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Impact of diesel price on coffee external transport cost and total cost in the Minas Gerais cities of Patrocínio and Guaxupé

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Abstract

Brazil's coffee production plays a significant role in the global economy. The country is the world's largest coffee producer, responsible for about a third of global production. Transportation is a relevant factor that impacts the coffee production chain, as it is essential for distributing production from the field to industries, export ports, and, eventually, final consumers. To calculate the costs associated with transport modes, it is essential to consider variables such as fuel prices — especially for diesel and S10 diesel —, which represent variable costs directly impacting price formation for transport services. In this context, the study aims to analyze the impact of diesel price on coffee external transport cost in relation to total cost in the cities of Patrocínio and Guaxupé, Minas Gerais, Brazil. This is a descriptive study, with a qualitative approach, using data from the National Supply Company (CONAB) on coffee production and from the Brazilian Agency of Petroleum, Natural Gas and Biofuels (ANP) on diesel and S10 diesel prices for 2013–2020 for the cities under analysis. The initial results showed a small variation in fuel prices over the period analyzed. Moreover, there was a strong relation between external transport and fuels, with a 0.010 significance level between the coffee external transport cost variable and total costs.

Keywords: coffee, diesel, transport

1 INTRODUCTION

According to data from the Brazilian Institute of Geography and Statistics (IBGE, 2024), Brazil is the largest coffee producer and exporter in the world, cultivating predominantly the species *Coffea arabica* and *Coffea canephora* (robusta, known as conilon in Brazil). Minas Gerais is notable as the main producing state, responsible for approximately 54.3% of the national production, followed by Espírito Santo, with 19.7%, and São Paulo, with 9.8%. In addition, the country is the second-largest global consumer of coffee, showing its relevance in the daily lives of the Brazilian population (MAPA, 2023).

According to CECAFÉ (2020), the wide diversity of producing states results in significant variations in coffee quality due to factors such as soil characteristics, altitude, temperature, and climate, which directly influence grains.

At the national level, "the coffee agribusiness represents an activity of marked socioeconomic relevance in national development. In addition, coffee farming has an important social function, since it has a relevant capacity to create jobs" (Fehr et al., 2012).

Coffee production is especially sensitive to variations in temperature, rainfall, and genetic and physiological characteristics. For example, crops of *Coffea arabica* can have the area available for cultivation reduced if average temperatures and rainfall rates increase, even if their genetic and physiological conditions are maintained (Assad et al., 2004).

Another relevant aspect is that coffee is a permanent crop, lasting for several years. This characteristic implies that the production stage has the highest costs for producers. In this context, knowledge about cost accounting is as essential for rural producers as it is for the industry (Duarte et al., 2013).

The high competitiveness of the sector means that costs are no longer the only variable to be considered by producers when setting the selling price. The price charged by competitors also becomes a fundamental variable. Thus, cost management expertise is crucial to evaluate the profitability of production and trace possible improvements in the production process to reduce costs (Fehr et al., 2012).

Reis et al. (2003) note that "coffee entrepreneurs must be fully aware of their expenses, adapting them to a context that enables the good administration of their enterprise, efficiency and achievement of planned goals." This point reinforces the need to manage costs efficiently to achieve better results.

Among the costs involved in production, we note transportation, on which diesel has a major impact as the main fuel used in trucks, buses, and trains (Rocha, 2015). Diesel price significantly impacts transportation costs, being one of the highest operating expenses of companies in the sector (Silva, 2015). When diesel price increases, companies pass along this additional cost to customers, raising the prices of transported products and services (Oliveira, 2020). On the other hand, a reduction in diesel prices can benefit consumers by stabilizing or decreasing transportation costs (Oliveira et al., 2020).

Therefore, this study seeks to answer the following question: "What is the impact of diesel price on external transport and total coffee cost?". The general objective is to analyze the impact of diesel price on coffee external transport costs in relation to total cost in the cities of Patrocínio and Guaxupé, Minas Gerais, Brazil, for 2013–2020. We aim to verify the relation between transport costs, total production costs and the relevance of diesel and S10 diesel prices in this context.

