ALINE CAROLINE RODRIGUES

THE ROLE OF PUBLIC INFORMATION IN THE BRAZILIAN LIVE CATTLE MARKET

Thesis submitted to the Applied Economics Graduate Program of the Universidade Federal de Viçosa in partial fulfillment of the requirements for the degree of Doctor Scientiae.

Adviser: Leonardo Bornacki de Mattos

Co-adviser: Julyerme Matheus Tonin

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"Verás um caminho difícil demais
Verás tempestades que te assustarão
Mas quando o sonho é Deus ninguém destruirá
Se Ele prometeu também cumprirá
Tenha paciência e saiba esperar
O melhor de Deus virá
Deixa Deus sonhar em ti"
(Deixa Deus sonhar em ti Frei Gilson)

ABSTRACT

RODRIGUES, Aline Caroline, D.Sc., Universidade Federal de Viçosa, February, 2024. **The role of public information in the Brazilian live cattle market.** Adviser: Leonardo Bornacki de Mattos. Co-adviser: Julyerme Matheus Tonin.

Commodities reports play a crucial role in access market information. In Brazil, one of the most relevant commodities is live cattle. Brazil holds significant positions in the meat market, being the largest exporter of meat, the second-largest producer, and the third-largest global consumer. The agricultural sector, particularly livestock, is a cornerstone of the Brazilian economy, contributing significantly to GDP, employment, and trade balance. The availability of information in the commodities market is critical for several reasons. First, accurate and timely information helps farmers and producers make informed decisions about production, investment, and resource allocation. Second, for traders and investors, market information reduces uncertainty, allowing for better risk management and strategic planning. Third, transparency in market information fosters trust and stability, which are essential for attracting both domestic and international investments. Considering the power of information for the market, this study focuses on analyzing the impact of information found in three national agricultural reports, Pesquisa Trimestral de Abates (IBGE), AgroConab (CONAB), and AgroMensal (CEPEA), on the formation of abnormal returns and volatility in the futures prices of Brazilian live cattle traded on the B3 Stock Exchange. Our research hypothesis was that the Brazilian cattle market is semi-efficient based on the analysis of these three public reports. Our results indicate the non-rejection of this hypothesis. Although we identified some abnormal returns, we cannot assert that they follow a consistent pattern with Fama's (1970) definition of semi-strong form efficiency. We employed the Event Study methodology, using Cumulative Abnormal Returns (CAR) and GARCH methodologies. volatility are identified, in some cases, abnormal returns are observed. Considering that the information in these reports is a public good, this research contributes to the formulation of public policies to promote and improve information disclosed in the market, ensuring that public information ensures market efficiency. Enhanced market information can lead to more efficient price discovery, reduce market distortions, and support the overall development of the agricultural sector.

Keywords: Live cattle; Futures returns; Market efficiency; Agricultural reports; CAR (Cumulative abnormal returns); GARCH.

RESUMO

RODRIGUES, Aline Caroline, D.Sc., Universidade Federal de Viçosa, fevereiro de 2024. **Papel das informações públicas no mercado futuro de boi gordo brasileiro.** Orientador: Leonardo Bornacki de Mattos. Coorientador: Julyerme Matheus Tonin.

Os relatórios de commodities desempenham um papel crucial no acesso à informação de mercado. No Brasil, uma das commodities mais relevantes é o boi gordo. O Brasil ocupa posições significativas no mercado de carne, sendo o maior exportador de carne, o segundo maior produtor e o terceiro maior consumidor global. O setor agrícola, particularmente a pecuária, é um pilar da economia brasileira, contribuindo significativamente para o PIB, o emprego e a balança comercial. A disponibilidade de informações no mercado de commodities é crítica por vários motivos. Primeiro, informações precisas e oportunas ajudam os agricultores e produtores a tomar decisões informadas sobre produção, investimento e alocação de recursos. Segundo, para traders e investidores, a informação de mercado reduz a incerteza, permitindo uma melhor gestão de riscos e planejamento estratégico. Terceiro, a transparência na informação de mercado promove confiança e estabilidade, essenciais para atrair investimentos nacionais e internacionais. Considerando o poder da informação para o mercado, este estudo foca na análise do impacto das informações encontradas em três relatórios agrícolas nacionais, Pesquisa Trimestral de Abates (IBGE), AgroConab (CONAB) e AgroMensal (CEPEA), na formação de retornos anormais e volatilidade nos preços futuros do boi gordo brasileiro negociado na Bolsa de Valores B3. Sob a hipótese de que a divulgação de informações inesperadas por esses relatórios produz movimentos anormais nos preços e volatilidades distintos da tendência, empregamos a metodologia de Estudo de Evento, utilizando Retornos Anormais Acumulados (CAR) e metodologias GARCH. Em alguns casos, são identificadas volatilidades e observados retornos anormais. Considerando que as informações nesses relatórios são um bem público, esta pesquisa contribui para a formulação de políticas públicas para promover e melhorar a informação divulgada no mercado, garantindo que a informação pública assegure a eficiência do mercado.

Palavras-Chave: Boi gordo; Retornos de preços futuros; Eficiência de mercado; Relatórios agropecuários; CAR (Retornos anormais cumulativos); GARCH

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SUMMARY

1. Introduction

1.1 Initial remarks

Commodities reports play a vital role in access to information from market players. Since 1970, researchers have sought to understand how public information in reports and other announcements are transmitted to commodity prices (Fama, 1969; Milonas, 1987; Schroeder, Blair, and Mintert, 1990; Sumner and Mueller, 1989; Colling and Irwin, 1990). However, the private sector began providing this information with the increase in market participants and the financialization of commodities markets (Alturki and Kurov, 2021). Hence, the literature started to evaluate the value of public information and the contribution to the market and society of those reports (Silveira *et al.*, 2017; Alturki and Kurov, 2021; Huang *et al.*, 2021; McKenzie and Yangmin, 2022).

Moreover, another characteristic of commodity's markets is that decisions can be based on future expectations. It is frequently used to protect assets from market uncertainties and price volatilities (Colling & Irwin, 1990). Initially, future market practices provided price discovery to producers and traders, allowing them to observe the evolution of prices as a benchmark. However, during the financial market's deregulation and the electronic sector's development, commodities have changed from an asset whose price was driven by physical consumption into assets with financial liquidation (Liu and Zhang, 2019; Ordu *et al.*, 2020).

The Efficient Market Hypothesis (EMH), our guiding theory, emphasizes that security prices at any time unbiasedly reflect all the available information (Fama, 1970). In addition, given the marketplace's rationality, the effects of an Event Study will be reflected immediately in the commodity price (Mackinlay, 1997). For example, a commodity report contains information about crops, production expectations, prices, and the number of live cattle, pork, and poultry, among other information. When a report is released, the market participants will confirm or not their expectations. If the market is efficient, it is assumed that the public information in these reports or news announcements will quickly be incorporated into market prices (Fama, 1969; Colling and Irwin, 1990).

However, providing this type of information has a high cost. As public reports are considered a public good, governments started to be responsible for transmitting them to agents, and the principal objective was to avoid traders from exploiting public

information to make it profitable (French and Roll, 1986). As the social benefits are not directly observable, one way to answer these questions is to examine the behavior of future prices given a change in the information in the reports (Huang *et al.*, 2021).

Over the years, researchers have used the Event Study to inspect the behavior of prices on days of report releases. Using Cumulative Abnormal Returns (CAR) and volatilities (GARCH models) measures to verify the effect of announcements on commodity futures prices. In the first case, the goal is to compare mean returns over the estimation window (the period before a recall event) with returns over the Event Study window (the Event Study, as a report release) (Moghadam, Schmidt and Grier, 2013). For the second case, the strategy is to estimate a volatility regression by adding dummy variables to control the Event Study released. The results of the dummy variable will guide the results to ensure the validity of reports on the volatility (Isengildina-Massa *et al.*, 2016; Alturki and Kurov, 2021).

Indeed, plenty of literature searches for the importance of public information in commodities markets using the United States Department of Agriculture (USDA) reports and international commodity's future prices (Lehecka, 2014; Isengildina-Massa *et al.*, 2016; Alturki and Kurov, 2021, Huang *et al.*, 2021). Different results are seen, conditionality to the time window and the kind of commodity used. Although the USA is a crucial player in commodities markets, Brazil is also a significant player, being the number one producer and exportation of soybeans and meat (Ji *et al.*, 2018, Fedoseeva, 2022). In fact, some international studies have used national crop information to explain international price volatilities[1]. Regrettably, the national market has not gained the same relevance as the abroad studies.

One of the most crucial commodities for the Brazilian economy is live cattle. Brazil holds prominent positions in the beef sector, ranking as the world's largest exporter, the second-largest producer, and the third-largest consumer of beef globally. However, the cattle market in Brazil presents certain peculiarities concerning market concentration. A few companies, such as JBS, Marfrig, and Minerva, dominate the Brazilian cattle sector, controlling a significant portion of beef production, processing, and exportation (Moita and Golon, 2014).

Additionally, this concentration raises concerns about the market power of these companies, which can influence prices, market practices, and sector policies. When a

[1] See Mattos and Silveira (2015) and Silveira *et al.* (2017),

few companies hold significant power over the market, they can gain access to privileged information and exert control over prices (Neto and Famá, 2001). This can lead to information asymmetry, where not all market participants have equal access to relevant information, thereby compromising market efficiency (Camargos and Barbosa, 2005).

Even though the Brazilian cattle market is highly concentrated, the futures market is largely driven by individual investors rather than companies. The total number of individual investors on B3 reached 13.1 million, a growth of 23% compared to December 2020 (B3, 2021). Since the introduction of the live cattle futures contract, this market has seen significant growth in trading activity, particularly among individual investors. In 2021 alone, nearly 11 million live cattle contracts were negotiated, with about 62% of them firmed by non-commercial participants in Brazil (B3, 2021). Although it is not the most liquid market on the exchange, especially when compared to the stock market, the increase in trading activity can enhance market liquidity and, consequently, improve market efficiency.

Based on the information presented, we have identified peculiar market to study. On one hand, there is high market concentration, which may compromise market efficiency. On the other hand, there has been an increase in contract liquidity in recent years, which can contribute to market efficiency. Additionally, we are dealing with a derivative product from a complex market: an extremely relevant commodity both nationally and internationally for the Brazilian market. Unfortunately, the analysis of market efficiency, specifically in its semi-strong form, has not yet been explored in this context. We aim to fill the gap in the Brazilian live cattle literature.

We investigate the impact of information contained in three public reports — *Agromensal (CONAB), Agromensal (Cepea*), and P*esquisa Trimestral de Abates (IBGE)* — on semi-strong form market efficiency. To examine this, we apply an Event Study to analyze abnormal returns and volatility measures, assessing the price behavior surrounding the publication of these reports. Understanding market efficiency in this context is essential to assess how information is incorporated into live cattle futures prices, influencing price dynamics, volatility, and investor behavior. Moreover, market efficiency analysis can provide valuable insights for public policies and market strategies, promoting a more transparent and efficient environment for all participants, from producers to investors and end consumers.

1.2 Research problem

In Brazil, the live cattle herd and the beef market exports are fundamental to agribusiness. In 2021, the Agribusiness GDP reached a record of 26.6% of the total Brazilian GDP (CEPEA, 2023). Despite the setback in 2022, due to input shortages, the sector maintains a strong representation in the total GDP, reaching 24.8% in 2022 (CEPEA, 2023). However, when analyzing the contribution of the GDP just from the livestock sector between 2021 and 2022, there was an increase of 2.11% directly to increases in production within the farm (*"dentro da porteira"*) and in meat exports.

According to the Brazilian Association of Meat Exporting Industries (ABIEC), the Brazilian live cattle -herd corresponds to 202 million heads -in 2022-, which places Brazil as the world's largest holder of live cattle (ABIEC, 2023). In addition, in 2022, there was an increase of 22,6% in beef exports comparing to 2021 due to the record slaughter of 42.31 million heads of live cattle (SECEX, 2023).

