Research, Society and Development, v. 13, n. 8, e1113846481, 2024
(CC BY 4.0) | ISSN 2525-3409 | DOI: http://dx.doi.org/10.33448/rsd-v13i8.46481

Coffee market price as a reflection of the brazilian harvest

Preço de mercado do café como reflexo da safra brasileira

El precio del café en el mercado como reflejo de la cosecha brasileña

Received: 07/18/2024 | Revised: 07/30/2024 | Accepted: 08/01/2024 | Published: 08/04/2024

Vítor Almeida Ferraz
ORCID: https://orcid.org/0009-0007-4083-2345
Independent researcher, Brazil
E-mail: vferraz1405@gmail.com
Gustavo de Souza e Silva
ORCID: https://orcid.org/0009-0006-3050-2118
Institute Pecege, Brazil
E-mail: costausp@hotmail.com

Abstract
Brazilian agribusiness has great importance in the constitution of national gross domestic product, reaching values of more than 27% representativeness. Within the agricultural products we have coffee as one of the great crops in our country. As it is known its market value fluctuates, like all products, by the most diverse factors. This work aimed to evaluate the existence or not of a correlation in the market price of coffee with production factors in Brazil. Variation along the years of Brazilian total coffee production, total area in production and area of crop formation was explored via a Pearson's correlation analysis with significance of 95%. Pearson's correlation analysis identified a negative correlation of -0.33 between the negotiation price of the coffee sack (60 kg) and the total production volume of the Brazilian crop. Considering that the market value of this product can be affected by numerous factors we conclude the significant existence of this correlation.
Keywords: Arabic; Coffea sp.; Conilon; Correlation; Pearson.

Resumo
O agronegócio brasileiro é de grande importância na constituição do produto interno bruto nacional, atingindo valores de mais de 27% de representatividade. Dentro dos produtos agrícolas, temos o café como uma das grandes culturas do nosso país. Como é sabido, seu valor de mercado oscila, como todos os produtos, devido aos mais diversos fatores. Por meio de análises exploratórias e correlação de Pearson ($p<0,05$), este trabalho teve como objetivo avaliar a existência ou não de correlação no preço de mercado do café com os fatores de produção no Brasil (produção total, área total em produção, área de formação da cultura). A análise de correlação de Pearson identificou uma correlação negativa de -0,33 entre o preço de negociação de uma saca de café (60 kg) e o volume total de produção da safra brasileira. Considerando que o valor de mercado deste produto pode ser afetado por inúmeros fatores, concluímos a existência significativa desta correlação.
Palavras-chave: Arábica; Coffea sp.; Conilon; Correlação; Pearson.

Resumen
El agronegocio brasileño tiene gran importancia en la constitución del producto interno bruto nacional, alcanzando valores de más del 27% de representatividad. Dentro de los productos agrícolas tenemos al café como uno de los grandes cultivos en nuestro país. Como es sabido, su valor de mercado fluctúa, como todos los productos, por los factores más diversos. A través de análisis exploratorios y correlación de Pearson ($p<0.05$), este trabajo tuvo como objetivo evaluar la existencia o no de una correlación en el precio de mercado del café con los factores de producción en Brasil (producción total, área total en producción, área de formación de cultivos). El análisis de correlación de Pearson identificó una correlación negativa de -0,33 entre el precio de negociación del saco de café (60 kg) y el volumen total de producción de la cosecha brasileña. Teniendo en cuenta que el valor de mercado de este producto puede verse afectado por numerosos factores, concluimos la existencia significativa de esta correlación.
Palabras clave: Arábica; *Coffea sp.*; Conilon; Correlación; Pearson.

1. Introduction

The Brazilian agribusiness sector, according to the Center for Advanced Studies in Applied Economics (CEPEA) of the ”Luiz de Queiroz” College of Agriculture – University of São Paulo (ESALQ/USP), in partnership with the Confederation

(CC BY 4.0) | ISSN 2525-3409 | DOI: http://dx.doi.org/10.33448/rsd-v13i8.46481

of Agriculture and Livestock of Brazil (CNA), has shown growth in its contribution to the Brazilian Gross Domestic Product (GDP) since 2018. From 2020 to 2021, with an 8.6% increase in its share of the Brazilian GDP, it reached 27.4%. This marks the highest participation since 2004, which was 27.53% (Cepea, 2022).

It is important to highlight that these figures are based on CEPEA's calculations in partnership with CNA, as there is a significant discrepancy when compared to data from the Brazilian Institute of Geography and Statistics (IBGE). This discrepancy arises because the CEPEA/CNA methodology considers the entire agribusiness sector (inputs, agriculture, industry, and services), whereas the IBGE methodology only considers the evolution of volume within the farm gate (Cepea, 2022).