The social contribution of this study lies in the importance of coffee for Brazil, as it is the world leader in coffee production. This activity creates a significant number of direct and indirect jobs. According to Lacerra (2013), each hectare of coffee planted in Brazil creates approximately 2.3 direct jobs and at least 4 indirect jobs. Estimates indicate that, in 2020, the coffee sector created about 8.4 million jobs from production chain to retail (Compre Rural, 2020). These data reinforce the socioeconomic relevance of the coffee business in Brazil.

From a theoretical perspective, the significance of logistical costs in coffee production justifies this work. High logistics costs can compromise the producer's competitiveness in the market (Coti-Zelati et al., 2018). Therefore, studies in this field are essential to propose improvements to the sector.

Logistics plays a fundamental role in the coffee production chain, being present in several stages and using different transport modes until the final product reaches consumers (Ribeiro et al., 2019). This context reinforces the importance of analyzing the relationship between logistics costs and coffee production.

As a practical contribution, this study seeks to broaden the understanding of how logistics costs impact coffee production, enabling more efficient planning to achieve better results. Transportation cost is the most representative among logistics costs. Additionally, because coffee is a bean, transporting it can result in losses due to inadequate road or vehicle conditions (Kussano, 2010). This study shows the need for a good understanding of the relevance of logistics costs in production.

Previous studies all agree that logistics costs are very important in the coffee production process, looking into how road conditions affect these costs and how they relate to the competitiveness of producers in the market.

2 THEORETICAL FRAMEWORK

2.1 Coffee in Brazil and its economic importance

Coffee is one of the main agricultural commodities produced in Brazil, with major economic importance for the country. Brazil is the world's largest coffee producer, responsible for about a third of global production. Moreover, coffee is one of Brazil's main export products, providing billions of dollars in revenue annually (Oliveira et al., 2015).

Coffee production in Brazil significantly impacts the economy of several regions, especially in the south of Minas Gerais State, and in the *Cerrado* of Minas Gerais, in the Alta Mogiana Area of São Paulo State, in addition to the states of Paraná, Espírito Santo, and Bahia. Coffee cultivation is responsible for creating millions of direct and indirect jobs, constituting a vital driver for the economy of these regions (Lopes & Silva, 2016; Paula & Magalhães, 2018).

Furthermore, coffee plays a key role in several industries that depend on the production, processing, and distribution of the product. Sectors directly benefited by coffee production include machinery and equipment, transport and logistics, food, and exports (Romano & Ribeiro, 2017).

Coffee also has a considerable impact on the Brazilian trade balance. In 2020, the country exported about 43 million bags of coffee, providing revenues of more than US$ 5 billion (MAPA, 2021). This volume places coffee among Brazil's main export products, alongside commodities such as soybeans, beef, and sugar.

2.2 Logistics

When studying the logistics costs of coffee, it is essential to understand the concept of logistics and its functions. According to Tabox (2012), the term "logistics" emerged in the military context, being used to describe activities of acquisition, transportation, storage, and maintenance of materials, equipment, and personnel. Currently, the concept has been expanded and can be defined as a process that involves the entire chain of transporting goods, whether for productive or administrative use. This context assesses several variables, including storage, transportation, distribution, losses, and returns.

Logistics is fundamental for any sector dependent on this process, because when properly managed, it can provide significant operational gains, especially in reducing costs and optimizing the labor employed (Tabox, 2012).

According to Carvalho (2013), logistics requires efficient management of the transport modes used in deliveries. Mismanagement of these resources can cause negative impacts on the process. Examples include the appropriate choice of transport service providers, the negotiation of contracts, and the structure of the vehicles used. We must integrate these factors to ensure that the logistics process does not treat transport management in isolation.

On the other hand, Caixeta Filho (2010) defines logistics as a process that seeks the global optimization of the system, aiming at streamlining procedures and reducing costs throughout the logistics chain. Its functions comprise supply activities, supplier development, production planning and scheduling, packaging, assembly, and customer service.

The diversity of concepts reinforces that logistics is a broad field. According to the aforementioned authors, it represents a crucial factor in planning transport in production, whether of final goods or raw materials.

