expenses on diesel (BRL/ton of coffee grains) it is observed that in decreasing order of economic efficiency there is: rodotrem, (BRL 16.99), truck (BRL 19.25), bitrem (BRL 20.00) and stump (BRL 20.63).

Thus, considering the total expenses sum of diesel and tires, per ton of coffee grains transported from Guaxupé to the port of Santos, the most economical is that of the rodotrem with retreaded tires (BRL 18.10), and the least economical is the stump with new tires (BRL 22.05), which means a difference of 18%.

From this point of view of economic efficiency, the same is observed in relation to the highway with low quality paving and unpaved road. That is, whatever the quality of the highway, the rodotrem with retreaded tires is shown to be the best option and the stump with new tires, the worst.

It was expected that the consumption of tires and diesel will be higher on highways with low quality paving and even higher on unpaved roads. On average, compared with the respective values observed on highways with good quality paving, the expenses with tires are 17.3% higher on highways with low quality paving and 38.6% higher on unpaved roads; diesel spending is 23% higher on a highway with low quality paving and 43.8% higher on unpaved roads.

This observation reflects the impact on economic costs of the lack of road investments through improvement, maintenance, and rehabilitation of pavements, as highlighted in the work [34,35].

In addition to the quality of the roads, another determining factor in the increase in economic costs is related to the competence of the driver, as they can generate a difference in fuel consumption of 10% to 12% when comparing the best and worst drivers [36].

From an environmental point of view, [37] emphasize that CO_2 emissions are directly proportional to the amount of fuel consumed by a vehicle.

In this sense, CO_2 emissions on a highway with low-quality paving and on unpaved roads are higher than on highways with good-quality pavement, because the increase in emissions is enhanced by deficiencies in the infrastructure of the highways, as it affects the inertia, rolling resistance, air resistance and slope of the road and prevents speed from being constant [37].

4 Final Remarks and Outlooks

In order to discuss economic and environmental issues, with different combinations of cargo vehicles and different road conditions (good paving, poor paving and no paving) the present work presented data reporting the conjuncture by which the production of coffee grain in Guaxupé is exposed when transported to the Port of Santos.

That said, the use of the tractor truck 420HP 6X4 for all the proposed situations standardized the evaluations, ensuring that the differences to be evaluated would be in the use of semitrailers.

It was observed that, in general, it is more economical to use retreaded tires instead of new tires. This fact can be considered as beneficial to the environment, as it is possible to retread a "new" tire twice before it is discarded as scrap. Another fact associated with the cost of tires is that for the different combinations of vehicles the difference in cost with tires per ton of coffee grain transported is not relevant.

In economic terms, the factor that has the greatest relevance is the cost of diesel per ton of coffee grain transported and the "rodotrem" is the best combination for cargo, because it has the lowest consumption of diesel per ton of coffee grain transported.

In the environmental aspect, the "rodotrem" is the combination of load with the best performance in all of the paving conditions which have been evaluated.

As a result of the above, it is evident that the quality of road paving is a primary factor for better economic and environmental performance for the transport of coffee grains. By comparing the total distances covered by paved and unpaved roads, it is possible to identify that Brazils transportation matrix needs investments, technologies to improve fuel consumption and tire performance.

Finally, it is important to highlight that this study contributes to national efforts to mitigate anthropogenic GHG emissions in Brazilian food production chains, however the reduction of GHG emissions will depend on the development of the model of transport matrix that the government intends to follow.

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