These data underscore the importance of agribusiness for Brazilian development. Within this context, coffee stands out as one of Brazil's main agricultural products (Barros et al., 2019). Originating from the African continent, coffee was introduced to Brazil and demonstrated significant adaptability, which facilitated its rapid expansion across the country (Volsi et al., 2019). Today, coffee is one of the most representative agricultural products in Brazil's export portfolio and a crucial revenue generator for Brazilian agriculture (Lanna and Reis, 2012). According to the Agrianual 2022, in 2020, coffee export revenues reached 5 billion dollars, and by November 2021, revenues had already hit 5.11 billion dollars. The Brazilian coffee harvest of 2020 produced 63.1 million bags, of which 39.7 million were exported, representing approximately 30% of the global coffee export market. Coffee cultivation is a significant source of income and employment in several tropical countries, with Brazil being the largest producer and exporter worldwide (Agrianual, 2022).

Minas Gerais is the leading coffee-producing state in Brazil, featuring the highest level of technological advancement in the country's coffee sector (Moreira et al., 2000). The state of São Paulo also plays a significant role in Brazilian coffee production. In 2020, São Paulo produced 6.18 million bags of coffee (Agrianual, 2022), with a harvested area of 201,477 hectares and an average productivity of 30.67 bags per hectare for that year.

Morphophysiologically, the coffee plant (Coffea sp.) exhibits three unique characteristics that primarily influence its productivity alternation. The first is that coffee fruits originate only from the nodes formed during the previous year's growth, between one flowering and the next (Damatta, 2007). The second characteristic is that coffee plants fruit and grow synchronously. Consequently, they require a specific supply of metabolites for both growth and fruiting sinks, with priority given to the fruiting sink over the growth sink (Cannel et al., 1976). This leads to a phenomenon known as biennial bearing, where high productivity in one-year results in reduced growth and, consequently, lower productivity in the following year (Pereira et al., 2011; Bernardes et al., 2012; Valadares et al., 2013). The third characteristic relates to the non-uniform flowering of coffee plants, resulting in uneven and variable productivity and fruit maturation (Camargo and Camargo, 2001). Flowering occurs with each water stimulus received by the buds (Santinato, 2016).

Understanding the variation in coffee productivity over subsequent harvests is crucial, necessitating knowledge of its phenological cycle of flowering and production. According to Camargo and Camargo (2001), the coffee plant undergoes several phenological phases, defined after multiple schematic attempts by the authors, into six distinct phases over two phenological years, starting in September.

The phases are described as follows: a) vegetative phase, from September to March, with long days; b) vegetative phase, from April to August, with short days, during which the vegetative buds on the nodes formed in the first phase are induced into reproductive buds, known as the floral initiation or evocation phase. By the end of the second phase, in July and August, the plants enter a dormancy period, forming one or two pairs of small leaves, observed during the relative dormancy period between the two phenological years. Following this is the maturation of reproductive buds after accumulating about 350 mm of potential evapotranspiration (ETp) from April; c) flowering and fruit expansion phase, from September to December. Flowering occurs about 8 to 15 days after the increase in water potential in the floral buds, triggered by rain or irrigation; d) fruit granulation phase, from January to March; e) maturation phase, where, after approximately 700 mm of accumulated ETp, fruit maturation occurs following the main flowering; f) senescence and death phase of non-primary productive branches, in July and August (Camargo & Camargo, 2001).

Coffee market price is known to be regulated by several factors, that can differ from other major staple foods (Hernandez et al., 2020). In the Ethiopian market, Abebe (2020) found that macroeconomics variables were important to explain the variation of coffee price along nine years. In the Brazilian scenario, Volsi et al. (2019) cite that prices are historically regulated by government intervention, spatial distribution of productive micro-regions, and the varieties of coffee produced. However, there is a lack of studies that try to relate coffee international price with the national variables of production, given the size of Brazilian production in the international market. In this context, given the biennial bearing characteristic of coffee production, this study hypothesizes that the base market price can vary according to the positive and negative biennial cycles of the Brazilian coffee harvest. Thus, the objective is to evaluate the trading price of coffee bags over the years and the correlation between the price and coffee production volume in Brazil.

2. Methodology

Data from six consecutive harvests of Brazilian coffee production, from 2015 to 2020, were obtained. Production volume (bags), area in production (ha), and area in formation (ha) data were sourced from the freely accessible historical series of the National Supply Company (Conab). The selling price per 60 kg bag (US$) was obtained from the freely accessible historical series of CEPEA.

An exploratory analysis was conducted to preliminarily observe any correlations in the obtained data.