During Brazil's consolidation as a major beef exporter, some transformations were needed in the production process, such as investments in genetics, which reduced the slaughter cycle, the relocation of production, and the meat industry to the Central-West North regions (ABIEC, 2021). The production process of Brazilian beef has three different cycle parts. The first is *"antes da porteira,"* which consists of choosing and buying lean cattle or calves for fattening. The chosen animal can be raised in confinement, on pasture, or in a hybrid system, and the production system can be extensive, semi-intensive, or intensive (da Fonseca *et al.*, 2018). The second is called *"dentro da porteira,"* which consists of the live cattle cycle: rearing, rearing, and fattening. It also involves animal welfare practices, reproduction, and transport (da Fonseca *et al.*, 2018). Lastly, "*fora da porteira*" comprises slaughter and industrial consumption processing (da Fonseca *et al.*, 2018)[2].

Regarding commercialization, live cattle is a product with low differentiation and is produced on a large scale. This implies the categorization as a commodity, where producers are price takers, and prices are determined by the supply and demand law (Loiola *et al.*, 2019). On the other hand, Brazil's association between slaughterhouses, feedstock suppliers[3], and distributors, mainly supermarkets, has oligopsonistic

[2] In some establishments the three processes can be seen together.
[3] Here we consider industrialized inputs such as animal feed.

characteristics as the concentration of market power into slaughterhouses, which pressures prices (Loiola *et al.*, 2019; Cammelli *et al.*, 2021).

Furthermore, the acceleration of globalization, advancements in information technologies, and the liberalization of capital flows have all contributed to the increased integration of commodities across the financial sector (Liu et al., 2013; Kalkuhl et al., 2016; Atenga and Mbodja, 2021). Besides, the acceleration of the global market, improved information technologies, and the liberalization of capital flows have increased the integration of commodities in the financial sector (Liu *et al.*, 2013; Kalkuhl *et al.*, 2016; Atenga and Mbodja, 2021).

Between the 1980s and 1991, the Brazilian cattle futures market witnessed a series of challenges due to political and economic instabilities, including changes in economic plans, currency fluctuations, price controls, and political events such as impeachments (Rochelle, 2019). It was only from 1991 forward that the contracts no longer experienced interruptions, while still maintaining physical delivery of the animals. However, this method of trading resulted in substantial information asymmetries, often leading to the delivery of cattle of lower quality than initially negotiated (Frick, 1996).

Consequently, the Brazilian Exchange implemented various modifications to the contracts to standardize the process. In May 1994, a significant change was introduced, mandating that physical deliveries of cattle occur in Araçatuba, SP, within accredited corrals equipped with scales certified by the Brazilian Exchange (Lazzarini, 1998). Despite these adjustments, the associated costs made the contracts less appealing, particularly for long positions situated far from Araçatuba, SP. Thus, by the end of 1994, the Brazilian Exchange introduced financial settlement as an alternative in the cattle futures market.

Certainly, the new contract format undoubtedly played a pivotal role in the integration of cattle futures contracts into the financial market. The number of positions surged from approximately 500 open contracts in December 1994 to around 3,500 contracts by September 1996 (Lazzarini, 1998). Moreover, Frick and Campos (1996) provided compelling evidence that the introduction of financially settled contracts enhanced the information efficiency, particularly in its weak form, within the futures market. In 2001, these contracts transitioning from being denominated in US dollars to

being denominated in Brazilian reais. Since then, the Brazilian Financial Settlement Live Cattle Futures (BGI) contracts have not undergone any changes[4].

The highest number of commodity contracts, with 3.28 million open contracts, was observed during the peak of the subprime crisis in 2008 (B3, 2021). At that time, investors increased their trading in other financial instruments in search of protection, providing evidence of commodities being firmly embedded in the financial market (Sanders, 2008). As for the cattle market, 2008 also witnessed the highest number of open contracts in a single day, totaling 39,838 on June 20 (B3, 2021).

In addition, the evolution of the electronic sector, including computers, trading algorithms, trading strategies, and online trading platforms, has led to a financial transition from using telephones in outcry trading to computer-based trading systems. As a result, market access expanded greatly, and trading costs declined (Massa *et al.*,2020). In Brazil, electronic trading was introduced in 2005 at B3[5], allowing faster information and trading between the market participants.

Public information has become a subject of extensive debate in the new context of 'big data' since agents are exposed to different types of it, and price changes can be caused by new market information (Adjemian and Irwin, 2019; Isengildina-Massa et al., 2020). As public reports are considered a public good, researchers have been occupied with verifying whether governmental reports benefit the market and its participants (Adjemian and Scott, 2018; Karali *et al.*, 2019; Isengildina-Massa *et al.*;2020; Moon and Tonsor, 2020). The international literature has confirmed that hypothesis on livestock, oils, and grains markets with public reports (Silveira, Mattos, 2016; Isengildina-Massa *et al.*, 2020; Alturki *et al.*, 2022).

There are some differences between B3 and the USA Exchanges. One of them is the liquidity contracts. It is known that Brazil's futures markets need liquidity to develop (Rocha and Souza, 2022). One of the ways to contribute to market liquidity is to generate information. The public information contributes to the market participant's understanding of the economic process, which results in more liquidity and market efficiency (Wang, X., 2014; Couleau, A. *et al.*, 2020).

The live cattle market and the coffee are the oldest assets traded in Brazil's futures markets. Also, the BGI contract is the most negotiated asset in the commodity futures market on B3, following corn (B3, 2021). However, the provision of

[4]Additional information about the current contracts can be found in the methodology section.
[5] At the time *Bovespa*

information about live cattle is relatively recent on the part of CONAB, the principal national agency. The *AgroConab*, a public agricultural report released by CONAB, started only to contain information on the live cattle market in 2021. For the grain market, there have been public reports since 2012. The oldest, around 2012, national public information source on live cattle markets comes from the Instituto Mato-grossense de Economia Agropecuária (IMEA)[6]. One of the institute's goals is to share information with the market participants.

Furthermore, the literature has noted that the livestock market is more concentrated than the grains markets in the USA (Irwin and Good, 2006; Karali *et al.*, 2019; Isengildina-Massa *et al.*, 2021). That is not evidence seen only in the U.S. market. The Brazilian live cattle have some concentrated market, mainly the slaughterhouses (da Fonseca Boechat A. M. et al., 2018; da Silva, A. C. et al., 2020). Although a market concentration exists in part of the bovine chain, in futures markets, the BGI contract is negotiated mainly by a natural person rather than legal entities (B3, 2021)[7]. Then, government announcements might be an alternative for the market participants to make strategies to allocate their resources (Karali *et al.*, 2019; Huang *et al.*,2022).

Over the years, the Event Study methodology has been adopted to verify public information's impact on commodities prices. Some authors have used the Cumulative Abnormal Returns (CAR) and Cumulative Abnormal Volume (Sanders *et al.*, 1992; Moghadam *et al.* 2013; Moon and Tonsor, 2022) and others have applied the GARCH measures (Adjemian and Irwin, 2019; Isengildina-Massa *et al.* 2020; Isengildina-Massa *et al.,* 2021). The seminal paper of Schroeder, Blair, and Mintert (1990) uses the Event Study by applying CAR to verify the impact of USDA inventory reports on future livestock prices in the USA. The results do not show strong evidence of abnormal returns, inferring no impact of new information on prices.

Irwin, Good, and Gomez (2001) used an Event Study to determine the value of USDA and World Agricultural Supply and Demand Estimates (WASDE) for the soybeans, corn futures, and options in the USA market. The results suggest that the mean difference for corn and soybeans on the report's day was significantly different from the previous day. This leads to the conclusion that USDA and WASDE information has significantly impacted corn and soybean markets (Irwin, Good, and Gomez, 2001).

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[6] A non-profit private Institute in partnership with APROSOJA, AMPA and ACRIMAT created in 1998.
[7] Small and medium ranchers are found in this category.

Another Event Study was developed for the Chicago Mercantile Exchange Live by Moghadam *et al.* (2013). Using the CAR, they found that Escherichia Coli O157:H7 news negatively impacted the live cattle futures markets quickly. No evidence was found the longtime. Moon and Tonsor (2020) applied the Event Study with CAR to the USDA live cattle and beef markets. Their results show that the beef market is more affected by the food safety information than the live cattle market.

The literature also employed GARCH models for Event Studies. In 2012, the Chicago Board of Trade eliminated morning trading in commodities markets that coincided with the regular publication of USDA commodity reports. Taking advantage of this exogenous Event, Adjemian and Scott (2018) demonstrate that the market participants had hours to review the information in the reports and adjust their strategies. Their GARCH estimations results show that agricultural futures markets presented volatility spikes in real-time trading on USDA crop announcements. Adjemian and Irwin (2019) demonstrated that continuous trading of government news (the Event Study USDA reports) coincided with higher daily price volatility ranges in the CBOT corn market. After the changes, traders must digest news under the real-time format elevated trading volatility, as concluded by the GARCH estimation.

Similarly, Isengildina-Massa *et al.* (2020) examined how reports information as production, inventory, and the crop from the USDA can affect the corn, soybeans, and wheat returns. They applied a GARCH model and found that reports information could change commodities production plans, especially corn and soybean, which suffered the most impact. In another study, Isengildina-Massa *et al.* (2021) found that reports impacted volatility in the hogs, cattle, and crop markets. They used daily data from Chicago Mercantile Exchange (CME) and parametric and nonparametric tests to verify the impact of various USDA information releases. Their study also used information from one report alone and from multiple reports together in a cluster. The results suggest that information clusters had the most significant impact on commodity prices.

Specifically, to live cattle markets volatility measures, the international literature on the value of reports is vast (Grunewald *et al.*, 1993; Isengildina *et al.*, 2006; Pendell *et al.*,2006, Isengildina-Massa *et al.*, 2021). Karali *et al.* (2018) investigated the impact of public and private livestock information on hogs and live cattle returns in USA markets. Their goal was to verify if the public information still impacts these products since the market concentration on the livestock market. They specified a GARCH

system and concluded that livestock reports provide valuable information to market participants beyond private analysts' expectations.

On the other hand, Karali *et al.* (2019) found contrasting results when verifying the impact of subsamples of reports on live cattle and hog returns in the U.S. markets. They used three reports subsamples: *feed inventory*, which represents the number of animals point in time, *placements* that are information on additions to these animal stocks, and *marketings* representing the information about reductions in these stocks. The authors applied a market surprise test and concluded that just *marketings* information impacts the live cattle futures prices.

In addition to the theme, the academy has tried to analyze the effects of reports with high-frequency data. In financial studies, this has become common (Christie–David *et al.*,2000; Drienko and Sault, 2013; Ekinci *et al.*, 2019; Hussain and Omrane, 2020). Price volatility is one way to assess an asset's market uncertainty and risk. With high-frequency data, the volatility can be measured over fewer windows with more observations, bringing greater accuracy to the results (Corssi *et al.*, 2001). In the case of commodities, several researchers have dedicated to explaining how these prices react to macroeconomic news using high-frequency data[8].

Few but recent studies have evaluated the impact of commodities reports on their prices via high-frequency data (Adjemian and Irwin, 2018; Adjemian and Irwin; 2022; Huang *et al.*,2022). Lehecka *et al.* (2014) used average absolute deviation to measure the volatilities by applying parametric and nonparametric tests. They concluded that USDA reports contain important information for the market since corn prices' reactions to the releases were found immediately after the market opened, which persisted for approximately ten minutes in the USA market. Joseph and Garcia (2018), using the same volatility measure in the study cited above, found that USA soybeans markets quickly incorporate public information on USDA announcements, concluding those reports are also important to the market.