The execution of logistics activities can utilize various transport modes. The main modes are road, rail, waterway, and air transport. Caixeta Filho (2010) emphasizes the importance of considering the time and product type when selecting the most suitable mode.

Caixeta Filho (2010) also notes the relationship between cost and speed of the modes. In this context, air transport is the fastest but also the most expensive. According to this logic, costs increase in the following order: road, rail, and waterway transport modes. We conclude that increased efficiency leads to increased costs.

Data from the National Confederation of Transport and Logistics Workers (CNTTL, 2020) indicate that the main transport mode used in Brazil is road transport. This is due to the 1950s' large investments in highway expansion, which is responsible for about 60% of the country's cargo transport.

In addition, Ribeiro and Ferreira (2002) say that the road transport mode can reach practically every place in the country, making it ideal for accessing places that are not covered by other modes. Despite its higher cost compared to rail and waterway transport, road transport offers the advantage of short- and medium-distance door-to-door deliveries when necessary.

Transport modes are interconnected, playing complementary roles in the logistics chain. It is necessary to analyze factors such as product type, customer profile, timeframe, and available budget to choose the most appropriate mode (Ribeiro & Ferreira, 2002).

The demand for efficient choice of modes has led to the development of strategies to optimize existing options, either by improving conditions or creating customized versions for specific cargos. The process of contracting freight operations for regions with higher demand has also been improved (Caixeta Filho, 2010).

Given the central role of road transport in logistics and its dependence on diesel as the main fuel, it is essential to manage the costs related to this input (Rocha, 2015).

Diesel cost is one of the main factors impacting road transport costs, representing a significant portion of the operating costs of transport companies. This affects product transportation prices directly, influencing competitiveness in several sectors, including coffee production (Oliveira, 2020).

Therefore, Rangel (2020) emphasizes the importance of diesel price monitoring in decision-making on logistics and transportation. Effective management of these variables can significantly improve the price competitiveness of coffee producers and logistics efficiency in general.

2.3 Cost Management in coffee farming

Cost management is essential to understand logistics costs in coffee farming and propose effective improvements. According to Pompermayer and Lima (2002), "good cost management has as its main objective the maximization of profits, whose most striking effectiveness is the natural achievement of cost leadership." This approach demonstrates that efficient management significantly increases the chances of gains at the end of the process.

However, there are specific challenges in the application of cost management in rural areas. Breitenbach (2014) notes that most research on cost management addresses the urban context, being necessary to adapt this knowledge to the rural setting. Lack of this distinction can lead to significant errors, especially because, in rural areas, producers themselves accumulate the functions of manager and worker in production. This overload, in addition to the lack of formal instruction on management, often prevents producers from knowing the real costs and profits of their business. Moreover, they face the challenge of balancing the production allotted for sale with the portion used for their sustenance, increasing the complexity of management (Breitenbach, 2014).

In the context of coffee farming, cost management becomes even more indispensable. According to Alvarenga et al. (2012), this accounting tool is crucial not only for surveying production costs but also for supporting producer decision-making. Efficient cost management in the coffee sector maximizes economic results and strengthens coffee's competitiveness in the market.

Additionally, logistics costs represent a significant obstacle for coffee farmers in Brazil. According to Silveira et al. (2016), coffee transport is affected by the precariousness of roads, which lack adequate infrastructure and safety. These deficiencies raise transport costs, already affected by high fuel prices and dependence on road transport. Machado (2018) reinforces that these conditions make transport to cooperatives an even greater challenge for producers.

In addition, production for export has additional costs, such as packaging, internal freight, insurance, handling, wharfage, and administrative expenses, which include the issuance of documents such as commercial invoices, bills of lading, and certificates of origin (Espírito Santo, 2002). To compete effectively in the international market, it is essential that producers adopt strategies to reduce and optimize these logistics costs, making their products more competitive (Espírito Santo, 2002).

Finally, Oliveira et al. (2004) note that, despite the challenges related to production, logistics, and marketing costs, product quality is decisive for success. Presenting high-quality coffee, both in the domestic and international markets, can maximize sales results and significantly value the crop.