To verify the dependence between the trading price of coffee bags and the selected production variables (volume, area in formation, and area in production), the correlation between data from the six productive harvests was measured. Pearson's correlation, eq. (1), was used at the level of significance of 95%:

$$\mathrm{r} = \frac{1}{n-1} \sum \left(\frac{xi-\bar{X}}{sx}\right) \left(\frac{yi-\bar{Y}}{sy}\right) \quad (1)$$

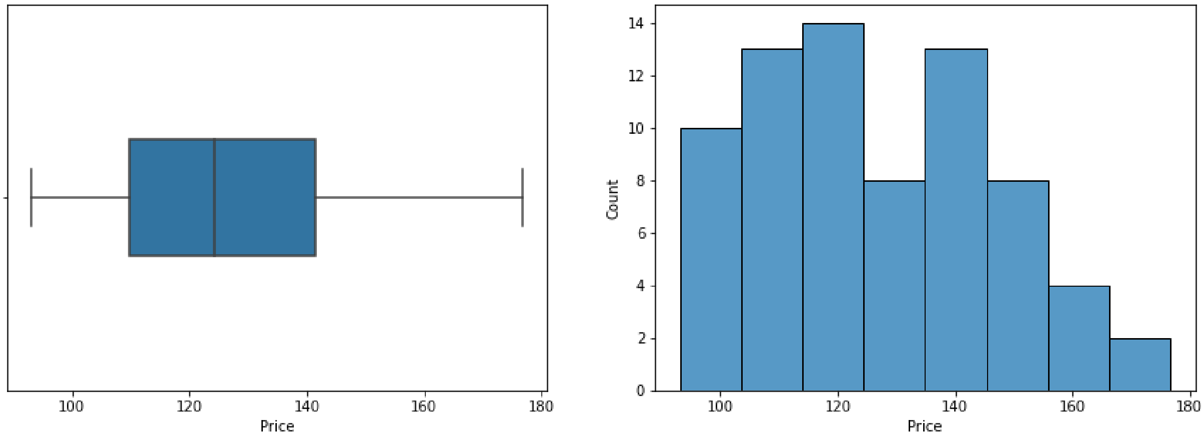
According to Stanton (2001), the Pearson correlation originated from collaborative work between Karl Pearson and Francis Galton. Various authors provide insights into this specific analysis in their works. For example, Moore (2007) defines correlation as a means to measure the direction and degree of the linear relationship between two quantitative variables. Garson (2009) further elaborates that the Pearson correlation represents the degree of relationship between two variables, expressed through a bivariate association measure (strength).

The Pearson correlation coefficient (r), also known as Pearson's r, calculates a dimensionless index with values ranging between -1.0 and 1.0, reflecting the degree of linear correlation between two quantitative variables. When r = 1, it indicates a perfect positive correlation between the two variables; if r = -1, it signifies a perfect negative correlation, meaning that if one variable increases, the other always decreases. If r = 0, it indicates that the two variables do not linearly depend on each other. However, it is important to note that the absence of linear correlation (r = 0) does not exclude the possibility of other forms of non-linear dependence. In such cases, other analyses should be conducted to investigate the relationship between the variables.

3. Results and Discussion

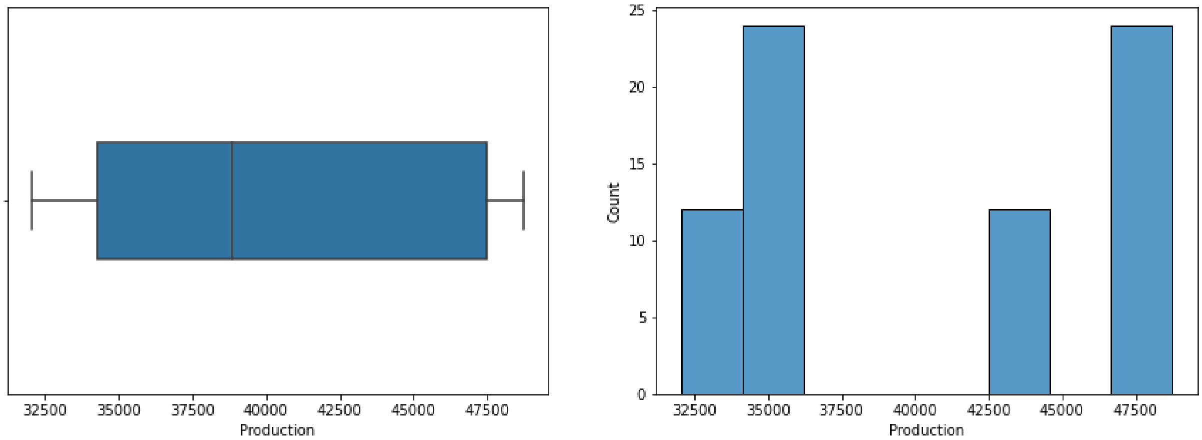
The distribution of observed values for the variables in the present study (price per sack, production, area in production, and area in formation) was evaluated using boxplot graphs and distribution histograms. The trading price of coffee per sack during the study period ranged from US$100.00 to US$160.00 per sack, with an average of US$125.00 (Figure 1). Coffee production during the study period ranged from 32,500 to 47,500 sacks (Figure 2). The area in coffee formation during the study period ranged from 230,000 to 300,000 hectares (Figure 3), while the area in production varied between 1,450,000 and 1,525,000 hectares (Figure 4).

Figure 1 - In this set of graphs, we can analyze that the trading range of coffee sacks during the scope period varied between USD 100.00 and USD 160.00 per sack, with a greater representation in values between USD 115.00 and USD 140.00, and an average of USD 125.00.