While Brazil plays a crucial role in global commodities markets, there has been a visible gap in research regarding the impact of information reports on Brazilian markets. The comprehension of how information dissemination can enhance market stability is a fundamental subject within economic literature. This study evaluates how live cattle futures prices in the Brazilian market respond to new information in livestock

[8] See, for example, Christie–David *et al.*,2000; Drienko and Sault, 2013; Ekinci *et al.*, 2019; Hussain and Omrane, 2020.

reports released by *Agromensal* from *CEPEA*, *AgroConab* from *CONAB*, *and Pesquisa Trimestral de Abates* from *IBGE*. The selection criteria for these reports were that they be publicly available, national, and that the source and data collection were proprietary.

We believe that unexpected information released by the reports contributes to market participants improving their strategies. We purpose to contribute to the discussion of information in the Brazilian live cattle market by verifying abnormal returns and volatility spikes at live cattle futures prices on announcement days.

The time interval corresponds from 01/01/2017 to 6/28/2023 and covers daily data. In 2017, a low phase in the cattle cycle began, with an increase in the slaughter of females. In 2019, the cycle reversed, starting a high phase that continued until 2021. From 2022, the cattle industry entered a new low phase, leading to increased slaughters and impacting prices in 2023. Therefore, the choice of this analysis period is justified, as it encompasses the entire cycle, including both high and low phases. Additionally, these years encompassed various significant events in both the domestic market (such as "*Operação Carne Fraca"* in 2017, suspicion of spongiform encephalopathy in 2021) and the international arena (such as the African swine fever in 2019, COVID-19 pandemic in 2019 and 2020).

In conclusion, motivated by the increases in food prices, climate change, and the necessity of food security strategies, the impact of public information is a significant source for policymakers to improve the functioning and stability of futures markets and more efficient allocation of economic resources. Then, our contribution to the literature is to analyze information from national public reports on Brazilian live cattle futures prices, applying two distinct methodological approaches. In the first approach (CAR), we seek to identify moments when information alters market expected returns, potentially leading to no fair gains. In the second approach, we propose to model volatility by introducing the reports as exogenous variables into the system. In that way allowing us to examine market behavior in response to the arrival of new information.

1.3 Hypothesis:

The Brazilian live cattle market exhibits semi-strong efficiency based on the public information from *AgroConab (CONAB)*, *Agromesal (Cepea),* and *Pesquisa Trimestral de* Abates (IBGE) reports.

1.4 General objective:

Study if information contained in national public reports impacts decision-making, the actions of agents, and the dynamics of the cattle market between January 2017 and June 2023.

1.5 Specific objective:

i) Search the private and public information of the Brazilian live cattle market.

ii) Verify whether the information contained in the reports alters the expected future prices returns of Brazilian live cattle.

iii) Analyze if the information contained in the reports affects the dynamics of the future prices' volatility for live cattle in Brazil.

2. Brazilian cattle market: History, concentration, cycle, and prices

2.1 Brazilian history and expansion of live cattle market

Throughout centuries, the history of livestock farming in Brazil has undergone a notable evolution. It began with the arrival of the initial cattle from Cabo Verde in the Brazilian Northeast during the 16th century and extended to substantial transformations in the 1990s. Initially brought in to aid sugar cane activities and serve as a source of sustenance, cattle later migrated inland, avoiding competition with sugarcane along the coastal regions (Marques, 1987).

The 18th-century gold rush marked a pivotal moment, pushing cattle into a crucial role in the country's internalization. This period opened new territories and provided provisions for the *Bandeirantes*. The trails forged by these animals led to regions now recognized as Minas Gerais, São Paulo, Goiás, Mato Grosso, and Mato Grosso do Sul (Marques, 1987). The 19th century witnessed the introduction of Zebu breeds, showcasing their remarkable adaptability. As mining declined in the 20th century, livestock farming evolved from a secondary activity to a predominant force in the central region of the country (Abreu *et al*., 2006).

The favorable conditions, characterized by expansive territories and the effective adaptation of the herd, turned the cattle market into a significant commercial venture, transcending its role as merely subsistence focused (Zen and Barros, 2005). The 1980s were characterized by challenges such as diseases and unstable meat supply (Yardley-Podolsky, 1981). Remarkable technological changes, allowing the emergence of the super early calf with a slaughter time of 13 months, such as artificial insemination, embryo transfer, and reduced slaughter time, were introduced (Moita and Golon, 2014).

In 1990, Brazilian beef cattle farming continued to be prominent, receiving incentives, particularly the Ministry of Agriculture's Ordinance No. 304/96, which made carcass classification mandatory, encouraging product quality improvement (Panza and Silva, 2007). In the same decade, the Brazilian economy underwent profound transformations, aligned with the trade liberalization implemented in the early years of the Collor government and subsequently maintained by Fernando Henrique Cardoso.

The removal of non-tariff barriers and the gradual reduction of protection for the domestic industry placed out as prominent features of this period. In 1994, the implementation of the Real Plan, focused on inflation control, resulted in the

appreciation of the national currency (Grasel, 2007). These changes in the economic background positively influenced livestock farming, creating a conducive environment for sector expansion (Grasel, 2007).

While this appreciation brought benefits to the general population and specific sectors such as large companies and professionals, it posed challenges to the agricultural sector. The overvalued exchange rate negatively impacted exporters, including the livestock sector, which felt the pressure from the loss of competitiveness in the international market. The economic context of the 1990s marked a phase of transition and challenges for Brazilian livestock farming, highlighting the complex interaction between economic policy, currency appreciation, and productive sectors (Souza, 2008).

In contrast to the expectation that the Brazilian agribusiness sector would surrender its status as the second-largest beef producer, a position it had held since 1992, trailing only the USA (FAO, 2022), the appreciation of the real currency powered a surge in productivity within the sector. Significant investments in technology were made to ensure competitiveness. As highlighted by Souza (2008), livestock farming was one of the sectors most impacted by the decline in inflation with the implementation of the Real Plan in 1994, given its historical reliance on currency devaluation. This new scenario required rural properties to transform into efficient enterprises, resulting in a considerable increase in productivity indices.

With the implementation of the Real Plan, the adopted exchange rate regime maintained the national currency semi-fixed and overvalued against the dollar. However, in 1999, due to trade balance deficits and capital flight, the country was forced to move to a floating exchange rate, placing it in a position of vulnerability and dependence on the flow of foreign capital (Fochezatto, 2003). With the flexibility allowed by the exchange rate regime, the real quickly depreciated. These depreciations, in turn, favored Brazilian exports, resulting in volumes exceeding 500 thousand tons for the first time, according to SECEX/MDIC (2007) data.

Thus, the national and international economic scenario in the 2000s provided new records for Brazilian livestock farming. In 2000, Brazil was the sixth-largest global exporter of beef. From 2004 onwards, it consolidated its position as the largest global exporter, a position it maintains to the present writing date (SECEX/MDIC, 2007). During the period from 1994 to 2007, the cattle population increased from approximately 160 million heads to over 200 million, and export volumes grew

significantly. Only in 1998, it represented 6% of the total produced, reaching 20% in 2004 (Zen and Barros, 2005).

It is relevant to emphasize that the success of the Brazilian livestock sector was not limited to changes in national economic policy and technological advances but also to its ability to respond to health crises. The epidemic Bovine Spongiform Encephalopathy (BSE) disease in the European Union in 2001 and in the United States and Canada in 2003 had significant repercussions on the global supply of beef (Silva, 2018). Faced with challenges related to food safety, both blocs implemented strict restrictions on cattle exports, drastically reducing their production and beef supply (Vicensotti, 2019).

Brazil shines even more in this scenario with its production based on pasture-raised cattle. This practice not only represents a more sustainable breeding method but also eliminates the risk of contamination by the agent causing BSE, giving Brazilian beef a reputation for food safety (Farina et al., 2003). The mentioned conjuncture opened doors for other countries to meet the global demand for beef, and Brazil emerged as one of the main beneficiaries of this situation. Its robust livestock industry and reliable production practices allowed the country to expand its participation in the global beef market, establishing itself as a prominent supplier and strengthening its position as one of the main players in the global beef industry (Neto, 2018).

The growth of Brazilian exports was largely a result of the reduction in European supply, especially due to the origin of pasture-raised cattle. The extensive territorial area, favorable climatic conditions, and programs focused on animal health and food safety position Brazil as one of the largest producers of beef, with great potential to meet the demands of the international market (Lopes *et al.*, 2010). Furthermore, Brazil stands out for its competitive advantage of having the lowest cost globally, as evidenced by Teixeira and Hespanhol (2014). As a result of these developments, over the past decades, Brazil has raised competitiveness in prices compared to competitors, effective cost control, and the ability to offer quality products, adhering to the required standards of animal health by major international markets (Neto, 2018).

Brazilian beef has been progressively integrated into a favorable international context, also regarding income. The increase in population and per capita income growth in developing countries, where meat consumption was still limited by income availability, drove international demand for the product, resulting in increased Brazilian

sector exports (Renó *et al.,* 2016). In the period between 2000 and 2013, the economic growth of developing countries was even more expressive, averaging 4.52% annually, in contrast to the 1.46% annual rate for the world average (World Development Indicators – WDI, 2015). This favorable economic environment contributed to the increased global demand for basic foods and the diversification of diets, including more industrialized products such as meats, dairy, vegetable oils, among others (Fuglie and Wang, 2012).

Economic growth in developed countries is often associated with an increase in the purchasing power of the population. As people have more resources available, the demand for higher quality and diverse products, such as imported meats, tends to expand. In China, a crucial sector in this process of economic growth and demographic changes was the animal protein industry. Economic growth in China, coupled with demographic shifts and the expansion of the urban middle class, has resulted in significant changes in the diet, with an increase in the consumption of animal protein replacing a traditionally grain-based diet (Jank et al., 2020).

China stands out in the beef market scenario, emerging as a growing market and becoming the main destination for Brazilian exports since 2018 (ABRAFRIGO, 2023). In that year, China was compelled to seek alternative protein sources due to the impactful African Swine Fever, which compromised a significant portion of its livestock (Silveira, 2023). The author emphasizes that, despite the recovery of domestic pork supply, demand remains high due to increased income availability in the country, leading to a diversification in consumer purchases and dietary habits.

Florindo et al. (2015) state that, throughout the years, favorable conditions for the expansion of new markets for Brazilian beef have emerged, primarily attributed to the implementation of meat control systems in the country to comply with the standards of international markets. Additionally, this development is coupled with enhancements in the quality and early maturation of the Brazilian herd, along with its cost-effectiveness compared to major competitors (Souza *et al.*, 2008).

Internally, meat sales are also experiencing changes where consumers are increasingly demanding. According to Brandão et al. (2015), conjunctural and structural changes in the population directly influence beef consumption patterns, especially directed towards exploring consumer market demands. Oliveira *et al.* (2015) affirm that in a competitive environment, organizations must have a consumer-oriented focus,

meaning understanding consumers deeply enough to anticipate their needs and desires, exceeding their expectations.

Boutique meat shops fulfill this role, offering a unique and personalized experience for consumers while contributing to the dynamics of the meat market. These specialized establishments have gained prominence, providing a differentiated alternative compared to conventional markets (Barcellos *et al*., 2016). In Brazil, most of the produced meat is directed to the wholesale market without differentiation, meaning a minimally standardized raw material with low added value and the absence of attributes perceived as superior quality (Forest *et al*., 2014).

According to Font-i-Furnols and Guerreiro (2014), there are two distinct consumption trends: one represented by the population with lower income, where price is the most important factor. A second, aimed at market niches, whose products are targeted at consumers with high economic standards, differentiated by quality, natural and or sustainable demand, as well as certifications such as breeds, animal welfare, or luxury brands. With specialized service and in-depth product knowledge, customers can explore different cuts, understand preparation techniques, and receive personalized guidance (Cavalcanti, 2014). This more intimate approach contributes to customer loyalty, creating an environment where the butcher's expertise is valued (Henchion et al., 2017).