2.4 Previous Studies

Alves and Arima (2004) examined historical aspects of logistics in Brazil, considering its development and the challenges faced in meeting e-commerce needs. The study indicates that the main points to be considered on the subject are product delivery and transaction safety.

In turn, Guerreiro et al. (2011) researched the extent of the application, in Brazil, of the concepts addressed in the literature on logistics and Supply Chain Management (SCM). The conclusions showed that, although 86% of the companies analyzed have a logistics sector, only 67% use SCM in their framework.

Xavier and Martins (2011) studied the interrelationship between the formation of logistics strategies and the processes for decision-making and strategy plannings at the global level. The analysis showed that companies with professional management adopt deliberate strategies focused mainly on growth and positioning goals. On the other hand, companies with non-professional management are characterized by emerging strategies focused on launching new products whose decisions are often supported by cognitive and intuitive apprehensions.

In the following study, Souza et al. (2014) analyzed practices for managing logistics costs in a food and beverage company from Rio Grande do Sul. The results indicated that, although the company uses tools for managing logistics costs, they are not yet fully integrated into the corporate setting.

Vargas et al. (2016) studied the measurement of logistics costs in a printing company that had undergone a restructuring in its logistics sector. The first step in restructuring was surveying the logistics process's activities and costs. The measurement of the logistics cost occurs at two different times, with freight costs representing 63.48% of the company's total logistics cost. These costs require an adequate measurement process, as they are often attributed to departmental costs, which makes them hidden in relation to the generating event.

According to Moreira et al. (2024), the socioeconomic impacts of a potential diesel shortage on the Brazilian economy were analyzed using an input-output model integrated with linear programming procedures. The research simulates direct, indirect and induced effects on income and employment, showing the vulnerability of the economy due to high dependence on diesel, especially in the transport sector. The results indicate a possible reduction of R$ 76.28 billion in GDP (1.5% of the 2015 GDP) and the loss of up to 1.8 million jobs in 10 days of supply restriction. The study contributes to energy planning, suggesting the formation of strategic diesel stocks and alternatives to mitigate risks.

Finally, according to Guimarães et al. (2024), the increase in fuel costs in Rio Grande do Norte between 2013 and 2022 was significantly higher than the growth in the minimum monthly wage in the same period. The analysis of secondary data and trend models showed that fuels such as diesel, LPG, and CNG had the highest variations, with growth rates above 8%, while the minimum monthly wage increased by just over 6%. This mismatch illustrates the growing pressure of fuel costs on consumers and sectors dependent on road transport in the region.

3 METHODOLOGY

In methodological terms, this research is considered descriptive, as it aims to describe the characteristics of a given phenomenon. According to Nunes et al. (2016), "in descriptive research, the study, analysis, registration and interpretation of the facts of the physical world are carried out without interference of the researcher. The purpose is to observe, record, and analyze the phenomena or technical systems, without, however, looking into the merits of the contents".

As for the approach to the issue, this is quantitative research, as it involves the calculation and measurement of indicators that assist in understanding and interpreting the subject under discussion. According to Gabriel (2014), "it should be noted that research with a quantitative design presupposes the definition of the role of each variable and the relation between them."

The study was based on research on data from the National Supply Company (CONAB), the institution responsible for providing strategic information and surveying and evaluating Brazilian crops — in the case of this research, coffee. We used product data tables and survey, and evaluation bulletins released between 2013 and 2020, which contain crop evaluations for the different cities of Guaxupé and Patrocínio, in the state of Minas Gerais. These data include economic analysis, planted area, productivity, production, supply, demand, and market analysis, among others.

As for fuel, we also collected data on Diesel and S10 Diesel monthly prices for the same cities and period from the website of the National Agency of Petroleum, Natural Gas and Biofuels (ANP). The prices were adjusted by the Extended National Consumer Price Index (IPCA), calculated by the Brazilian Institute of Geography and Statistics (IBGE, 2023), in the analyzed period to reflect the present price values' situation, ensuring monetary uniformity in the evaluation.

