DETERMINANTS OF ASYMMETRIC COSTS IN SOYBEAN PRODUCTION

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ABSTRACT

Purpose: The study aimed to analyze the determinants of the asymmetric behavior of fixed costs in soybean production.

Theoretical background: Although previous research indicates the presence of asymmetric costs (sticky costs theory) in the agricultural sector and, specifically, in soybean production, there is still a gap in testing which determinants explain this asymmetric condition.

Methodology: The study used a quantitative methodology, with the estimation of a multiple linear regression model and parametric correlation tests, using data on costs, production capacity, production quantity and soybean prices for the period from 2009 to 2022.

Results and conclusion: The results showed that the capacity and price factors were statistically significant in explaining the asymmetry of fixed costs. Price was also significant in explaining total and variable costs, which were also shown to be asymmetrical by the models used.

Research implications: The study advances in verifying the determining factors of asymmetry and not just in pointing out the behavior of costs in this sector, as previous literature has done.

Originality/value: The approach of the work and its results contribute to expanding empirical research related to the assumptions of the sticky costs theory in a relevant economic activity.

Keywords: Determinants, Asymmetrical Costs, Soybean Production.

DETERMINANTES DOS CUSTOS ASSIMÉTRICOS NA PRODUÇÃO DE SOJA

RESUMO

Objetivo: O estudo objetivou analisar os determinantes do comportamento assimétrico dos custos fixos de produção de soja.

Referencial teórico: Apesar das pesquisas anteriores indicarem a presença de custos assimétricos (teoria de sticky costs) no setor agropecuário e, em específico, na produção de soja, ainda há uma lacuna em testar quais determinantes explicam essa condição assimétrica.

Metodologia: O trabalho utilizou-se de metodologia quantitativa, com a estimação de um modelo de regressão linear múltipla e testes de correlação paramétricos, com uso de dados de custos, capacidade produtiva, quantidade de produção e preço da soja relativos ao período de 2009 a 2022.

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Resultados e conclusão: Os resultados apontaram que os fatores capacidade e preço foram estatisticamente significativos para explicar a assimetria dos custos fixos. Ademais, observou-se que o preço foi expressivo para explicar os custos totais e variáveis que também se mostraram assimétricos pelos modelos utilizados.

Implicações da pesquisa: O estudo avança em verificar os fatores determinantes da assimetria e não apenas em apontar o comportamento dos custos desse setor como a literatura anterior tem se dedicado.

Originalidade/valor: A abordagem do trabalho e seus resultados contribui para ampliar as pesquisas empíricas relacionadas aos pressupostos da teoria de sticky costs, em uma atividade econômica relevante.

Palavras-chave: Determinantes, Custos Assimétricos, Produção de Soja.

1 INTRODUCTION

Traditional cost theory shows that total production costs are subdivided generally into variable costs and fixed costs (Anderson, Banker, & Janakiraman, 2003). The behavior of variable costs would have a symmetrical response in relation to production when accompanying the increase or decrease in a proportional manner (Calleja, Steliaros, & Thomas, 2006). Fixed costs, on the other hand, would show different behavior, responding asymmetrically to increases and reductions in productive activity (Pamplona, Fiirst, Silva, & Zonatto, 2016; Pereira & Tavares, 2020). From this perspective, the original literature undertook several tests in order to analyze the behavior of costs in relation to revenue variations (Subramaniam & Watson, 2016).

However, with the results of the research of Noreen and Soderstrom (1997) and especially those of the research of Anderson et al. (2003), the understanding on cost behavior expanded to analyze other explanatory determinants for the divergent results of proportionality and cost direction when compared to revenue (Pamplona et al., 2016). These seminal studies showed that costs tend to behave asymmetrically when compared to revenue. It is therefore a new approach to interpretation called sticky cost theory (Richartz & Borget, 2014).

Accordingly, a new frontier of research has dedicated itself to verifying what other factors are significant in this asymmetry of costs (Calleja et al., 2006). Since managers lack practical incentives to change their cost structure in proportion to their revenue variations, which reinforces the sticky cost theory approach (Kama & Weiss, 2013).