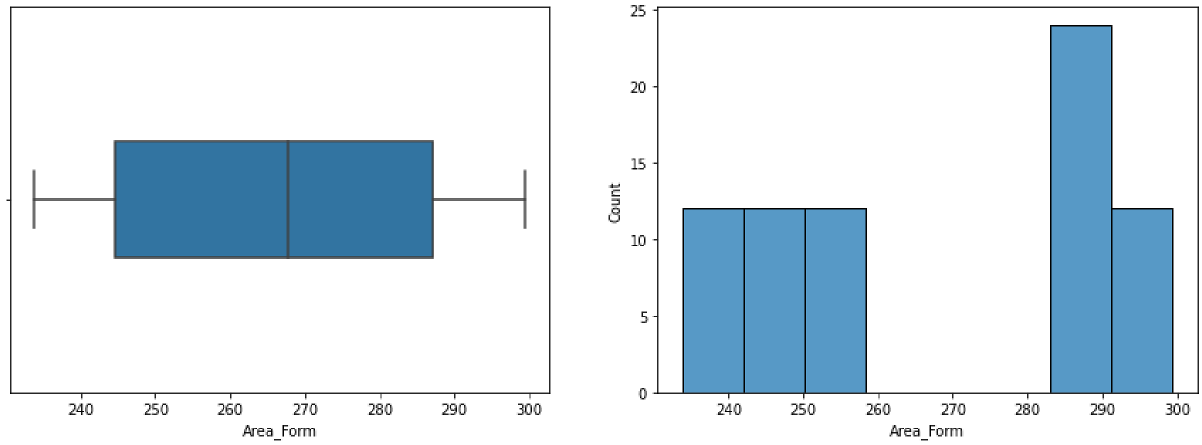
Source: Authors.

Figure 2 - In this set of graphs, we can analyze that coffee production during the scope period ranged from 32,500 to 47,500 sacks, with greater representation in the values of 35,000 and 47,500 sacks. The average was approximately 39,000 sacks.



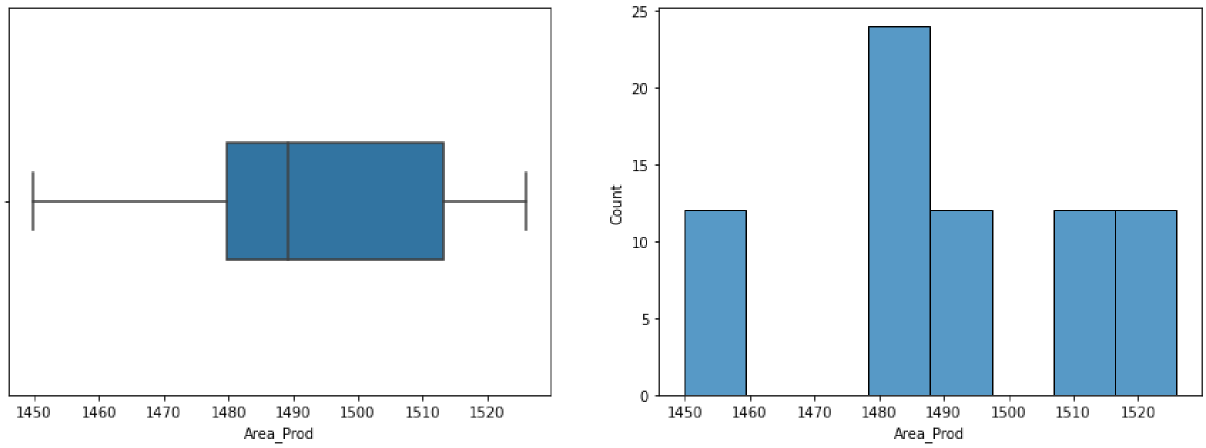
Source: Authors.

Figure 3 - In this set of graphs, we can analyze that the area under coffee cultivation, within the scope period, ranged from 230 to 300 thousand hectares, with an average close to 270 hectares.



Source: Authors.