In order to address the issue raised in this research, the Multiple Linear Regression model was applied. According to Hair et al. (2009), this technique aims to use the independent variables whose values are admitted to predict the values of the chosen dependent variable. The following are Equations 1 and 2, which define the econometric model of this research:

$$TRANSPEXkg_{it} = \beta_0 + \beta_1 DIESELS_{it} + \beta_2 DIESEL_{it} + \beta_3 CTkg_{it} + \varepsilon_{it} \quad (1)$$

$$CTkg_{it} = \beta_0 + \beta_1 DIESELS_{it} + \beta_2 DIESEL_{it} + \beta_3 TRANSPEXkg_{iit} + \varepsilon_{it} \quad (2)$$

Figure 1
Meaning of the variables

Parameter	Meaning
TRANSPEXkg	External transport cost per 60 kg coffee bag
CTkg	Total cost per 60 kg coffee bag
DIESELS	Average price of S10 diesel
DIESEL	Average price of S500 diesel

Source: Authors' elaboration.

The dependent variables (Figure 1) are TRANSPEXkg, which represents the external transport cost per 60 kg bag, and CTkg, which refers to the total cost per 60 kg bag. The independent variables are DIESELS, which is the average price of S10 diesel, and DIESEL, which is the average price of S500 diesel. The variable i refers to each city in the period t, and ϵ represents the stochastic error term of the regression, which includes all other factors that may be associated with the dependent variable and that are not included in the model.

We conducted tests to validate the multiple linear regression models utilized in this research. Among these tests, the residuals were analyzed in order to verify the existence of evidence of violations in the assumptions of normality, independence, and homogeneity of variance of the residuals. The software used to perform linear regression was STATA, a statistical program often used for econometric analysis, applicable to cross-section data, panel data, and time series estimation.

In checking if the residuals follow a normal distribution using the Kolmogorov-Smirnov test, the p-values were 0.07182 for Equation 1 and 0.05147 for Equation 2 at a 5% significance level. Therefore, we accepted the test's H0, indicating that the model's residuals follow a normal distribution. To check if the residuals are independent, the Durbin-Watson test was used, which assumes that the errors in the regression model follow a specific pattern. The test obtained a p-value of 0.7602 and 0.2404 (for Equation 1 and Equation 2, respectively), which resulted in acceptance of H0 of the test at a 5% significance level, indicating that the model residuals do not present first-order serial autocorrelation.

We applied the F-test to verify the homogeneity of variance of the residuals. The obtained p-value was 0.5744 and 0.002433 (for Equations 1 and 2, respectively). In the model of Equation 1, the p-value was greater than the 5% significance level, and therefore the H0 of the test was accepted, indicating that the variances are homoscedastic. However, for Equation 2, H0 was rejected, and heteroscedasticity was corrected by the robust command in R.

In addition, the Variance Inflation Factor (VIF) test was applied to verify if the data had multicollinearity problems. The VIF was 4.35 and 4.84 (respectively for Equation 1 and Equation 2), values that are less than 10 (Hair et al., 2009), indicating that there were no multicollinearity problems in the database of this study.

Student's t-test was used to evaluate whether the means of the samples between the evaluated cities (Guaxupé and Patrocínio) are significantly different from each other for each variable. The null hypothesis (H0) of the test states that the means of the samples are equal at a 5% significance level.

4 RESULTS

This section presents the results of the analysis carried out in this research, which sought to verify whether there is an association between S10 and S500 diesel prices with external transport costs and with the total costs of the 60 kg coffee bag, using data for the period of 2013–2020. Table 1 shows the descriptive statistics of the sample, and by looking at the coefficient of variation, we can see that both variables have low variability compared to the average of the data.

Table 1
Descriptive statistics of the sample

Variable	Obs.	Mean	Standard Deviation	Minimum	Maximum	Coefficient of variation (CV)
S10 DIESEL	16	4.3468	0.1939	3.9675	4.6710	0.0446
S500 DIESEL	16	4.1752	0.2009	3.8722	4.5564	0.0481
TRANSPEXkg	16	2.0910	0.5817	1.4272	2.9878	0.2782
CTkg	16	599.2468	199.3909	452.5765	1,308.9490	0.3327

Source: research data.