Following these assumptions and considering that managers are reluctant for some time to make changes in costs, as they would incur worse organizational results, it is expected that there is a rigidity of the cost structure that provokes behaviors of intensiveness and direction different from those pointed out by the traditional approach (Subramaniam & Watson, 2016). Therefore, as important as understanding whether the cost behavior is asymmetric or not, is to verify which determinants explain the presence of asymmetry.

Along these lines, Cannon's 2014 study highlights three key determinants for understanding asymmetry: (1) maintaining idle capacity as demand falls; (2) asymmetrically adjusting selling price relative to capacity adjustments, rather than leaving idle capacity when demand decreases, so that managers fill existing capacity by lowering sales prices to stimulate sales volume; and (3) increasing fixed costs for expanding productive capacity as demand grows.
The asymmetry of costs appears to be spread across different sectors of the economy. In Brazil, the agribusiness sector stands out for being significant in the composition of the Gross Domestic Product (GDP), which justifies studies carried out on this theme in the sector. To highlight, the farming sector and, in the specific case, the soybean production sector, the characteristics demonstrate that there are asymmetric costs in this type of activity, as pointed out by the studies by Geneiro, Ferreira and Carvalho (2018), Amurim and Callado (2021) and Viegas and Souza (2021). However, they did not devote themselves to analyzing which determinants explain this asymmetric condition. For this reason, there is a gap in indicating which determinants actually explain the presence of asymmetry of fixed production costs in this segment (Ibrahim, Ali, & Aboelkheir, 2022). In the light of this scenario, the following research problem arises: What are the determinants of the asymmetric behavior of the fixed costs of producing soybeans?

Thus, the objective of this work is to analyze the determinants of asymmetric behavior of fixed costs of soybean production. To do so, the methodology used was quantitative, with the estimation of a multiple linear regression model where the response variable was the fixed cost of production value and the independent variables were the production capacity, market price and quantity of soybeans produced, with data from the period 2009 to 2022.

In this way, it is expected that the results of the study may broaden the research related to the theory of sticky costs as the empirical tests carried out show which of the determinants tested have explanatory power regarding the asymmetry of costs in this sector. In practical terms, knowing the determinants of this condition will help to broaden the understanding about how the decisions of the managers in this area have consequences on the behavior of the costs of the sector.

2 THEORETICAL FRAME

2.1 Asymmetric Cost Determinants

The literature on the determinants of asymmetric costs is rich in establishing the factors that help explain this type of behavior (Ibrahim et al., 2022). Thus, the study by Guenther, Riehl & Rößler (2014) is seminal in pointing out the various determinants that involve legal reasons, social, personal and operational policies, company employability, psychological and agency-related reasons. Bugeja, Lu & Shan (2015) indicate that observable variables associated with managers’ assessments of future demand and the costs of removing invested resources, macroeconomic conditions, past changes in demand and asset structure are also relevant elements in explaining cost asymmetry.

Also, Priantana and Sayuthi (2020) explain that the development of studies related to asymmetric costs over the years are concentrated in three broad groups: (1) asymmetric cost behavior, which is dedicated to identifying the existence of asymmetry; (2) asymmetric cost determinants, i.e. what leads to this asymmetric behavior; and (3) the consequences of asymmetric costs for organizations, verifying how this affects, for example, outcomes, stock price, profit forecasts, among others. The authors suggest that there is room for development in the three perspectives of studying asymmetric costs, particularly in environments little explored, such as emerging economies.

In the present study, we specifically address the three factors mentioned by Cannon (2014) related to production, price and production capacity.
2.1.1 Asymmetric costs and production adjustments

The original cost theory assumes a proportional relationship between cost change in the face of activity changes (Porporato & Werbin, 2012). However, it has already been shown that these adjustments do not occur, for the most part, symmetrically, but rather with different intensities and or directions (Silge & Wöhrmann, 2019). This phenomenon stems from some practical factors, in which managers are involved in the decision-making process on production and its respective costs, so that the relationship between costs and volume of production activity becomes complex and non-linear (Malik, 2012).

The increase in production, considering an optimum idleness, will only be verified after a certain time of maturing investments and, as a result, the costs of this new frontier will adapt in still different period and in possibly different proportion considering a certain previous and future productivity (Azeez, Dongping, & Mahmood, 2018). Therefore, it is possible for administrators to choose to apply expansive investment resources, which incurs higher fixed costs and disproportionate to the increase in driving demand, causing asymmetry in their behavior (Banker & Byzalov, 2014).