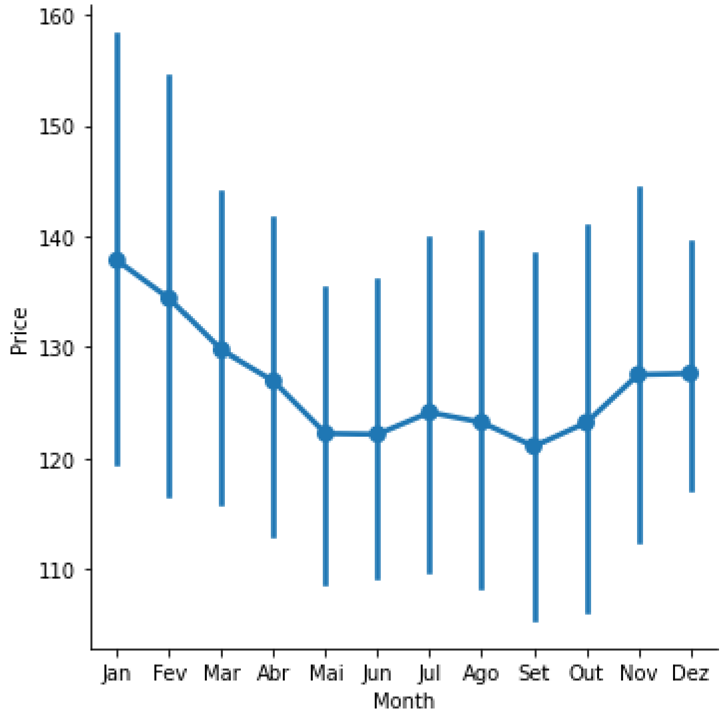
Figure 4 - In this set of graphs, we can analyze that the area in coffee production, within the scope period, varied from 1,450 to 1,525 thousand hectares, with an average of approximately 1,490 hectares.



Source: Authors.

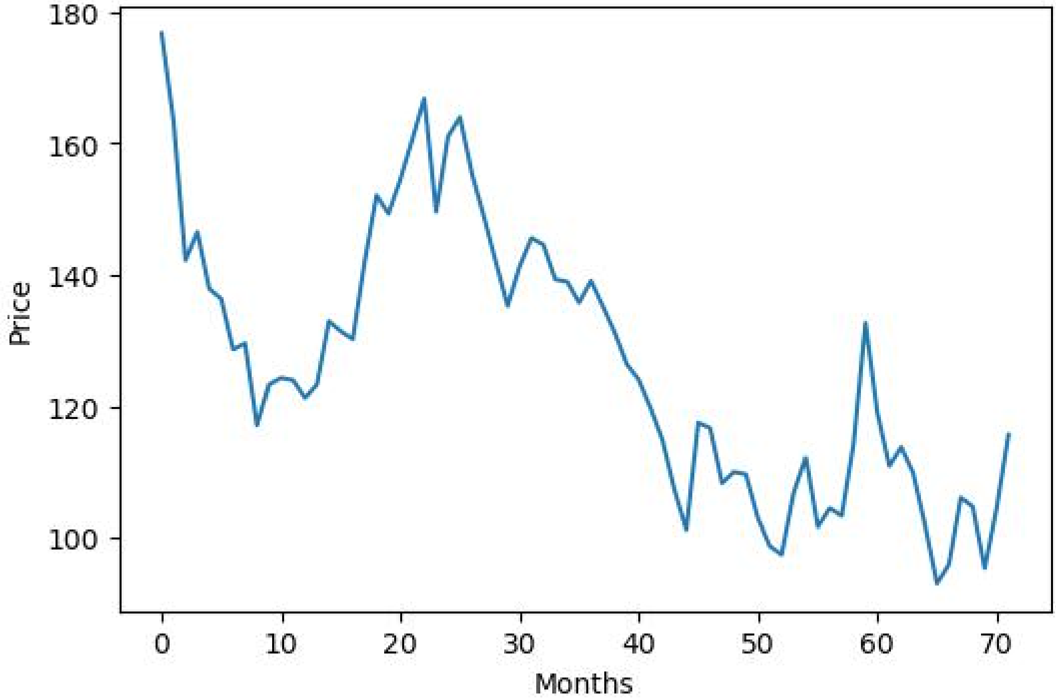
Figure 5 demonstrates the price trend throughout the year, based on the average monthly prices observed during the harvest seasons included in this study. It is observed that a few months after the start of the harvest (March), when it is assumed that the product begins to flow to the market, given that coffee beans require post-harvest processes (processing, sorting, drying, and roasting), the lowest average trading prices were recorded. The highest average prices occurred during the off-season months, particularly before the start of the harvest, in January and February. However, when analyzing Figure 6, it is noticeable that, despite the price range being the one mentioned above, there was, in the observed period, a general downward trend in the price of coffee.

Figure 5 - In the image period of the year vs. price (USD/bag), it is observed that the coffee price spike occurred in the off-season months, January and February, with a decline in the months following the harvest month (March).



Source: Authors.

Figure 6 - In this image, where we compare the analyzed period (2015 - 2020) vs. price (USD/bag), it is observed that, overall, there was a downward trend in coffee prices.