Unlike large chains, these establishments often opt for partnerships with local producers and specialized suppliers, standing out for the careful selection of cuts and breeds (Carvalho; Zen, 2017). The rise of boutique meat shops is also aligned with contemporary consumption trends, where consumers seek more authentic experiences and connections with the origin of food (Morales et al., 2013). This creates opportunities for market diversification, with space for promoting less conventional breeds and production methods, enriching the variety available to consumers (Carvalho and Zen, 2017).

Indeed, JBS's market share corresponds to 32.39% of the Brazilian market, followed by Marfrig (18.80%) and Minerva (13.41%). Together, Marfrig and Minerva still fall below JBS's market share (Foreign Trade Balance and Trade Statistics, 2022). Only three companies account for over 65% of the meat market in Brazil. Since 2018, Forbes Brazil has published the Agro100 list of the 100 largest companies in the Brazilian agribusiness sector. Cattle-related companies hold prominent positions, with JBS ranked first, Marfrig Global Foods fifth, and Minerva fifteenth, when compared

across all sectors (Forbes Brazil, 2022). This high concentration leads to a verticalized management, allowing large firms to have greater administrative and financial capacity to gather information (Isengildina-Massa, 2016).

2.2 Growth, specialization, and concentration in the Brazilian meatpacking industry

The success achieved by the livestock sector not only propelled production but also brought significant changes in the market structure. The adoption of advanced practices such as artificial insemination, cutting-edge genetics, and controlled nutrition contributed to the improvement of productivity and efficiency in beef production. Increased demand, industry verticalization, and the concentration of large companies led to a reconfiguration of market dynamics (Carvalho and Zen, 2017).

In addition to changes related to animal breeding, slaughterhouses also underwent major transformations. The verticalization of agribusiness, characterized by the integration of different stages of the production chain allowed for more efficient and optimized management of the entire chain, with greater control over quality, costs, and logistics. However, it contributed to the concentration of power in the hands of a few major players, impacting commercial relationships and competitiveness among various participants in the livestock market (Moita and Golon, 2014).

According to analysts from Valor Econômico (2008), initially, sector concentration occurred through the incorporation of smaller companies by larger ones. Indeed, in May 2007, Friboi, currently JBS, significantly expanded its operations in the beef sector in Brazil through the acquisition of the American company Swift Company, becoming JBS-Friboi, and entering the cattle and pork markets in the US and Australia (JBS, 2012). Additionally, the company went public in 2007, and its shares are traded on BM&FBovespa (now B3) (JBS, 2012).

The initial public offering (IPO) of shares by JBS in 2007 was a pioneering move that influenced other companies in the sector to pursue a similar path. In the same year, the Marfrig meatpacking plant also announced its intention to go public, followed by Minerva (Moita and Golon, 2014). This surge of IPOs set off a chain of mergers and acquisitions, shaping the landscape of the beef market from 2007 to 2013.

In 2009, JBS-Friboi played another major role by acquiring the *Berntin* slaughterhouse. In 2013, JBS-Friboi expanded its operations by acquiring the

Independência slaughterhouse, demonstrating an aggressive growth strategy through acquisitions. Brasil Foods emerged in 2009 through a merger between two companies, Sadia and Perdigão, where Perdigão changed its corporate name to BRF Brasil Foods S.A., and Sadia was incorporated (BRASIL FOODS, 2017).

Another highlight during this period was the Marfrig group, which in 2009 acquired the *SEARA* food group, *Margem*, and *Mercosul* (Macedo and Lima, 2011). These operations not only strengthened the companies' positions in the market but also highlighted the dynamics of consolidation and expansion that permeated the cattle sector during this period. Aggressive competition among major companies in the sector drove these strategic moves, significantly shaping the configuration of the beef market in Brazil.

The second moment of slaughterhouse concentration, according to Valor Econômico (2008), was the participation of the National Bank for Economic and Social Development (BNDES) as a major sector financier. The BNDES played a crucial role in encouraging the internationalization of Brazilian companies. Its involvement aimed at strengthening the domestic industry, enhancing competitiveness, expanding exports, accessing technology, and generating foreign exchange. This strategy contributed significantly to the growth of companies through overseas subsidiaries (Costa and Souza-Santos, 2010).). In fact, the first financing by the BNDES was for JBS when it acquired the Swift company (Garcia, 2011; Rocha, 2014).

However, the State's involvement in credit distribution brought about speculations of privileges within the sector. Lazzarini (2015) argues that there is a partisan political view between companies, the government, and BNDES. The authors identified that the BNDES gave preference to loans for companies located in regions governed by politicians allied to the federal government, receiving more capital. Moreover, between 2005 and 2017, 80% of the credit released by BNDES went to the meat sector, around 11.7 billion. Only JBS received about 5.5 billion in BNDESPar[9] credit compared to 2.5 billion for the internationalization of the Bertin slaughterhouse (Estadão, 2017).

These mergers and acquisitions have made the beef industry increasingly vertically integrated and more concentrated. Moreover, concentration in the slaughterhouses can directly impact the prices paid to cattle ranchers for beef (Fonseca

[9] BNDESPar is a holding company associated with BNDES that invests directly in companies through the purchase of stocks, bonds, and equity participations.

Boechat and Parré, 2018). The lack of robust competition among slaughterhouses can result in less pressure to offer fair prices to producers, thus affecting the income and economic viability of cattle farming (Moita and Golon, 2014).

Considering the increased concentration in the sector, in 2005 the National Confederation of Supply (CNA) reported to the Administrative Council for Economic Defense (CADE) allegations of price coordination and anticompetitive practices. In 2005, José Batista Júnior, president of the *Friboi* slaughterhouse at the time, was involved in recordings indicating a possible cartel scheme: the slaughterhouses agreed on a discount table for cattle ranchers (CADE, 2005).

In 2007, the same CADE (2005) condemned the Minerva, Bertin, Mataboi, and Franco Fabril slaughterhouses for price collusion, based on the existence of an identical discount table for all these slaughterhouses, resulting in a fine of 5% of the 2004 turnover (Moita and Golon, 2014).

Since then, several researchers have sought scientific evidence of collusion and cartel behavior. Rosa's study (2004) revealed that in 2004, there were over 1,000 inspected slaughterhouses in the country, out of which about 350 met the requirements of the Federal Inspection Service (SIF). However, only 17 of them contributed to nearly 100% of the revenue generated by beef exports. The top 5 groups concentrated over 80% of this revenue, with the leading 2 groups retaining approximately 50%. These findings, as per the author, indicated signs of market power.

Pigatto *et al.* (2006) sought to analyze the strategies adopted between slaughterhouses and cattle ranchers. Through a case study focused on cattle ranchers in the region covered by the Regional Development Office of Tupã. The authors identified that slaughterhouses have bargaining power by establishing a standard pricing and discount table. In contrast, the strategy of cattle ranchers was to keep the animals in the pasture to obtain higher prices. However, cattle ranchers had low negotiation power since slaughterhouses purchased animals from greater distances to press down the price of closer animals.

Moita and Golon (2014) analyzed the beef cattle chain in Brazil, seeking to empirically identify if there is market power in the commercial relationship between rural producers and slaughterhouses between July 1994 and December 2008. Weak evidence of market power was found in the sector, allowing the hypothesis of cartel behavior to be ruled out. Silva and Filho (2017) investigated monopsony power in the fat cattle market and monopoly power in the beef market from 1996 to 2014 in Brazil.

Through annual time series, their results showed significant monopoly price distortions in the beef market and monopsony price distortions in the fat cattle market. Moreover, such distortions showed a growing trend over the period, probably caused by the increased concentration in the meat processing and retail sectors.

Boechat and Parré (2018) sought to answer whether more concentrated markets of beef slaughterhouses registered in the SIF exert buying power over cattle ranchers in Brazil, impacting the price paid for live cattle. Using the multidisciplinary concept of Thiessen Polygons (1911), the authors found that there is buyer power in the Brazilian beef production chain, with the greatest exercise in more concentrated markets, resulting in a lower price paid to cattle ranchers for live cattle.

2.3 Significance of the live cattle market for GDP and global destinations

Agribusiness plays a pivotal role in the Brazilian economy. This sector was instrumental in the recovery of the Brazilian GDP in 2017, which rebounded by 1% after two years of recession in 2015 and 2016, marked by a -3.5% decline. The agricultural sector surged by 13% in that year, driven by a record-breaking crop. Excluding the contribution of agribusiness, the growth would have been a mere 0.3%, highlighting its indispensable influence on economic growth (IBGE, 2018).

In the subsequent years, the trend continued with a 1.87% growth in 2018 and a 3.81% increase in 2019. The year 2020 marked an exceptional period, with an impressive growth of 24.31%, and in 2021, the sector showed an 8.36% growth (CEPEA, 2019, 2020, 2021, 2022). Notably, in 2021, the agribusiness GDP accounted for 27.40% of the total Brazilian GDP, the highest percentage since 2004 when it reached 27.53% (CEPEA, 2022). However, in 2022, the agricultural GDP experienced a decline of 4.22% compared to 2021 (CAN, 2023). A significant portion of this decline was attributed to the elevated cost of inputs in 2022. Nevertheless, when examining the agricultural sector in isolation, it demonstrated a growth of 2.11% in 2022 compared to the previous year (CEPEA, 2023).

Brazil is the third largest beef consumer, after China and the United States, the second largest producer, behind the United States, and the largest exporter (FAO, 2022). In addition, about 10% of the food that supplies the world is Brazilian and, by 2050, Brazil is expected to produce 40% of the global food demand (FAO, 2022). This is one of the reasons the country is known as "*the world's barn*." Brazil has solid agricultural

potential due to its magnitude, tropical and dynamism with the extensive arable land area, climate, favorable geography, and technologies, enabling productivity increase (IBGE, 2022).

Indeed, the Brazilian agribusiness of beef cattle is a promising sector. Even with the challenges brought by Covid-19, in 2021, Brazilian exports reached US$ 9.2 billion, an increase of 8.40% compared to 2020. Considering only *in natura* meat (which corresponds to more than 80% of the total meat volume exported) in 2022, the values negotiated also registered a record of 2.26 million of tons, an increase of 22.6% compared to 2021 (ABIEC, 2023). Also, in 2022, the Brazilian cattle herd was estimated at 202 million and the number of slaughters 42.31 million of animal, which places Brazil as the world's second holder of live cattle, behind just India and the second producer, after USA (ABIEC, 2023). The main destinations for beef exported in 2022 were China, the second United States, and third, Japan (ABIEC, 2023). Table 1 shows the main international destinations for Brazilian beef:

Table 1: Main international destinations of Brazilian beef in 2022

Country	**Volume** (tons)	**Volume** (%)
China	1.238.483	54.70
United States	134.250	5.93
Egypt	96.585	4.27
Hong Kong	94.961	4.19
European Union	85.366	3.77
Chile	79.446	3.51
Philippines	61.401	2.71
Arab Emirates	58.558	2.59
Russia	49.852	2.20
Israel	40.022	1.77
Others	325.256	14.37
World	**2.264.180**	**100%**

Source: Elaborated by the author using data from ABIEC (2023) and SECEX (2023).

Exports contribute positively to the Brazilian balance of payments, and agribusiness has played a key role in the surplus in recent years. In 2022, meat exports moved about 12.97 billion dollars, three billion more than the previous year (ABIEC, 2023). In 2022, Brazilian meat exports accounted for 4.50% of the country's total exports, generating a revenue of $12.9604 billion, whereas in 2021, revenue amounted to $9.20039 billion. In the agribusiness sector exclusively, beef exports account for 9.4%, generating a revenue of 14,962.73 million dollars. When we add up the revenue

from all other animal protein sources, the total value is 14,332.75 million dollars. This means that, when combined, the other meats do not surpass beef in terms of revenue. (MAPA, 2022; ABIEC, 2023).