For this reason, Cannon (2014) exposes that increasing fixed costs to expand productive capacity as demand grows is a possible determinant for asymmetric cost behavior. Thus, the following assumptions were made in order to assess the relationship between production and costs:

H0: The quantity of soybeans produced is statistically significant to explain the behavior of the fixed costs of producing soybeans.
H1: The quantity of soybeans produced is statistically significant to explain the behavior of the total costs of producing soybeans.
H2: The quantity of soybeans produced is statistically significant to explain the behavior of the variable costs of producing soybeans.

2.1.2 Asymmetric costs and Production Capacity adjustments

Adjustment between production capacity and sales volume does not happen synchronously, because resources are expensive to achieve new productive capacity within organizations. Therefore, the use of resource capacity as a source of explanation of asymmetric cost behavior, mainly fixed costs, can thus attempt to predict the phenomenon of sticky costs within organizations (Cannon, 2014; Priantana & Sayuthi, 2020).

This observed timelessness is often justified by the optimism of managers who, when perceiving falls in sales, believe that the reduction will be temporary, not justifying an immediate change in idle capacity, or even that managers may prefer to operate with idle resources because it is cheaper than adjusting them, causing costs to behave rigidly (Anderson et al., 2003). Chen, Lu and Sougiannis (2012) argue that the incentives for hiring new resources when activity increases are not the same to terminate idle resources when activity decreases.

Golden, Mashruwala and Pevzner (2020) explored the changes in production capacity from the perspective of adjusting the available workforce associated with the company's level of cost rigidity. The authors pointed out that managers can resist laying off employees with high skills when there is a drop in sales, thus not altering production capacity in the face of a new reality of demand, maintaining idleness for a long period.

Thus, Cannon (2014) points out that capacity adjustments, especially maintaining a level of idleness as demand falls, explains the cost asymmetry. Therefore, the following assumptions have been made in order to assess the relationship between production capacity and costs:

H3: Production capacity is statistically significant to explain the behavior of fixed costs of soybean production.
H4: The production capacity is statistically significant to explain the behavior of the total costs of soybean production.

H5: The productive capacity is statistically significant to explain the behavior of variable costs of soybean production.

2.1.3 Asymmetric costs and sales price adjustments

Historically, studies on cost asymmetry have used the association between costs and revenues to verify this behavior, as done by He, Teruya and Shimizu (2010) and Richartz and Borget (2014). This is because when the price goes up, there is an incentive to increase production which in turn leads to increased costs (Balakrishnan, Labro, & Soderstrom, 2014). It so happens that the intensity and direction of these adjustments hardly occur symmetrically (Banker, Byzalov, & Plehn-Dujowich, 2014; Kama & Weiss 2013). Richartz and Borgert (2021, p. 15) point out that "questions of fixing the price, affects the productive structure of companies and, consequently, the asymmetry of costs", so that the more regulated the sector or with little autonomy in determining prices it is, the less freedom there will be to have a hardened productive structure (Avelar, Santos, Souza, & Cailleau, 2021).

It should also be noted that the revenue used is the one resulting from the multiplication of output and price, so that the price factor is not analyzed in isolation from its effects on cost behavior. Thus, it can be an explanatory determinant, as explained by Cannon (2014) when analyzing that managers can make price adjustments rather than capacity adjustments, which explains the occurrence of asymmetry since administrators tend, with increasing demand, to adjust prices to achieve gains and achieve results goals. That is to say, with the fall in production, they tend to maintain or to diminish prices, only to afterwards act on the cost structure.

Along these lines, as highlighted by the study by Ibrahim et al. (2022), there is little research examining the asymmetric costs related to price decisions. For this reason, the following assumptions have been made in order to assess the relationship between prices and costs:

H6: The price is statistically significant to explain the behavior of fixed costs of producing soybeans.

H7: The price is statistically significant to explain the behavior of the total costs of producing soybeans.