The coefficient of variation (CV) of the DIESELS AND DIESEL variables indicates considerable volatility in fuel prices, which can result in significant impacts on the production cost framework, especially on external transport. This factor reinforces the need for mitigation strategies to minimize the effects of these variations on total cost (CTkg).

As shown in Table 1, the S10 Diesel variable has a coefficient of variation of 4.46%, indicating a small variation in prices during the analyzed period, with a mean of R$ 4.3468 for the same time interval. The same applies to the S500 Diesel, which obtained a coefficient of variation of 4.81%, with an average price of R$ 4.1752.

As for the “TRANSPEXkg” variable, a higher coefficient of variation of 27.82% was observed, with a minimum value of 1.4272 and a maximum value of 2.9878, resulting in a mean of 2.0910 over the years. Finally, the variable with the highest coefficient of variation is the total cost, which varied between R$ 452.5765 (minimum) and R$ 1,308.9490 (maximum), with a coefficient of variation of 33.27%.

The variables that presented normal distribution were submitted to Pearson’s correlation test, with the objective of evaluating the linear relation between the variables of price of diesel and the costs. This test is intended to determine whether a change in one variable is associated with a proportional change in the other.

Table 2
Pearson correlation test for arabica coffee

Coefficients	TRANSPEXkg	CTkg
S10 DIESEL	0.6771*	0.0510
S500 DIESEL	0.7021*	0.0082
TRANSPEXkg	1.0000	0.3644
CTkg	0.3644	1.0000

Source: research data.

The S10 Diesel and S500 Diesel variables showed a strong/moderate and significant correlation with external transport costs per 60 kg bag, with coefficients of 0.6771 and 0.7021, respectively. It can be inferred that this occurs because fuel, as a variable cost in cargo transport, represents a considerable portion of transport price formation. These findings corroborate the study of Pera, Costa and Filho (2018), which showed that the diesel price variation, between January 2017 and May 2018, was similar to the transportation cost variation in the same period. Paula et al. (2019) also showed that the diesel oil price represents up to 33.60% of the road transport freight cost, which reinforces the strong relation between fuel price and transport cost. To meet the research objective, we presented the results for the analysis of the simple linear regression model, as reported in Table 3.

Table 3
Multiple Linear Regression Models

	TRANSPEXkg (Equation 1)					CTkg (Equation 2)				
	Estimated Coefficient	Standard Error	t-value	Pr(>|t|)		Estimated Coefficient	Standard Error	t-value	Pr(>|t|)	
(Intercept)	−7.2334	2.3203	−3.1170	0.0089	***	−177.2490	324.3570	−0.5460	0.5948	*
DIESELS	0.3803	1.3028	0.2920	0.7754		555.8690	243.9280	2.2790	0.0418	**
DIESEL	1.6895	1.2553	1.3460	0.2032		−407.6980	226.4290	−1.8010	0.0969	*
CTkg	0.0010	0.0005	1.9850	0.0705	**					
TRANSPEXkg						6.6920	38.7320	0.1730	0.8657	
R^2	0.6243					0.5793				

Note: *, **, and *** indicate significance level at 10%, 5%, and 1%, respectively.
Source: research data.

To meet the research objective, we presented the results for the analysis of the simple linear regression model, as reported in Table 3. Thus, we present the estimated values of the multiple linear regression models between External Transport Costs and Total Costs variables and the S10 Diesel and S500 Diesel prices, according to the models in Equation 1 and Equation 2. Intercepts, or linear coefficients (B0), were significant, with p-values of 0.0089 and 0.5948 at a 10% significance level.

It is noted that the DIESELS and DIESEL variables play an important role in explaining external transport costs (TRANSPEXkg), highlighting that changes in fuel prices can greatly affect production and transport costs. The sector's high dependence on road transport intensifies this impact.