2.4. The distribution of the cattle herd in Brazil

While Brazil is the largest exporter, its consumption of beef in Brazil is also high. By 2020, the Brazilian states with the highest number of herds are Mato Grosso, followed by Minas Gerais and Mato Grosso do Sul (IBGE, 2023) as showed in Figure 1:

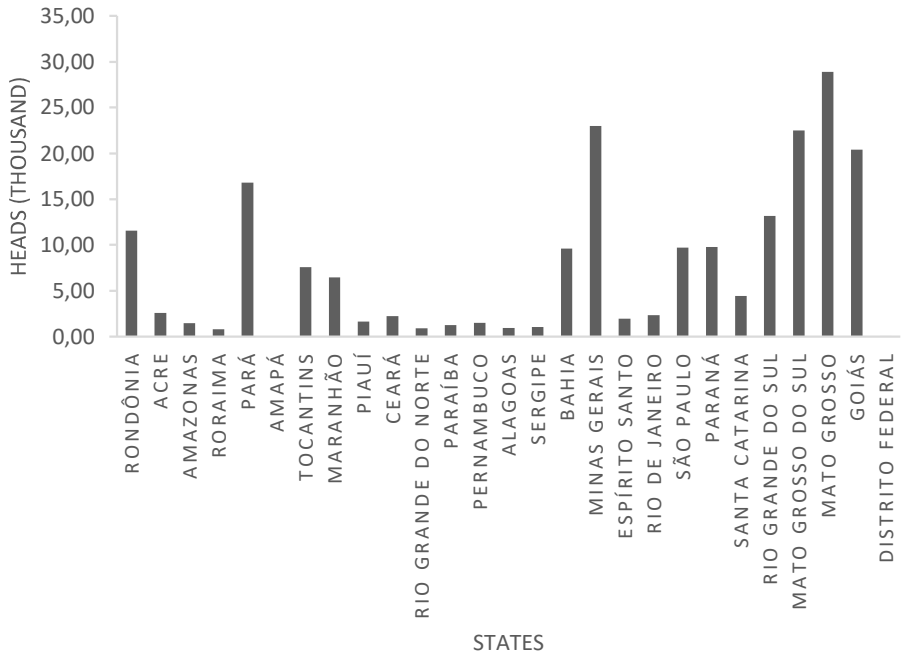

Figure 1: Largest cattle producers in Brazil by the state in 2022
Source: Elaborated by the author using data from ABIEC (2023)

About the municipalities, over the last 20 years, São Félix do Xingu in the north has become the one with the highest number of cattle. This increase is related to the "*Programa Nacional de Pecuária*" whose objective was to supply the domestic demand and provide a surplus for exports (EMBRAPA, 2020). Moreover, the south, southeast, and central-west regions began to occupy crops such as soybeans, corn, and forests, due to the technologies used in these regions that made it possible to increase productivity (Fernandes, 2015). Indeed, the central west and northern regions collectively account for over half of Brazil's total cattle herd, as represented in Figure 2.

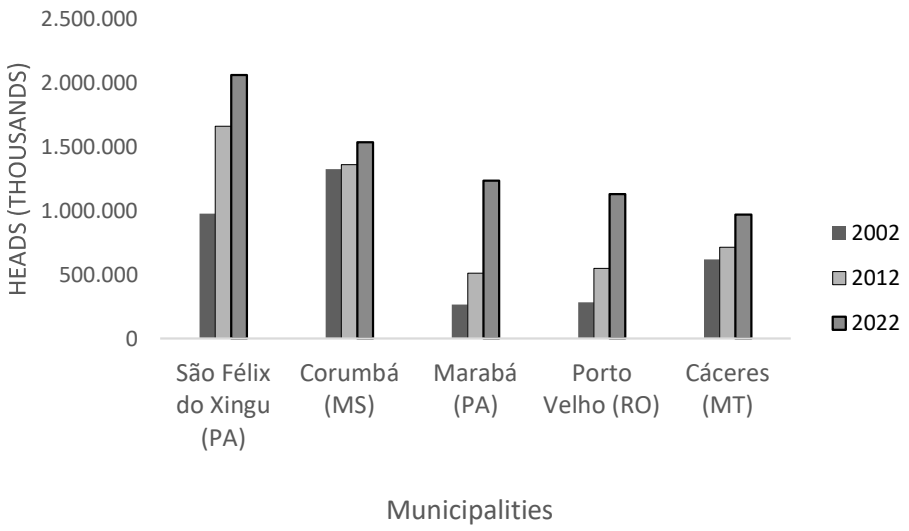

Figure 2: Herd of the five largest Brazilian municipalities over 20 years
Source: Elaborated by the author using data from ABIEC (2023) and IBGE (2022).

Additionally, the IBGE study, *"Monitoramento da Cobertura e Uso da Terra"* reveals that in 2018, the land use ranking was led by Pará with 83,400 km², followed by Mato Grosso with 45,449 km² in the second position, and Rondônia with 33,259 km² in the third position (IBGE, 2022). Figure 3 illustrates the share of land use for agriculture in each Brazilian microregion:

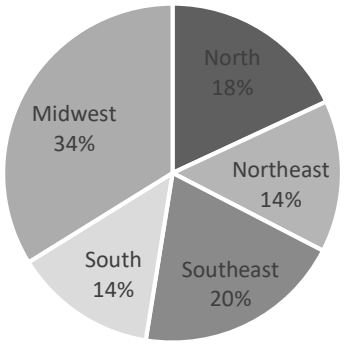

Figure 3: Regional herd share in the total of Brazil (%) in 2022
Source: Elaborated by the author using data from IBGE (2020).

The success of the domestic and global live cattle and beef industry is commonly ascribed to the favorable climate and diverse range of Brazilian pastures (Fernandes, 2015). Not only that, but some transformations were also necessary for the production process, such as investments in genetics, which reduced the slaughter cycle, the

displacement of production, and the meat industry to the Midwest and North regions (ABIEC, 2021). In the following subsections, we address these topics.

2.4 Brazilian live cattle production systems

The beef livestock sector is typically divided into three distinct phases. Da Fonseca *et al.* (2018) present them as *"antes da porteira"* involves the selection and acquisition of calves for fattening. The chosen animals can be raised in confinement, on pasture, or through a hybrid system, with production systems varying between extensive, semi-intensive, and intensive methods. The second phase, known as *"dentro da porteira"* encompasses the entire lifecycle of live cattle, including raising, nurturing, and fattening. Upon completing the fattening process, the animal is referred to as live cattle. This phase also entails the implementation of animal welfare practices, reproduction, and transportation. The third phase, *"depois da porteira"* involves the processes of slaughter and industrial consumption. Producers have the option to engage in a single stage or oversee the entire production cycle.

Furthermore, the nomenclature assigned to animals plays a significant role in determining their ultimate purpose. Santos et al. (2009) delineate the distinctions between calf, ox, bull, and cow. A calf, whether male or female, encompasses the period from birth to 12 months. Following weaning, from 13 months until the point of slaughter, a male is referred to as an ox, and a female is designated a heifer. Subsequently, following the first calving, the female is recognized as a cow. Bulls encompass the period from weaning to the breeding stage, typically spanning from 2 to 3 years of age. Oxen, on the other hand, are mature bovines aged over three years, having been castrated, and they are primarily designated for agricultural labor, commonly referred to as live cattle.

Regarding the fattening process of animals, there are three systems: extensive, semi-extensive, and intensive. Cezar *et al.* (2005) defined extensive as using pasture alone as the only source of food and energy. Soil fertilization is conducted to replace the cattle's elements from the plants during grazing. Semi-extensive systems correspond to the sum of pasture use with mineral and energy supplementation to reduce the period of the livestock cycle. The main energy sources most used are oats, sorghum, corn, and millet; the proteins are soybean meal, cottonseed, corn gluten meal, soybean, and urea. The intensive system includes the use of confinement for the fattening of cattle. This

system aims to reduce the fattening cycle of the animal from 60 days to a maximum of 110 days. The animals are treated with energy and protein concentrates, the main ones being the same as the semi-intensive ones, with an increase in the concentrated volume, it is more common in the last stage of production, fattening. (Cezar *et al.*, 2005, Carvalho and Sabbag, 2016).

According to the IBGE (2017), about 2.5 million rural establishments practice livestock activities, and the pasture areas occupy more than 160 million hectares. Of the total pastures, about 30% are natural pastures, while 70% are planted pastures. The EMBRAPA (2017), the most used system in Brazil corresponds to the extensive system with 95% of production. The total pasture area is estimated at 167 million hectares (EMBRAPA, 2017). This system allows for lower production costs. However, pastures are deficient in certain minerals necessary for animal nutrition (Carvalho and Felema, 2022). At some point, it is necessary to use a supplement in animal feed (Carvalho and Sabbag, 2016). Furthermore, in 2023, only about 18.02% of the animals slaughtered come from confinement (ABIEC, 2023).

Another characteristic of the Brazilian herd is its breeds. Due to the ability to adapt and produce in the tropics, Zebu breeds represent more than 80% of Brazil's cattle as pure or crossbred animals (ABCZ, 2022). In Brazil, most of the herd is made up of Nelore, a type of zebu breed. The Table 2 shows the estimated number of Zebu in 2020.

Table 2:Estimates of the number of zebus in Brazil in 2020

Zebu Breed	Numbers
Nelore	11.034.056
Brahman	224.481
Gir	807.790
Guzerá	499.526
Indubrasil	215.002
Sindi	34.448
Tabapuã	461.794

Source: Elaborated by the author using data from *Associação Brasileira dos Criadores de Zebu* (ABCZ, 2020)

There are still two zebu breeds Cangaian and Punganur, but Brazil has no estimated numbers. The other breeds, such as those of European blood, especially Angus and Hereford, are more concentrated in the Rio Grande do Sul. Moreover, in the Center-North region, the industrial crossing of the Nelore with European breeds, mainly Angus, is increasing (Teixeira and Hespanhol, 2014).

Regarding meatpacking companies, the market concentration is divided among five major companies, with José Batista Sobrinho Company (JBS) out as the largest processor of animal protein in the world and holding 35% of the *Associação Brasileira de Proteína Animal* (ABPA, 2021). The second largest meatpacking company in Brazil is Brasil Foods S.A (BRF), responsible for 14% of the country's chicken slaughter. Minerva Foods follows with approximately 11% of cattle slaughter, while Marfrig Global Foods is responsible for approximately 10% of cattle slaughter. Finally, Aurora Alimentos Co, one of the largest food production cooperatives in Brazil, accounts for approximately 8% of pig slaughter in the country. This market concentration raises important questions regarding competition, information, market power and price formation in the meatpacking industry in Brazil.

2.5 Brazilian live cattle cycle and price formation

We aim to study the impact of livestock reports on the live cattle futures' prices. From this section, we will refer to this category of animals. As previously described, live cattle are the steer that has passed through the fattening phase until the slaughter. In Brazil, live cattle negotiations are represented in arrobas (@). One arroba is equivalent to 15 kilos and refers to the animal's carcass, the weight of meat on the bone. It does not consider leather and hull, for example, used for other purposes.

Regarding commercialization, live cattle is a product with low differentiation and produced on a large scale, which implies the categorization as a commodity, where producers are price takers. Prices are determined by the supply and demand law (Loiola *et al.*, 2019). In this process, buyers and sellers act to obtain greater profits. According to (Shikida *et al.* 2016), when the supply of animals becomes more restricted, ranchers hold sales, keeping animals in the pasture in search of appreciation in the prices paid. In the harvest periods, the industries look to lower prices due to the greater availability of animals. Thus, producers and the agroindustry use different strategies to protect themselves from price volatility (Carvalho and Felema, 2022). Moreover, the formation of prices in the bovine market involves other points such as basic production costs, the price of corn and soybeans used in animal supplementation, seasonality, as well as economic factors such as the exchange rate, herd growth, demand and supply of animals, and slaughterhouse concentration among others (Santos *et al.* 2015).