H8: The price is statistically significant to explain the behavior of variable costs of soybean production.
2.2 Characteristics of agribusiness in the soybean production sector

Agribusiness stands out as one of the most representative sectors in the Brazilian economy, but, in addition, the very history of agribusiness is mixed with that of the country and its colonization process (Miranda, 2020). According to data from the Center for Advanced Studies in Applied Economics (Cepea), of Esalq/USP, in partnership with the Confederation of Agriculture and Livestock of Brazil (CNA), in 2022, the participation of Brazilian agribusiness in the GDP of the country had a decrease of 4.22%, after the record GDP in 2021, however, agribusiness continues to be significant for the economy, representing 24.8% of the Brazilian GDP in the year 2022 (Cepea, 2023).

Also according to CEPEA, the result of the fall is justified mainly by the costs with inputs that grew more significantly than the income of the period, highlighting the agricultural branch that had an increase of inputs in the order of 37.4% and 9.0% for agricultural production and for agro-industry, respectively (Cepea, 2023).

In the midst of this scenario, one of the most significant products in the GDP of agribusiness is soybeans. According to information from the 11th Survey of Grain Harvest 2022/2023 of the National Supply Company (Conab), the soybean harvest reached 154,603.4 thousand tons, which is 1.48% higher than the first crop estimate made by Conab in October 2022 and 10.9% higher than the old production record reached in the 2020/2021 harvest (Conab, 2023a). The good results are justified by the favorable climatic conditions in most producing regions and by the high technology employed by producers (Menegon et al., 2023).

Among the soybean-producing states in Brazil, the state of Mato Grosso stands out, which in the year 2022 continued to be the largest Brazilian producer, with a production in the last harvest of approximately 45 million tons (Embrapa, 2023b), justifying the choice of this state for analysis in the present study. In addition, the significance of agribusiness for the state of Mato Grosso, which accounts for 51% of the collection of ICMS and 50% of its GDP (Brazilian Association of Soy Producers - Aprosoybean Brazil, 2023). Figure 1 represents the evolution of soybean production over the years, segregated by producing states.

![Figure 1. Evolution of Soybean Production by federal states](source: Conab (2023b))

In a survey carried out by Embrapa in June 2023, Brazil exceeded by 12% the production of soybeans from the last harvest in comparison with the USA, thus configuring it as the main...
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world exporter of soybeans (Inacio & Cortez, 2023). Thus, given the significant representativeness of soybean production and exports in the Brazilian economy, it is justified to delimit research in this sector (Embrapa, 2023a).

3 APPROACH

The present research has a quantitative approach, so the statistical method of multiple linear regression was chosen for providing results that allow analyzing the theoretical hypotheses used and, consequently, achieving the objective pursued by the research. Its choice, as well as the variables used, was based on the Cannon study (2014) dealing with asymmetric cost determinants.

3.1 Sample definition and data collection

Data from the production of the state of Mato Grosso were used for the study. This cut-off is due to the fact that the said federative unit has the largest percentage weight in the production of soybeans carried out in Brazil, according to data from Conab (2023b). Therefore, their information is relevant for making inferences about the possible determinants of asymmetric behavior of the costs of such cultivation at national level.

The variables used were price, fixed costs, variable costs, total costs and production capacity. The study period covers the years 2009 to 2022, when data were collected available on Conab’s website for prices, considering the annual average. On the other hand, the information on fixed, variable and total costs was extracted from the Aprososoya Brasil website, whose database is updated annually according to the soybean harvest.

The method of cost measurement used by Conab (2023b) to present the variables is the annual average of the cost data per hectare. Similarly, for the variable of production area capacity, the average of the annual data for each thousand hectares is taken into account. Then there is the variable of production, which takes into account the annual average for each thousand tons produced in the harvest.

The collected data was tabulated and processed in the Python®, SPSS® and Gretl® software, the results of which were presented in the respective tables.