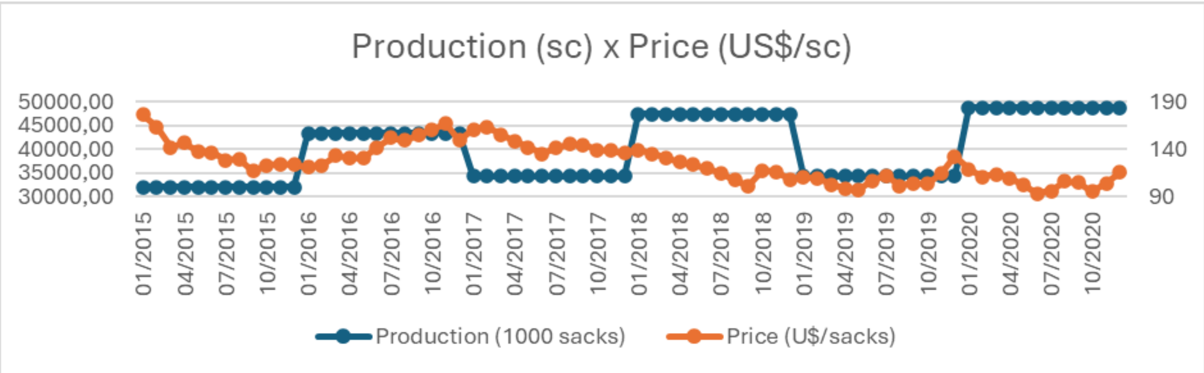
Source: Authors.

The joint observation of the variation in production values (hectares) x price (US$/sack) (Figure 7) suggests a relationship between these factors. It is noted that in 2015, production was low, and the price of coffee in the subsequent year, 2016, increased. Conversely, when coffee production was high in 2016, there was a decrease in coffee prices in the following year. However, in the subsequent years 2018, 2019, and 2020, coffee prices remained stable regardless of the previous year's production.

Figure 8 illustrates the relationship between production area (hectares) x price (US$/sack). Similar to the previous relationship, a trend is observed where the production area in one year and the price in the following year were inversely proportional (2015/2016 and 2016/2017). However, in the following years 2018, 2019, and 2020, coffee prices remained stable regardless of the production level of the previous year.

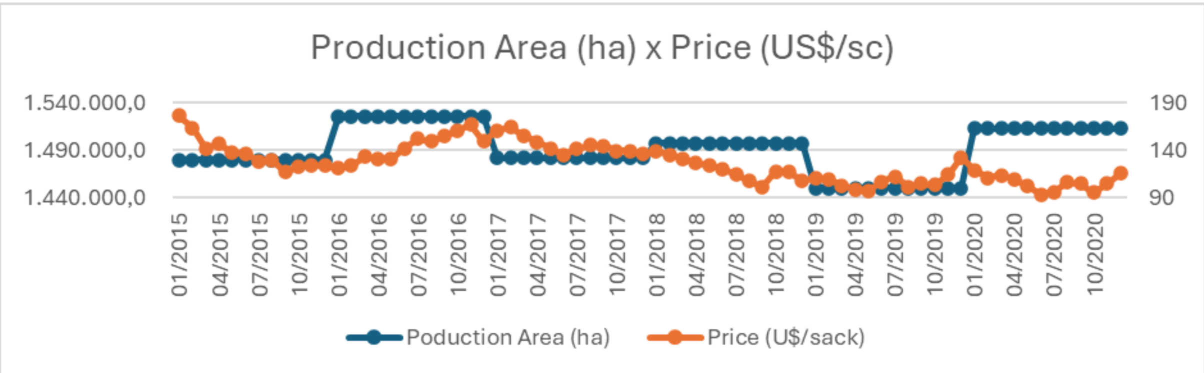
Figure 9 demonstrates the relationship between formation area (hectares) x price (US$/sack). Initially, there is a directly proportional relationship between consecutive years (2015/2016 and 2016/2017). When the price was low in one year, the formation area decreased in the following year, and when the price was high in one year, the formation area increased in the next year. However, in the subsequent years 2018, 2019, and 2020, the formation area of coffee fluctuated despite price stability.

Figure 7 - The exploratory analysis between production (hectare) vs. price (USD/bag) suggests a relationship between the factors, as when there is low production in one year, the following year sees an increase in coffee prices. The opposite also occurs, when there is high production in one year, the following year sees a decrease in coffee prices.



Source: Authors.

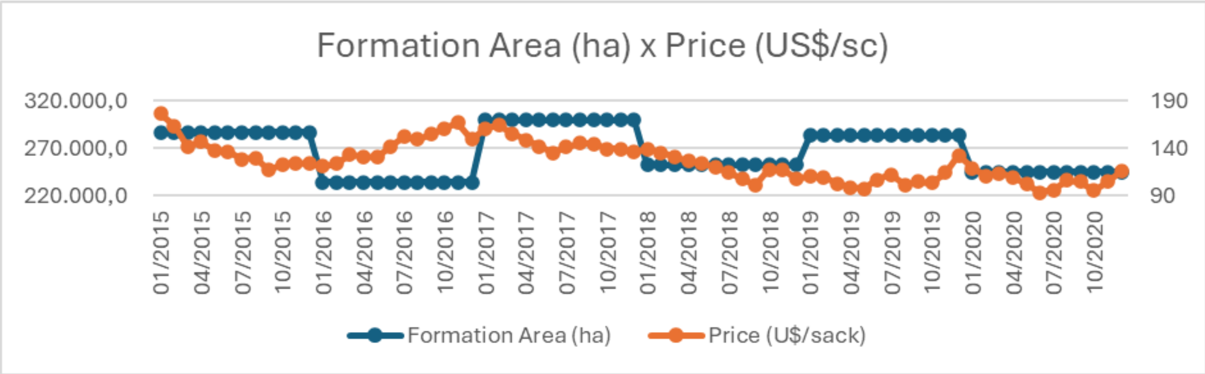
Figure 8 - Area in production (hectare) vs. price (USD/bag). Analyzing these two variables, it is observed that from 2015 to 2017 there was an inversely proportional relationship. However, in the following years (2018 to 2020), the coffee price remained stable regardless of the area in production the previous year.