According to Carvalho and Sabbag (2016), the arroba price is influenced by the costs of bovine feed. Supplementation for cattle comes from soybeans and corn. Therefore, when the price of the food base rises, the production chain of live cattle also suffers from the increase in prices (Carvalho and Sabbag, 2016). Seasonality is also a key point in determining the arroba's price. In the rainy season, between October and March, the quality of the pasture tends to increase, which allows the rancher to keep the cattle on pasture. As the system is mainly extensive, this delays the delivery of the animal, raising its prices (Shikida *et al.* 2016). In the dry season the opposite. Hence, the rainy and dry seasons influence pasture quality and availability, making adjusting the number of animals in the pastures difficult. In drought times, for example, animals tend to reduce weight, which is reflected in the sector prices (Carvalho and Felema, 2022).

The calves ' supply is another factor related to the live cattle market's spot price. By 2020, livestock is in the high phase of the livestock cycle, raising live cattle prices (IBGE, 2022). In short, livestock cycles are high and low. Oliveira Silva *et al.* (2017) define the high in the cycle as an increase in the slaughter of females, which reduces the supply of calves and consequently generates an increase in the Price of the arroba of live cattle. While the cycle is low, there is a reduction in the slaughter of females, which increases the supply of calves and consequently reduces the Price of the arroba of fattened cattle. According to the IBGE (2020), in 2020, cattle supply fell for the first time in three years, reaching 29.7 million heads. During this period, there was a reduction in the slaughter of females, one of the explanations for the rise in meat prices (IBGE, 2021).

According to the *Centro de Inteligência da Carne Bovina* (CiCarne, 2020), the duration of the entire livestock cycle was originally around eight years. However, technological innovations in the beef cattle sector, including advancements in animal management, genetic improvement, and food supplementation, have significantly reduced these cycles to approximately five or six years. This transformation has had a direct impact on the relationship between meat supply and slaughter operations.

The Brazil's association between slaughterhouses, feedstock suppliers, and distributors, leading supermarkets, has oligopsonistic characteristics as the concentration of market power into slaughterhouses pressures prices (Loiola *et al.*, 2019; Cammelli *et al.*, 2021). Between 2007 and 2016, the number of slaughterhouses remained stable. This indicates the slaughterhouses' concentration since their growth did

not follow the slaughter of animals. The study of Ferreira and Vieira Filho (2019) reveals that the number of bovine slaughterhouses between 2007 and 2017 remained between 1100. Another relevant point for the capacity to expand production and, mainly, meat exports in Brazil is the number of establishments with Sistema de Inspeção Federal (SIF).

According to *Ministério da Agricultura, Pecuária e Abastecimento* (MAPA, 2018), 431 slaughterhouses spread across Brazil have SIF. The three states with the most slaughterhouses are Paraná State (69), Minas Gerais (57), and São Paulo (51). The number of federal agricultural and veterinary medical auditors (AFFA-MVs) from MAPA who have worked in these slaughterhouses is 872, with an average of just two professionals per slaughterhouse. According to the authors, these results indicate the sector's ability to expand.

Other influential economic factors affecting prices include interest rates, government interventions, and sanitary barriers. Given Brazil's prominent position in the global market as the largest beef exporter, exchange rates significantly impact both live cattle and beef prices. Santos et al. (2017) elucidated that a devaluation of the Brazilian real against the US dollar enhances the attractiveness of exports. Then, it would increase the demand and, consequently, it would accelerate the national production with the increase in the demand of the industries to acquire more live cattle.

National government interventions aim to control prices and maintain domestic consumption. This action was widely used in the 1980s (Kassouf and Hoffmann, 2019; Shikida *et al.*, 2016). There are also issues related to sanitary barriers. Sanitary barriers can hurt prices as there is uncertainty about the health of animals (Boechat, 2013; Gaio and Capitani, 2019).

Among all the explanations mentioned above, the one that has the most weight in the rise in prices is the Chinese demand for meat. From the pandemic beginning in March 2020 until April 2022, the average price of beef increased by 42.6% (IPEA, 2022). The research points out that the main reason is that from March 2020 to March 2022, beef exports to China increased by 30.4%, which reduced domestic supply.

Hence, the beef market in Brazil has peculiar characteristics, presenting cycles with periods of high and low prices, reinforcing the importance of price forecasting techniques to guide agents in this market (Santos *et al.*, 2017; Gaio and Capitani, 2019; Carvalho and Felema, 2022). Thus, the futures market emerged as a protective environment for both the producer and the buyer. The main protection tool is the hedge.

However, with the evolution of this market and the advancement of technologies, more agents began to enter these environments, giving rise to speculators, arbitrators, and hedgers. In the following section, we discuss the futures market for live cattle in Brazil in more detail.

2.6 Live cattle futures market in Brazil

The future market of any asset is a *Derivative* which implies that its value derives from another product. In this thesis, the derivative chosen is the Brazilian live cattle futures market, which is based on the variation of the spot price of the Brazilian live cattle market. The spot price is the current price of an asset with immediate payment, and the buyer takes delivery immediately or within a few days. A futures contract is a financial instrument traded on the stock exchange, obliging an asset's owner and buyer to transact the asset at a specified future date and a predetermined price (Hull, 2002).

In Brazil, the history of the futures market began in 1917, when the São Paulo Mercantil Exchange was created to trade cotton futures contracts. In 1991*, Bolsa de Mercadorias de São Paulo (BMSP)* firmed an agreement with *Bolsa Mercantil & de Futuros (BM&F)*, founded in 1985 and traded financial contracts. In 1997, the Brazilian Futures Exchange, located in Rio de Janeiro, joined this union, and São Paulo became the only state in Brazil to operate a stock exchange. In March 2017, *BM&FBovespa*, created in 2008, merged with *Cetip*[10], giving rise to B3 and becoming the 5th largest Stock Exchange in market value worldwide (B3, 2022).

In the 1980s, Brazil was going through a high period of inflation and many government interventions, fact that hampered derivatives negotiations. In the 1990s, derivatives started to increase with the liberalization of trade, control of inflation, the Plano Real, and a decrease in government intervention (Souza, 1998). Currently at B3, the agricultural derivatives trading includes futures contracts: Arabica coffee, live cattle, soybeans, corn, crystal sugar, cotton, and anhydrous ethanol fuel.

As for the live cattle futures contracts trading in Brazil began in 1980 on the São Paulo Mercantile Exchange (BMSP). In October 1986, during the Plano Cruzado, the Central Bank determined the compulsory liquidation of the contract. In 1991, the newly created Commodities & Futures Exchange (BM&F) launched the live cattle foreign

[10] The Central de Custódia e de Liquidação Financeira de Títulos Privados (CETIP) was founded in 1984, but only became operational in March 1986.

exchange futures contract. The contract version had as its object of negotiation the fat, castrated, well-finished live cattle, weighing between 450kg and 550kg and with a maximum age of 60 months. Each contract involved the negotiation of 330 net arrobas. Eight trading months were defined: February, April, June, August, September, October, November, and December. In the case of the physical settlement of the contract, four cities were established for the delivery of animals: *Araçatuba* (SP), *Barretos* (SP), *Presidente Prudente* (SP), and *São Paulo* (SP) (Rochelle, 1997).

However, the physical delivery of cattle was subject to some problems. The animals did not always contemplate what was foreseen in the contract. There were disputes between sellers, who wanted to deliver a low-quality product, and buyers who demanded higher quality animals (Rochele, 1997). Therefore, in May 1994, at the time, the BMF&Bovespa created a contract with a financial settlement. In addition, contracts with physical delivery would be subject to regulations imposed by the Exchange, such as: to reduce costs, delivery would only be in *Araçatuba*, and the Exchange would carry out the weight of the animals at a pre-established establishment (Frick, 1995).

Since the end of 1994, financial settlement has been a feature of Brazilian cattle contracts. Starting with the 2001 version, these beef cattle contracts introduced maturity dates for each month of the year. The contracts specify the trading of male bovines, requiring a minimum weight of 16 net arrobas and capping the age at 42 months. Each contract boasts a size of 330 net arrobas. These contracts exhibit the abbreviation BGI and quote prices in Brazilian reais per net arroba, rounded to two decimal places. The minimum trading variation amounts to BRL 0.05, and contract maturity falls on the last business day of each month.

When a contract is developed, the exchange stipulates every detail as rights and obligations of the parties involved. Futures contracts specify the asset traded, the size of the contract, the delivery and settlement procedures, whether physical or financial, and the contract maturity. Among its functions, the main one is to protect interested parties from unfavorable variations by setting the purchase or sale price at a specific date, to minimize the risks of loss (Anderson, 1983; McKenzie, 2002; Kyle, 2019). Santos and Silva (2015) explained that the main feature of the futures contract is to lock in a price independent of what the spot market established at expiration. When an investor carries his future position to expiration, the price he paid during the trade will equal the amount he wanted to buy the asset when he made the contract. Thus, the futures market fulfills

its mission of protecting investors from price changes (Carter, 1999; Hull *et al.*, 2013; Kyle, 2019).

As the live cattle market is inserted into the futures market, decisions can be based on future expectations. Since it is frequently used to protect assets from market uncertainties and price volatilities (Colling and Irwin, 1990). Initially, future market practices provided price discovery to producers and traders, allowing them to observe the Price's evolution as a benchmark. However, amid the financial market's deregulation and the electronic sector's development, commodities have changed from an asset whose price was driven by physical consumption into assets with financial liquidation (Liu and Zhang, 2019; Ordu *et al.*, 2020).

One of the main agents of the futures market is the hedger, whose objective is to take positions in the futures market of equal magnitude, but with opposite signs, to their positions in the spot market. By doing this operation, the risks are reduced or non-existent (Silveira Bueno, 2002). On the other hand, according to Working (1953), the hedge would not be insurance but an arbitrage operation in which investors would be concerned to take advantage of favorable changes. This would explain why agents sometimes use hedging and sometimes they do not.

Futures markets have evolved over the years and have come to feature participants with distinct objectives: 1) Hedge, which intends to reduce the price risk movements in an asset. Usually, a hedge takes an opposite position in a related security. 2) Speculation: which intends to take risks. The operations are based on expectations about the market's future direction, for example, the anticipation of future price movements to obtain gains significant enough to offset the risk. 3) Arbitration is an operation to obtain financial gains from identifying market imbalances Hull (2002).

As previously presented, several variables influence the price of live cattle. In this way, the futures market appears with the primary objective of protecting sellers and buyers. Live cattle prices vary due to economic scenarios, seasonality, and uncertainties during the harvest and the off-season. For Brazilian beef cattle, the "cattle harvest" consists of when more cattle are available for slaughter, usually between January, April, and, consequently, lower prices. This information is fundamental for the financial planning of each production system. For the rancher, this moment is decisive in terms of strategy in measuring the results of his activity (CNA, 2022).

Hedging is an example of a protection tool for producers and buyers from price risks. For example, during the fattening process, the price of live cattle may vary due to

increases in the price of feed and variations in the prices of meat substitutes such as pork and chicken (B3, 2022). These variations can compromise the value received by the producer, which may prevent him from covering his expenses (Monteiro *et al.*, 2013). By applying a hedge, the producer can protect himself from fluctuations when taking opposite positions in the market (Colling and Irwin, 1990; Hull *et al.*, 2013; Kyle, 2019).

May and October are attracting the most attention from live cattle market participants. Cattle raising in Brazil is mainly carried out on pastures, about 95% (EMBRAPA, 2016). Therefore, cattle fattening is related to natural events such as the dry and rainy[11] seasons. Consequently, the harvest and off-season occur in months when natural conditions are favorable for the sale of the animal (EMBRAPA, 2016). The peak of the live cattle harvest occurs in May when the rainy season ends, and the dry season begins in Brazil. Thus, the cattle pasture fattening from this period is longer due to food scarcity since the pastures are dry. At the end of October, the off-season peak occurs when the rains return. In addition, with the end-of-year festivities, the demand for meat increases. Hence, in these periods, the hedge rate tends to increase as cattle farmers want to take advantage of the rise in prices while slaughterhouses desire to protect themselves from price rises (Carvalho and Felema, 2021).