3.2 Model and statistical treatment

In addition to correlation testing and residue assumptions, the present study used three multiple regression models with data from the period under review, which covers the years 2009 to 2022. Each model served to analyze the study's hypotheses following the methodology applied by Cannon (2014). In doing so, the following econometric models were estimated:

**Template 1**

\[
CF = \beta_0 + \beta_1 \text{CAPACITY} + \beta_2 \text{PRICE} + \beta_3 \text{PRODUCTION} + \epsilon
\]

Where:

- \(CF\): Total Fixed Cost;
- \(\beta_0\): Intercept of the model, corresponds to the constant, i.e. the place where the line intersects the y axis;
- \(\beta_1\text{CAPACITY}\): Production Capacity;
- \(\beta_2\text{PRICE}\): Price;
- \(\beta_3\text{PRODUCTION}\): Quantity produced;
- \(\epsilon\): Error term, relationship disturbance.
With this model, it was possible to verify the relationships between the variables, as well as to test the theoretical hypotheses indicated in this study that are related to fixed cost.

**Template 2**

\[
CT = \beta_0 + \beta_1 \text{CAPACITY} + \beta_2 \text{PRODUCTION}
\]  \hspace{1cm} (1)

Where:

- \( TC \): Total Cost;
- \( \beta_0 \): Intercept of the model, corresponds to the constant, i.e. the place where the line intersects the y axis;
- \( \beta_1 \): \text{CAPACITY}: Production Capacity;
- \( \beta_2 \): \text{PRICE}: Price;
- \( \beta_3 \): \text{PRODUCTION}: Quantity produced;
- \( \epsilon_i \): Error term, relationship disturbance.

With this model, it was possible to verify the relationships between the variables, as well as to test the theoretical hypotheses indicated in this study that are related to the total cost.

**Template 3**

\[
CV = \beta_0 + \beta_1 \text{CAPACITY} + \beta_2 \text{PRODUCTION}
\]  \hspace{1cm} (3)

Where:

- \( CV \): Total Variable Cost;
- \( \beta_0 \): Intercept of the model, corresponds to the constant, i.e. the place where the line intersects the y axis;
- \( \beta_1 \): \text{CAPACITY}: Production Capacity;
- \( \beta_2 \): \text{PRICE}: Price;
- \( \beta_3 \): \text{PRODUCTION}: Quantity produced;
- \( \epsilon_i \): Error term, relationship disturbance.

With this model, it was possible to verify the relationships between the variables, as well as to test the theoretical hypotheses indicated in this study that are related to variable cost.

Statistical tests on normality, independence and multicollinearity of residues were also performed, as well as testing on model consistency and endogeneity. This is because these assumptions in regression models aim to facilitate the interpretation of results, make statistical techniques simpler and enable hypothesis testing (Johnson & Wichern, 1998).
4 RESULTS AND DISCUSSION

4.1 Description

Initially, descriptive statistics are presented to outline general aspects about each of the independent variables: Capacity, Price and Production. Also presented in this section is the descriptive statistic of the response variable, which used information from Total, Fixed and Variable Costs. Table 1 summarizes the main descriptive measures of the variables used in the study.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Medium</th>
<th>Median</th>
<th>D.P.</th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>TC</td>
<td>2 900.91</td>
<td>2 533.84</td>
<td>1 449.98</td>
<td>1 436.01</td>
<td>7 553.70</td>
</tr>
<tr>
<td>CF</td>
<td>309.86</td>
<td>205.26</td>
<td>294.16</td>
<td>12.27</td>
<td>1 281.84</td>
</tr>
<tr>
<td>CV</td>
<td>2 282.26</td>
<td>2 169.56</td>
<td>1 177.57</td>
<td>1 014.09</td>
<td>6 213.45</td>
</tr>
<tr>
<td>CAPACITY</td>
<td>9 023.74</td>
<td>9 231.50</td>
<td>1 670.52</td>
<td>6 224.50</td>
<td>12 086.00</td>
</tr>
<tr>
<td>PRICE</td>
<td>73.68</td>
<td>57.91</td>
<td>40.90</td>
<td>32.44</td>
<td>169.56</td>
</tr>
<tr>
<td>PRODUCTION</td>
<td>30 087.36</td>
<td>29 266.30</td>
<td>7 795.13</td>
<td>18 766.90</td>
<td>45 600.50</td>
</tr>
</tbody>
</table>

Source: Prepared by the authors

In the period analyzed, the production capacity had an increase of 51.50% and the production of soybeans an increase of 41.16%, reflected precisely by the expansion of capacity. Price in the period experienced a growth of 19.13%, while total costs increased 19.01%. Fixed costs increased by 0.96% and variables by 16.32%. This already suggests that the cost behavior was not linear and proportional when compared to capacity, production and prices. This asymmetric behavior had already been pointed out by other studies such as Geneiro, Ferreira e Carvalho (2018), Amurim e Callado (2021) and Viegas e Souza (2021).