Source: Authors.

(CC BY 4.0) | ISSN 2525-3409 | DOI: http://dx.doi.org/10.33448/rsd-v13i8.46481

Figure 9 - Area under formation (hectare) vs. price (USD/bag). Analyzing these two variables, it is observed that from 2015 to 2017 there was a directly proportional relationship. However, in the following years (2018 to 2020), the area under coffee formation fluctuated, even with price stability.

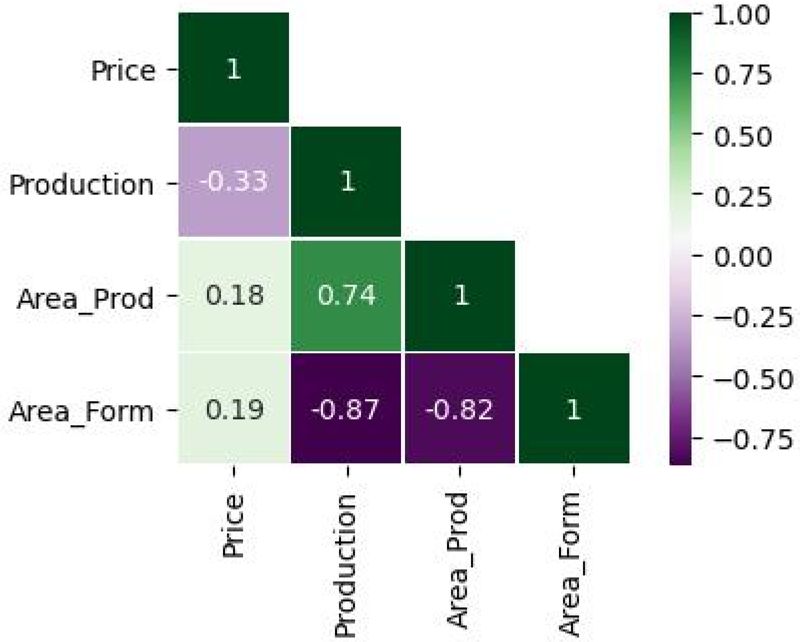


Source: Authors.

A detailed analysis of the variables of interest in this study helps understand their distribution and infer possible relationships, aiding in the interpretation of the results obtained in the analysis, which is the objective of this study.

The Pearson correlation between the variables used in this study is depicted in Figure 10. A weak correlation was observed between price and production area and formation area, with values of 0.18 and 0.19, respectively. There is a considerable positive correlation of 0.74 between production area and production. However, it is important to note that factors other than production, such as climatic conditions during the harvest, also affect agricultural crop productivity. Therefore, the correlation between area and production volume is limited by these other factors.

Figure 10 - Matrix of the pearson's correlation analysis between the variables price of the coffee sack (price), total coffee production (production), area in production (area prod), and area in formation (area form). * significative at 95%.



Source: Authors.

It is noted a strong negative correlation of -0.82 between the formation area and production area. This is likely due to CONAB considering formation area as areas undergoing zero crop management (Conab, 2022). This technique involves drastic pruning adopted by producers, typically in years of negative biennial cycles, aiming to recover productivity or standardize plants (Matiello et al., 2020). Therefore, if an area undergoes this management, it will not produce and thus is not considered in production area calculations. This could explain the strong negative correlation between these variables.

Regarding the correlation between production and price, a significant negative correlation of -0.33 was observed. This indicates that the price of coffee in Brazil is affected by production levels. However, it should be emphasized that market price is adjusted multivariately (Wang & Feng, 2020), also for commodities (Chen et al., 2023; Halim et al., 2022) meaning it is influenced by more than one variable, not solely production. Factors such as foreign crop failures in other major coffee-producing countries like Colombia, Indonesia, and Vietnam, as well as economic crises, can affect coffee prices. As a non-durable consumer good classified as non-essential, coffee demand tends to decrease during economic downturns (Mankiw, 2009).

4. Conclusion

In conclusion, a negative correlation was observed between market price and coffee production within the Brazilian harvest. It is important to consider that coffee prices in the national market are also influenced by factors beyond production, thus the obtained correlation should be taken into account. During the study, a high negative correlation was also observed between formation area x production area and formation area x production, reflecting management techniques adopted, particularly in years of negative biennial cycles, where producers prune coffee plants to improve productivity in subsequent positive cycles.