A sales hedge is called when the investor buys the product in the physical market (or produces it) and sells futures contracts, seeking protection against a price drop. The purchase hedge consists of buying futures contracts and selling (if applicable) the product in the physical market, allowing protection against possible price increases. As futures market prices are correlated with physical market prices, the loss in one market tends to be offset, at least in part, by the gain obtained in the other (Carter, 2003).

The Brazilian literature has been dedicated to verifying the effectiveness of the hedge for the live cattle market. Over the years, the results have been divergent. Silveira and Ferreira Filho (2003) analyzed the cross hedge between calves and cattle effectiveness' using contracts from the BM&F between 1995 and 2001. Their results indicated low hedge effectiveness due to basis risk.

On the other hand, Silva and Faria (2016) identified that the hedge was effective for the region and Itapetininga in Bahia between the years 2012 to 2015. Gaio and Capitani (2020) also analyzed the live cattle hedge effectiveness' for the largest

[11] In Brazil is called as “Período das águas”

producing places in Brazil between the years 2012 to 2016. Applying a VEC and a BEKK, their results indicated the low effectiveness of the hedge, especially in the more distant places of the price formation. The dynamic model also suggested that the local futures contract has not been efficient in meeting the demand of potential hedgers.

Oliveira Neto and Figueredo (2020) verified the possibility of the volatility price risk mitigating in the Paraguayan live cattle spot market through hedging in the Brazilian live cattle futures market. The results suggest that Brazilian live cattle futures contracts, traded on the BM&FBovespa (currently, B3), allow adequate management of the price risk for Paraguayan live cattle in the spot market between the analysis period from 2012 to 2014.

In addition to reducing the risk of price variation, two other reasons have been accepted for using hedging: profiting from the expected behavior of the base and using futures contracts to diversify this portfolio, which should be composed of available commodities and other investments (Blank *et al.*, 1991). Indeed, the literature argues that derivatives are very versatile instruments (Colling and Irwin, 1990; Hull *et al.*, 2013; Kyle, 2019). In some cases, companies that initially intend to 'hedge' their risks can inadvertently transition into speculators, increasing the need for hedging (Hull *et al.*, 2013). One prominent example in Brazil was the significant loss incurred by Sadia.

3. Theoretical reference: The Efficient Market Hypothesis on Brazilian live cattle market

The foundation of this study is rooted in the Efficient Market Hypothesis (EMH), which was widely disseminated by economist Eugene Fama in the 1970s. The EMH posits that financial asset prices in markets incorporate all available information. Essentially, it contends that prices comprehensively capture the collective knowledge and expectations of all participants in the market (Fama, 1970).

Individual and institutional investors utilize the EMH as a guiding principle for shaping their investment strategies. According to Brown (2020), if markets operate efficiently, the practice of selecting stocks based on either technical or fundamental analysis might not be a reliable strategy. Dempsey (2013) further asserts that in efficient markets, effective resource allocation is ensured as asset prices inherently embody all accessible information. The EMH, as emphasized by Langevoort (1992), holds implications for the development of financial policies and regulations. In instances of market efficiency, there may be a diminished necessity for regulatory intervention aimed at safeguarding investors.

The underlying idea is that, in an efficient market, all this information is swiftly incorporated into asset prices. This means that if investors want to consistently achieve above-average profits, they will need information that is either unknown or not reflected in prices, which the Efficient Market Hypothesis (EMH) argues is extremely difficult to consistently achieve (Fama, 1970).

The relevant information mentioned encompasses all available data that can impact the value of an asset. This includes past, present, and, depending on the form of the EMH, even future or non-public information. Examples of such information include:

i) Financial statements, such as revenue reports, balance sheets, and cash flow statements of a company.

ii) Economic indicators, such as GDP growth rates, interest rates, unemployment indices, and other macroeconomic factors.

iii) Trends and specific developments within an industry that can affect the performance of companies in a particular market segment.

iv) News and events, such as announcements of mergers and acquisitions, product launches, geopolitical events, etc.

v) Performance and developments related to competing companies that can influence the prospects of a specific company.

vi) Future expectations about the future, such as earnings forecasts, growth projections, and other anticipatory indicators.

vii) Privileged information (strong form of EMH), non-public information accessible only to a few market participants. The strong form of EMH suggests that even such information cannot be used to gain an advantage in the market.

viii) Technical Information (in cases of weak and semi strong forms), past price patterns, and technical indicators that investors use to predict future trends. The weak and semi strong forms of EMH imply that such technical information is not effective in gaining an advantage.

However, it is important to note that the EMH is not universally accepted. Critics argue that markets may not always be efficient due to factors such as irrational investor behavior, information asymmetry, and unpredictable events that can impact asset prices (Malkiel, 2003, 2005; Ball, 2009; Subramanian, 2010; Cornell, 2018). In this section, we present the theoretical model upon which our research is based. We will discuss its origin, concepts, forms of efficiency, mathematical modeling, and its limitations.

3.1 The Efficient Market Hypothesis (EMH) origin

The Efficient Market Hypothesis (EMH) was officially formulated by Fama in the 1970s. However, discussions concerning price behavior in financial markets have a much earlier history. In 1900, the French mathematician Louis Bachelier published the findings of his thesis. He developed the theory of speculation, and his research revealed that price changes in the stock market are both independent and probabilistic (Bachelier, 1900), a concept that closely corresponds with what we now refer to as a "random walk." Bachelier's pioneering work served as the basis for the subsequent development of the EMH by Fama and played a significant role in shaping our understanding of financial markets (Ying, 2019).

Working (1934) also described that commodity prices in stock markets behaved like numbers in a lottery, hence being random Nevertheless, some authors also sought to demonstrate that prices were not random. It was the case of Eugen Slutsky (1937) and later revisited by Kendall (1953). Slutsky argued that random variables could be the

result of a cyclical process. Kendall analyzed 22 weekly series searching for cyclical behavior and empirical evidence for Slutsky's claims. However, he found that prices did not exhibit any pattern. They were random walks.

Continuing the discussion on empirical evidence, Friedman (1953) made a compelling case for market efficiency by emphasizing the crucial role of arbitrage. He argued that arbitrageurs play a key role in ensuring market efficiency by capitalizing on any deviations from the underlying fundamental values of assets. This perspective suggests that even with the presence of arbitrage-related trading strategies, markets tend to correct themselves, ultimately leading to efficiency.

Adding to the body of evidence, Roberts (1959) and Osborne (1959) conducted pioneering research that shed light on the seemingly random nature of stock prices. Their empirical findings indicated that stock price movements often exhibited characteristics of a random walk, where future price changes were not systematically predictable based on past information. This finding further supported the notion of market efficiency, as it implied that attempts to profit from historical price patterns or trends may be challenging due to the randomness observed in stock price movements.

Indeed, Fama (1965) first used the term "efficient market," asserting that an efficient market follows a random walk. In the same year, Samuelson (1965) provided mathematical evidence that a martingale characterizes an efficient market. These contributions were fundamental in developing and understanding the Efficient Market Hypothesis (EMH). Also, Roberts (1967) distinguished between weak and strong form tests, which became the classic taxonomy in Fama (1970).

Fama (1970) characterized an efficient market as one in which prices consistently and fully incorporate all available information. The Fama’s EMH also explained that prices accurately reflect an asset's true value, and their returns should exhibit serial independence. Their fluctuations become unpredictable. Then, no investor can leverage distinct strategies or privileged information to gain an advantage over other participants, even if such information originates from the issuing company itself (Fama, 1970). Saying that a market is efficient if *all* available information raises the challenge of finding a market where all information is readily available. To address this skepticism, Fama (1970) subdivided the definition of EMH into three parts:

- **Weak Form Market Efficiency:** This form of efficiency assumes that current prices already incorporate all past prices and market information. As

a result, investors cannot gain an advantage by analyzing historical price data or trading patterns since all previous information has already become a part of current prices. Consequently, technical analysis of historical data would prove ineffective in forecasting future price movements (FAMA, 1991).

- **Semi-Strong Form Market Efficiency:** In this form of efficiency, in addition to past information, it is assumed that all public information, including news, reports releases, and relevant events, is readily available and has already been incorporated into financial prices. It means that even newly disclosed public information cannot be used to gain trading advantages, as prices react instantly to such information (FAMA, 1991).
- **Strong Form Market Efficiency:** In the strong form of efficiency, the premise is that all types of information, whether public or private, are fully incorporated into financial prices. It implies that not even insider information, available only to a select group of individuals, can be used to achieve extraordinary returns in the market, as the market has already priced in such information (FAMA, 1991).

Like any theory, certain assumptions are listed. In the case of EMH, Fama (1970) defined the following sufficient conditions for the EMH to hold: a) absence of transaction costs in the trading of securities; b) all information is available to all market participants at no cost; c) consensus among investors' expectations about the effects of information on current stock prices. Those conditions are sufficient but not necessary (FAMA,1970).

It means that even if there are transaction costs, they do not prevent prices from adjusting as information arrives. Additionally, if investors act efficiently, processing and responding quickly to information, this can contribute to market efficiency. Then, the greater the number of agents with access to information, the higher the probability of the market being efficient. The greater the availability of information in the market, the greater the tendency for it to be efficient (Damodaran, 2002).

Our research focuses on analyzing the influence of agricultural reports on the return’s dynamics of the Brazilian cattle futures market. As commodities are integrated into the financial market, we understand that information is crucial for comprehending price movements in this market. Therefore, we use the Efficient Market Hypothesis

(EMH) to guide our study, just as (Mattos and Siqueira, 2015 Siqueira *et al.*, 2017 Karali *et al.*,2019 Isengildina-Massa *et al.*,2021).

Recognizing that information is the basis of EMH. Our investigation corresponds to the semi-strong form of the EMH, where asset prices incorporate all publicly available information. Before proceeding with the economic modeling, we present some points about the liquidity and maturity contracts in the next section.

3.2 The relationship between EMH, liquidity, and contract maturity

Liquidity is also a key factor in EMH, as it influences how quickly, and accurately new information is reflected in prices. Many traders quickly absorb new information in markets with high liquidity (Indriawan *et al.*, 2021). Prices adjust rapidly, and there is less opportunity for traders to exploit information imbalances as they are quickly corrected.

In markets characterized by low liquidity, the adjustment of prices to new information may occur at a relatively slower pace. This phenomenon can create opportunities for informed traders to exploit the lag in price adjustments (Lehecka *et al*. in 2014). This aligns with the principles of the EMH, as it suggests that in highly liquid markets, it becomes more challenging for traders to consistently identify mispriced assets or opportunities for profit due to the rapid assimilation of information into prices (Stout, 1995). We comprehend that the higher the liquidity, the greater the probability of verifying the EMH. Then, we comprehend that the higher the liquidity, the greater the probability of verifying the EMH.

Zhang *et al.* (2019) claim that liquidity induces changes to commodity price trends and should be informative for anticipating episodes of future economic instability. When the market becomes more (less) liquid, all commodity prices tend to move up (down) in the same direction. As a result, such liquidity generates aggregate price shocks and amplifies volatility (Zhang *et al.*, 2019). Lehecka *et al.* (2014) affirms that the less liquid a market is, the more difficult it is to ensure informational efficiency.

A market may be less than (semi-strong form) efficient, and not all new information may be reflected in prices immediately. In this context, the speed of adjustment to new information is slower in less-liquid asset markets (Lasfer *et al.*, 2003; Lehecka *et al.*, 2014; Zhang *et al.*,2019; Indriawan *et al.*, 2021). Investors tend to be

more interested in contracts with greater liquidity, so a commodity report may not impact prices as participants are not interested in less liquid contracts.

The commodities market exhibits a noticeable sensitivity to the interaction of supply and demand dynamics, geopolitical influences, and liquidity constraints. Liquidity is particularly salient as commodities vary in tradability and market complexity (Zhang *et al.*, 2019). Wang *et al.* (2012) point out that the dates of government production reports impact the cost of derivative liquidity in futures markets. This author highlights that when the information is good, the probabilities of contracts with long positions are more significant, leading to more rollover of contracts.