Considering the measures of dispersion of the variables, especially the standard deviation, it is possible to note that the metrics used had normal distribution of the data. This fact was confirmed by the tests of normality and homocedasticity carried out in the model, by which no transformation or adjustment was carried out in this respect.

4.1.1 Residue Assumptions Testing

Analysis of assumptions may indicate additional treatments to be performed to validate the use of parametric tests, as idealized in this study. In this way, Table 2 consolidates the test results.

<table>
<thead>
<tr>
<th>Assumption</th>
<th>Test</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normality</td>
<td>Shapiro-Wilk</td>
<td>0.054 b</td>
</tr>
<tr>
<td>Independence</td>
<td>Durbin-Watson</td>
<td>2.275 b</td>
</tr>
<tr>
<td>Homoscedasticity</td>
<td>Breusch-Pagan</td>
<td>0.051 c</td>
</tr>
</tbody>
</table>

Note:

a p-value greater than α of 5% = normality.
b p-value in the range (dl=1.40 and 4-du= 2.39) = independence.
c p-value greater than α of 5% = homoscedasticity.

Source: Prepared by the authors

Thus, the assumption of normality has been verified, as well as the residues are independent and have homogeneity of variance.
4.2 Analysis of correlations

Carried out the descriptive analysis and the tests of assumptions in which the normality of the sample was verified, we started to analyze the correlations, by means of Pearson's coefficient, between the variables used in the research according to the structuring of each model, in such a way as to show the direction and intensity of the interactions. Considering the central analyzes of the study presented in Model 1, the results presented in Table 3 were obtained.

Table 3 - Correlation matrix of the variables analyzed in Model 1

<table>
<thead>
<tr>
<th></th>
<th>CF.</th>
<th>CAPACITY</th>
<th>PRICE</th>
<th>PRODUCTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>CF.</td>
<td>1.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CAPACITY</td>
<td>0.565**</td>
<td>1.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PRICE</td>
<td>0.792**</td>
<td>0.855**</td>
<td>1.</td>
<td></td>
</tr>
<tr>
<td>PRODUCTION</td>
<td>0.649**</td>
<td>0.972**</td>
<td>0.894**</td>
<td>1.</td>
</tr>
</tbody>
</table>

Note. **Significant correlation at 0.01 level.
Source: Prepared by the authors

It is noted by means of Table 3 that all correlations were significant, and that Capacity and Production, Capacity and Price, Price and Production presented high correlation with values higher than 0.8, indicating that there is multicollinearity between them. With regard to the Fixed Cost response variable, the strongest correlation was with Price.

On the other hand, the signals allow to identify the directions of the interactions between the response variable and the explanatory variables, so that all showed positive signs with the response variation (CF). Frame 1 summarizes the directions found and compares them with those expected.

<table>
<thead>
<tr>
<th>Dependent variables</th>
<th>Direction of correlation with dependent variable</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Expected</td>
</tr>
<tr>
<td>CAPACITY</td>
<td>Positive</td>
</tr>
<tr>
<td>PRICE</td>
<td>Negative</td>
</tr>
<tr>
<td>PRODUCTION</td>
<td>Negative</td>
</tr>
</tbody>
</table>

Table 1. Comparison between expected and found correlations of Model 1
Source: Prepared by the authors

The variables Production and Price presented different behaviors than was expected, indicating that the asymmetry of fixed costs does not occur only by intensity, but by its direction according to the study by Subramaniam and Watson (2016) and not only by revenue (Price), but also by Production.