Finally, future research may incorporate the international coffee market into the analysis, including the production volumes of the five largest producing countries. This will allow for an examination of the overall impact of the international market compared to the effect.

Acknowledgments

I would like to express my sincere gratitude to Gustavo for his guidance in this research, and to my friends and family who always supported me, especially to Ricardo Canal, who provided significant support for this project.

References

Abebe, T. H. (2020). Modeling time-varying coffee price volatility in Ethiopia. *Journal of Applied Economics*, 23(1), 497-518.

Agrianual: Brazilian anuary of agriculture (2022). 185-203. São Paulo, SP, Brazil.

Barros Jr, F., Ferreira, A. L., Marcondes, R. L., & Prioste, R. R. W. (2019). Coffee exports and industrialization in Brazil. Applied Economics Letters, 26(9), 712-716.

Bernardes, T., Moreira, M. A., Adami, M., Giarolla, A., & Rudorff, B. F. T. (2012). Monitoring the biennial bearing effect on coffee yield using MODIS remote sensing imagery. *Remote Sensing*. 4 (9), 2492-2509.

Center for Advanced Studies on Applied Economics - CEPEA (2022). PIB do Agronegócio. https://www.cepea.esalq.usp.br/upload/kceditor/files/Cepea_CNA_PIB_JAn_Dez_2021_Mar%C3%A7o2022.pdf. Acessed in 19 may 2022

Camargo, A. P., & Camargo, M. B. P. (2001) Definições e esquematização das fases fenológicas do cafeeiro arábica nas condições tropicais do Brasil. *Bragantia*, 60(1), 65-68.

Cannell, M. G. (1976) *Crop physiological aspects of coffee bean yeld – a review Kenya Coffee*, 41, 245-253.

Chen, S., Li, Q., Wang, Q., & Zhang, Y. Y. (2023). Multivariate models of commodity futures markets: a dynamic copula approach. *Empirical Economics*, 64(6), 3037-3057.

DaMatta, F. M., Ronchi, C. P., Maestri, M., & Barros, R. S. (2007). Ecophysiology of coffee growth and production. *Brazilian journal of plant physiology*, 19, 485-510.

Garson, G. D. (2009). Statnotes: Topics in multivariate analysis. North Carolina State University. https://faculty. chass. ncsu. edu/garson/PA765/statnote. htm (accessed Feb. 02, 2021).

Halim, M. P., Yudistira, N., & Dewi, C. (2022). Multicommodity Prices Prediction Using Multivariate Data-Driven Modeling: Indonesia Case. IEEE Transactions on Computational Social Systems.

Hernandez, M. A., Pandolph, R., Sänger, C., & Vos, R. (2020). *Volatile coffee prices: Covid-19 and market fundamentals* (Vol. 2). Intl Food Policy Res Inst.

Lanna, G.B.M.; Reis, R.P. (2012). Influência da mecanização da colheita na viabilidade econômico-financeira da cafeicultura no sul de Minas Gerais In Portuguese. *Coffee Science*. 7(2), 110-121.

Mankiw, N. G. (2009). *Principles of Economics*. (5a ed.), Harvard.

Matiello, J. B. (2005). Cultura de café no Brasil: novo manual de recomendações In Portuguese. MAPA/Procafé; Varginha: Fundação Procafé.

Moore, L. M. (1996). *The basic practice of statistics*. Freeman.

Silva, F. M. D., Salvador, N., & Pádua, T. D. S. (2002). Café: mecanização da colheita. In Portuguese. Brazilian Research Symposium of Coffee. Poços de Caldas, MG, Brazil.

Pereira, S. O., Bartholo, G. F., Baliza, D. P., Sogreira, F. M., & Guimarães, R. J. (2011). Productivity and coffee biannuality depending on the crop spacing. Pesqui. *Agropecuária Bras*, 46, 152-160.

Santinato, F. (2016). Inovações tecnológicas para cafeicultura de precisão In Portuguese. 119f. [PhD dissertation] – São Paulo State University, Jaboticabal, São Paulo, Brazil

Stanton, JM (2001). Galton, Pearson e as ervilhas: Uma breve história da regressão linear para instrutores de estatística. *Journal of Statistics Education*, 9 (3).

Valadares, S. V., Neves, J. C. L., Rosa, G. N. G. P., Martinez, H. E. P., Venegas, V. H. A., & Lima, P. C. D. (2013). Yield and production bienniality of dense coffee plantations under different levels of N and K. *Pesquisa Agropecuária Brasileira*, 48, 296-303.

Volsi, B., Telles, TS, Caldarelli, CE, & Camara, MRGD (2019). The dynamics of coffee production in Brazil. *PloS one*. 14 (7), e0219742.

Wang, H. Y., & Feng, Y. S. (2020). Multivariate correlation analysis of agricultural futures and spot markets based on multifractal statistical methods. *Journal of Statistical Mechanics: Theory and Experiment*, (7), 073403.