In the regression model of Equation 1, the S10 Diesel and S500 Diesel variables were not significant at a 10% significance level; that is, External Transport costs were not significantly related to either the S10 diesel price or the S500 diesel price. On the other hand, total costs per bag showed a positive and significant association with External Transport costs. This change occurred because fuel, as a variable cost in cargo transport, represents a considerable portion of transport pricing. These findings corroborate the study of Pereira et al. (2016), who verified in a fertilizer production company that transport cost is very significant for total product cost, directly impacting the product sale value, according to the necessary logistical performance.

In the regression model of Equation 2, the S10 Diesel and S500 Diesel variables were significant at a 10% significance level; that is, total costs had a significant and positive relation with S10 diesel price and a significant and inverse relation with S500 diesel price. This occurred because, as shown in the analyses presented in Table 3, fuel price constitutes a significant portion of total production costs and varies linearly with its monthly price changes. Fuel is a variable cost; this cost is passed on to the final price of the product or service, since it interferes directly with total production costs.

The R^2 presented in Table 3, which deals with the coefficient of determination or fit measure of the model, indicates that the total variability of the data of the model in Equation 1 is explained in 62.43%, while the variability of the model in Equation 2 is explained in 57.93%.

Table 4
Student's T-test

Parameter	*p-value*	H_0 (Sig. 5%)
CTkg	0.0933	Accepted
TRANSPEXkg	0.0405	Rejected
S10 DIESEL	0.0340	Rejected
S500 DIESEL	0.0973	Accepted

Source: research data.

As shown in Table 4, for the variables of cost of External Transport per 60 kg bag and S10 Diesel, the p-value was lower than the pre-established 5% significance level. Thus, the null hypothesis was rejected, indicating a significant difference between the mean costs between the cities of Guaxupé and Patrocínio.

On the other hand, in the variables of total costs per 60 kg bag and S500 Diesel, the null hypothesis was maintained, with insufficient evidence to affirm that the means are different between the two cities.

These results suggest that the location of the municipalities, Guaxupé in the southwestern Minas Gerais and Patrocínio in the Alto Paranaíba region, may have a significant influence on the analyzed variables, possibly due to logistical, geographical, or economic factors specific to each region.

FINAL CONSIDERATIONS

This study sought to analyze the relationship between diesel prices (S10 and S500), transport costs, and total coffee production costs, specifically in the cities of Guaxupé and Patrocínio, located in the state of Minas Gerais, Brazil, between 2013 and 2020. The effect of fuel price, which is one of the biggest changing costs in road transport, was clearly seen, supporting previous studies that show diesel is a key factor in logistics costs (Paula et al., 2019; Pera et al., 2018).

The results indicated a strong correlation between S10 diesel price and external transport costs, with significant coefficients. As for S500 diesel, although it showed a significant correlation with total costs, the relationship was inverse, which suggests that fluctuations in S500 diesel prices may affect the total production cost differently. These findings reinforce the idea that fuel has a considerable influence on the formation of logistics costs and, consequently, on the final price of the product (Pereira et al., 2016).

In addition, analysis of the regression models indicated that external transport costs were not significant for diesel prices in all equations, but total costs per coffee bag showed a positive and significant association with S10 diesel and a negative one with S500 diesel. This behavior aligns with economic theory, which suggests that as fuel costs increase, the impact on production costs also rises, potentially leading to variations in the final prices of products.

Fuel price volatility represents a challenge for the production chain, especially in sectors dependent on road transport. The results of this study suggest that fuel price variations can significantly change total cost, requiring attention to strategies to mitigate impacts on logistics and production.

The research also found that the cost variables between the cities of Guaxupé and Patrocínio showed statistically significant differences for external transport costs, indicating that geographical location can substantially affect logistics costs, considering the specificities of the regions' transport infrastructures and networks.

Finally, this study contributes significantly to the understanding of the factors that affect coffee production costs in Brazil, highlighting the importance of efficient management of logistics costs and monitoring of fuel prices. The understanding of these variables supports coffee producers toward adopting more effective strategies, mitigating the negative impacts of variable costs, and improving competitiveness in the national and international markets.

In the future, it would be relevant to expand the study to include other coffee-producing states and examine the impact of public policies, such as tax incentives or fuel subsidies, on total production cost. That can provide valuable insights to enhance logistics and management strategies in the agricultural sector.

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