Another relevant finding of these correlation analyzes is in the comparison of Fixed Cost with Price. This may suggest behavior explained by the assumption made by Cannon (2014) that managers may incur more fixed costs to expand productive capacity, as a consequence increase production and prices rise due to higher demand or external economic factors. This result reinforces the use of resource capacity as one of the determinants of asymmetric cost behavior, enabling greater understanding about sticky costs and their consequences (Cannon, 2014; Priantana & Sayuthi, 2020). The same positive directional behavior was found when analyzing the dependent variables of Model 2, total cost, and Model 3, variable cost.
4.3 Analysis of regression results

Multiple linear regression and model variations analyzes were performed. The significance level $\alpha$ of 5% ($\alpha = 0.05$) was adopted for the interpretation of the results. Thus, "when the $p$-value of a hypothesis test is less than the chosen value of $\alpha$, the test procedure leads to the rejection of the null hypothesis" (Hill, Griffiths, & Judge, 2006, p. 119). Therefore, regression of Model 1 showed the values specified in Table 4.

<table>
<thead>
<tr>
<th>Table 4- Model 1 regression results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coefficients</td>
</tr>
<tr>
<td>Intersection</td>
</tr>
<tr>
<td>CAPACITY</td>
</tr>
<tr>
<td>PRICE</td>
</tr>
<tr>
<td>PRODUCTION</td>
</tr>
</tbody>
</table>

Source: Prepared by the authors

The regression model had a coefficient of determination of $R^2$ of 0.6926, that is, 69.26% of the average Fixed Cost in the period 2009 to 2022 is explained by the regressors. In addition, the model was shown to have adequate adjustment, according to the variance test (ANAVA).

It is noted, from the results presented in Table 4, that there was statistical significance for Price and Capacity, with $\alpha$ of 5%, accepting the theoretical hypotheses H3 and H6 that these variables are statistically significant to explain the behavior of fixed costs of soybean production. On the other hand, the H0 hypothesis that the quantity of soybeans produced is statistically significant to explain the behavior of fixed costs was not accepted. Despite this non-confirmation, it should be noted that there is multicollinearity between the Capacity and Production data, according to VIF test in the value of 24.

This means that these two variables express the same statistical information, so that one of them can be suppressed without prejudice to the adjustment of the model. As a result, regression using robust standard errors to heteroskedasticity is equally significant for the variable Production.

It is important to highlight the negative sign of the Capacity regressor coefficient, which confirms the asymmetric character of fixed costs. In this line, the results have an explanation given by Cannon (2014) that points out the decisions about Capacity and Price as determinants to explain the cost asymmetry, since managers can first use of capacity or production adjustments and prices to only later change their productive costs in a relevant way. Thus, it is reinforced that the timeliness between increased demand/revenue and the change in productive capacity often justifies cost asymmetry, because the adequacy between productive capacity and revenue adjustments demand different decision times and results (Anderson et al., 2003).

Thus, it can be stated that by the research findings that Capacity and Price are determinant for the asymmetry of fixed costs in soybean production, within the period analyzed. With the observation that the quantity produced is also a determinant that can replace the variable Capacity.

However, for the fixed cost analysis model 2 and 3 regressions were still carried out. In the case of Model 2, where the dependent variable is Total Costs, the results are shown in Table 5.
### Table 5- Model 2 regression results

<table>
<thead>
<tr>
<th></th>
<th>Coefficients</th>
<th>Standard Error</th>
<th>Stat t</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intersection</td>
<td>-472,943</td>
<td>911.741</td>
<td>-0.518</td>
<td>0.606</td>
</tr>
<tr>
<td>CAPACITY</td>
<td>0.045</td>
<td>0.274</td>
<td>0.165</td>
<td>0.869</td>
</tr>
<tr>
<td>PRICE</td>
<td>22.063</td>
<td>5.887</td>
<td>3.747</td>
<td>0.000*</td>
</tr>
<tr>
<td>PRODUCTION</td>
<td>0.044</td>
<td>0.068</td>
<td>0.653</td>
<td>0.517</td>
</tr>
</tbody>
</table>

**Source:** Prepared by the authors

This model had a coefficient of determination of R² of 0.7934, that is, 79.34% of the average Total Cost in the period 2009 to 2022 is explained by the regressors. The Price regressor was the only one with statistical significance, thus accepting the theoretical hypothesis H7 and rejecting H1 and H4, since Capacity and Production did not prove to be significant to explain the Total Costs.

Model 3, on the other hand, in which the dependent variable is Variable Costs, has its results shown in Table 6.

### Table 6- Model 3 regression results

<table>
<thead>
<tr>
<th></th>
<th>Coefficients</th>
<th>Standard Error</th>
<th>Stat t</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intersection</td>
<td>-1261,786</td>
<td>676.560</td>
<td>-1.865</td>
<td>0.069</td>
</tr>
<tr>
<td>CAPACITY</td>
<td>0.184</td>
<td>0.203</td>
<td>0.908</td>
<td>0.369</td>
</tr>
<tr>
<td>PRICE</td>
<td>14.411</td>
<td>4.369</td>
<td>3.298</td>
<td>0.002*</td>
</tr>
<tr>
<td>PRODUCTION</td>
<td>0.027</td>
<td>0.050</td>
<td>0.535</td>
<td>0.595</td>
</tr>
</tbody>
</table>

**Source:** Prepared by the authors

The regression Model 3 had a coefficient of determination of R² of 0.8275, that is, 82.75% of the average Variable Cost in the period 2009 to 2022 is explained by the regressors. The Price regressor was the only one with statistical significance, thus accepting the theoretical hypothesis H8 and rejecting H2 and H5, since Capacity and Production did not prove to be significant in explaining Variable Costs.

The Price variable proved to be a significant determinant of costs in all models, an important finding that aligns with the study by Cannon (2014). This finding is supported by Richartz and Borgert's proposition (2021) that price change is a factor that directly affects the productive structure of organizations and, consequently, the asymmetry of costs. It should be noted that the evidence of these analyzes with the measurement method used, in addition to the results obtained, provides a theoretical and methodological amplification on the theme of cost asymmetry that, in spite of its current relevance, still lacks empirical tests on its explanatory determination.

### 5 CONCLUSIONS

The objective of this study was to analyze the determinants of asymmetric behavior of fixed costs of soybean production. Thus, this research incorporates into the literature the carrying out of empirical tests with respect to the determinants indicated by the theory of *sticky costs* as responsible for the explanation of the existence of asymmetric costs in the said sector. The verification of this relationship, in a statistical way, widens the boundaries of the measurement variables adopted in the model, in such a way as to show, empirically, the relationships of choices that actually can explain the asymmetry of costs existing in this kind of economic activity.

For this purpose, descriptive analyzes, correlation and estimation of three multiple linear regression models were carried out, in which the response variables were fixed, total and variable costs and the regressors were capacity, price and production with secondary data for the period 2009 to 2022.
The correlation results obtained showed that the production and price variables presented different behaviors than was expected when analyzed in isolation with fixed, total and variable costs. This indicates that the asymmetry of fixed and total costs does not occur only by intensity, but also by its direction as stated by the theory of sticky costs.

Regarding regression findings, Model 1 demonstrated that there was statistical significance for price and capacity, accepting the theoretical hypotheses H3 and H6 that these variables are statistically significant to explain the behavior of fixed costs of soybean production. Thus, it is possible to state that price and production are explanatory determinants for the presence of cost asymmetry in soybean production.

The regression Model 2 showed the acceptance of the H7 hypothesis that price is significant as a determinant of total costs, while Model 3 indicated the acceptance of the H8 hypothesis that price is significant as a determinant of variable costs.

Thus, it can be stated that, according to the research findings, capacity and price are determinants for the asymmetry of fixed costs in the production of soybeans, within the period analyzed. Price is also the determining factor for total and variable costs. In addition, it is important to note that decisions regarding capacity and price are relevant to explain the asymmetry of soybean production costs, so that adjustments to these elements can be made prior to changes in the cost structure.

Accordingly, the results of the study advance in verifying the determinants of asymmetry and not only in pointing out the behavior of the costs of this sector, also contributing towards expanding the empirical researches related to the assumptions of the theory of sticky costs in a relevant economic activity.

As suggestions for other work, the inclusion of other determinants or other variables aimed at capturing the impacts of management decisions regarding the cost structure in the sector can be mentioned. Differentiated indicators can be tested, as can the methodology of analysis. Accordingly, it is expected that there will be an expansion of the studies about the explanations about the real motivations for which the costs are asymmetrical in this kind of activity.
REFERENCES