Shang *et al.* (2018) found that the liquid costs are low around the USDA reports around the commodities index market. The batch auction (a mechanism built into the CME electronic trading platform) was studied in corn markets by Huang *et al.* (2022). They concluded that around report releases, a reduced speed advantage, lowered market volatility, and improved liquidity. Reports add more information to the market, inducing liquidity expectations during the month and the year (Indriawan *et al.*, 2021).

Thompson *et al.* (1988, 1993) emphasize that the time to maturity of a contract is a significant determinant of liquidity costs. Contracts with distant maturities tend to incur higher liquidity costs, providing one explanation for why market participants often prefer assets with shorter maturities.

In addition, there is a preference for the short term since the liquidity is a decreasing function of maturity: the longer the contract maturity, the lower its liquidity (Isleimeyyeh *et al.*, 2021). Indeed, the relationship between contract maturity and liquidity in the context of the EMH implies that contracts with longer maturities tend to have reduced liquidity, and their prices may not respond as quickly to new information (Lehecka *et al.*, 2014).

The contracts traded in commodity markets cover several maturities, implying they are appropriate for short-term and long-term investments (Isleimeyyeh *et al.*, 2021). However, the nearby contract is the most liquid and the best to reflect the market (Isengildina *et al.*, 2006; Lehecka *et al.*, 2014; Yang and Wang, 2021). Furthermore, a more informed participant in the market can make wiser decisions, such as dismissing its contract before expiry or rolling over the contract for the next month.

Moreover, Abitante (2009) points out that in the futures market, a contract at maturity aggregates all market information. Then, the price discovery process becomes more efficient in these months. The first nearby contract was and still is viewed as the

best proxy for the spot price and allows one to avoid trading physical commodities (Geman *et al.*, 2008; Hull, 2012).

The semi-strong form of the EMH better illustrates its validity when the product has a shorter maturity. Isengildina-Massa *et al.* (2008) argued that although other maturities exist in different months, the first maturity is the one that best measures the impact of the reports. In the literature, the nearby contract is also frequently chosen to assess the impact of reports on future prices. Irwin *et al.* (2001) and Isengildina-Massa *et al.* (2008) use the nearby contract to analyze crop reports on grain prices. They argued that the nearby contract shows greater liquidity and volume at maturity because it reflects the price impact of both old and new crop information.

Lehecka *et al.* (2014) affirmed that the nearby contracts allow an accurate measure of the market response to the USDA announcements since they are the most traded and liquid contracts. Indriawan *et al.* (2021) also chose the nearby contracts. The preference for this preference is related to attractiveness and liquidity. Shang *et al.* (2018) focused on the nearby contracts because they were the most liquid, allowing a more precise assessment of the market response to USDA announcements. Therefore, we understand that liquidity tends to be higher in nearby contracts, aligning with EMH, where prices reflect all available information. In contrast, longer-term contracts may have lower liquidity, and their prices might not adjust as rapidly to new information. However, they can still be considered efficient to the extent that they reflect all available information up to that point. In the next section, we present the economic modeling of the Efficient Market Hypothesis (EMH).

3.3 Expected return or "*Fair Game*": Without abnormal gains or losses

Capital markets play a crucial role in the economic development of a country by directing savings into investment resources. This mechanism provides signals for securities pricing, which should always accurately reflect the information within the economic system (FAMA, 1970). The most usually accepted and employed definition of market efficiency is the one proposed by Roberts (1967) and developed by Fama (1970, 1991). The Efficient Market Hypothesis (EMH) posits that asset prices incorporate all available market information.

Fama (1970) presents that future prices (t_{+1}) absorb all available information at time *t*. Assuming that returns are random variables, and their distributions are close to

normal. Fama's (1970) model can be written as Equation (1):

$$E\left(\tilde{p}_{j,t+1}\middle|\Phi_t\right) = [1 + E\left(\tilde{r}_{j,t+1}\middle|\Phi_t\right)]\, p_{j,t} \quad (1)$$

where E is the expected value; $p_{j,t}$ is the price of commodity j at time t; $p_{j,t+1}$ is the commodity j price at t + 1; $r_{j,t+1}$ are the commodities prices return in one period $[(p_{j,t+1} - p_{j,t}) / p_{j,t}]$; Φ_t is a general symbol for whatever set of information at *t* time; and the tildes indicate that $\tilde{p}_{j,t+1}$ and $\tilde{r}_{j,t+1}$ are random variables at *t+1*.

The EMH assumes that the possibility of achieving returns higher or lower than the current return in an efficient market does not exist. This only occurs in isolated and random instances. In such cases, buying or selling the asset would cause its price to adjust to the true market value. This implies that an efficient market is *a Fair Game*, as Equation (2):

$$z_{j,t+1} = r_{j,t+1} - E\left(\tilde{r}_{j,t+1}\middle|\Phi_t\right)$$
$$E\left(\tilde{z}_{j,t+1}\middle|\Phi_t\right) = 0 \quad (2)$$

Where z_j is sequential of *"Fair Game"* concerning the information Φ_t. The $\left(\tilde{z}_{j,t+1}\middle|\Phi_t\right)$ = 0 implies that investors have no opportunities to win or lose based on information at *t*. At *(t + 1)* there will be a set of information $\alpha_i(\Phi_t) = [\alpha_1(\Phi_t), \alpha_2(\Phi_t), \ldots, \alpha_n(\Phi_t)]$ available for time *t*. Fama (1970) expresses the net market value at *(t+1)* based on a summary of transactions conditioned on the set of information $\alpha_i(\Phi_t)$, as in Equation (3):

$$V_{t+1} = \sum_{j=1}^{n} \alpha_j(\Phi_t)\left[r_{j,t+1} - E\tilde{r}_{j,t+1}\middle|\Phi_t\right] \quad (3)$$

since in a *Fair Game*, there are no possibilities of gains different from what is expected, as expressed in Equation (4):

$$E(\tilde{V}_{t+1}|\Phi_t) = \sum_{j=1}^{n} \alpha_j(\Phi_t) E\left(\tilde{z}_{j,t+1}\middle|\Phi_t\right) = 0 \quad (4)$$

in Equation (4), $(\tilde{V}_{t+1}|\Phi_t)$ represents the summary of expected net market values at time *(t + 1),* where $\{[r_{j,t+1} - E\tilde{r}_{j,t+1}|\Phi_t] = E(\tilde{z}_{j,t+1}|\Phi_t) = 0\}$, ensuring that the excess is zero conditional on $\alpha_i(\Phi_t)$. This means that there is no excess in price formation in this market. It leads to a *Fair Game*, in which investors face neither an advantage nor a disadvantage. Essentially, this suggests that no participant possesses an unfair edge in making investment decisions. All investors share access to the same publicly available information, ensuring an equitable foundation for making well-informed decisions.

We can observe that the (EMH) is integrated into our study, as we aim to determine whether the cattle futures market is efficient in a semi-strong form. All the reports we have used originate from public sources. Then, mathematically, we have Equation (5):

$$BGI_{t+1} = r_{BGI\,t+1} - E(\tilde{r}_{BGI,t+1}|\Phi_t) = 0 \quad (5)$$

where BGI_{t+1} it is the excess market value of live cattle futures price in period t+1, $r_{BGI\,t+1}$ it is the return observed in the market and $E(\tilde{r}_{BGI,t+1}|\Phi_t)$ its expectative condicionate a set of information. As we are in a Fair Game, this excess will equal zero. Meaning that what was observed in the market was precisely as expected. Emphasizing that various types of information influence asset prices, such as past prices, future earnings, volatility, financial analysis, reports releases, economic variables, and political factors. Then, we understand that Φ_t has information about reports.

Two accepted methods for testing the EMH are the martingale and random walk. Both are considered fair games. A model that describes price formation as an unbiased random process is called the Martingale (Samuelson, 1965). In financial markets, past price movements do not provide helpful information for predicting future price movements (Samuelson, 1965).

The Random Walk model relies on two distinct hypotheses: a) the current security price reflects all available information, indicating that price movements over time constitute a series of random numbers (serial correlation equal to zero); b) price changes follow the same probability distribution (Fama, 1965).

The methodology most used to verify the semi-strong form is the Event Study. It involves analyzing how the prices of assets react before, during, and after the Event Study in question. In our study, the Event Study in question is the public report releases. The details are presented in Methodology, section 4.

3.4 Limitations of the EMH

As with any theory, there exist limitations. The Efficient Market Hypothesis (EMH) has faced significant critique regarding the notion of a random process. One of the criticisms concerns the rationality of market participants, known as the *Behavioral Anomalies*. Some authors argue that not all market participants are rational many act on intuition and emotion (Latif, 2011; Gokhale *et al.*, 2015; Sattar *et al.*, 2020). Behavioral anomalies and emotional biases can lead to market inefficiencies (Shiller, 2003).

Investors can exhibit irrational behaviors and overreact to new information, whether good or bad, creating opportunities for abnormal gains. Then, psychological factors can lead to irrational behaviors and impact asset prices, often resulting in volatility and market movements that fundamental analysis cannot fully explain (Gokhale *et al.*, 2015; Goodell, 2023 *et al.*).

Transaction costs are also viewed as another critique of the EMH. In the real world, transaction costs exist, such as brokerage commissions and taxes. It can affect the speed at which information is incorporated into prices (Alajbeg, 2012). If transaction costs are high, it may take longer for information to be fully reflected in prices, potentially creating opportunities for investors to exploit mispricings before they are corrected (Naseer, 2015; Svogun, 2022). These actions contradict the underlying assumptions of the EMH.

In the real world, private information is not universally accessible to all participants. Insiders and institutions with access to non-public information may have an advantage, which contradicts the EMH assumption of equal access to information (Mustafa, 2020). Other forms of information asymmetry exist, such as manipulation and market friction. Information is not always evenly distributed, and some investors may have better access to information, creating information asymmetry (Bouattour, 2019; Di Toro, 2022).

According to Damodaran (2001), when relevant information is released, the market can behave in three different ways: a) react immediately to the disclosure (confirming the semi-strong efficiency hypothesis) b) react gradually, with a gradual price increase or decrease following the disclosure, allowing investors to engage in arbitrage until complete adjustment occurs. c) prices in the market react instantly to the disclosure but inappropriately, with correction taking place in the following days. So,

there can be delays in incorporating new information into asset prices, especially in less liquid markets (Malkiel, 2003).

Lastly, some authors have initiated discussions on calendar anomalies, asserting that specific events can disqualify prices from being entirely random (Samuelson, 1965; Milonas, 1991; Karali, 2012; Qadan *et al.*,2021). A calendar effect refers to a recurring and predictable pattern or anomaly in financial markets associated with specific times of the year (Ariel, 1987). These patterns often repeat annually and can be observed in asset prices, future markets, trading volumes, or other metrics. Calendar effects suggest that market participants may exhibit certain predictable behaviors during these periods, which contradicts the EMH (Osborne, 1962). Common examples of calendar effects include:

- **January Effect:** The January Effect is a calendar effect where stock prices tend to rise in January. This phenomenon is often attributed to tax-related selling in December, followed by buying in January as investors reallocate their portfolios (Wachtel, 1942; Rozeff and Kinney, 1976; Fama, 1991)[12].
- **Holiday Effects:** Markets can exhibit abnormal behavior around holidays, such as increased trading volumes before major holidays or lower trading activity during holidays (Ariel, 1987; Osborne, 1962).
- **Turn-of-the-Month or Maturity Effect:** Some studies have shown that stock returns tend to be higher around the turn of the month when investors receive dividends or when mutual funds reallocate their portfolios (Ariel, 1987; Lakonishok and Smidt, 1988).
- **Month-of-the-Year Effect:** This comprehends patterns associated with specific months, where some investors reduce their equity exposure during some months (Shahriar, Bubnys; 1992).
- **Weekend day Effect**: suggests that stock returns tend to exhibit certain patterns related to the days of the week, particularly the difference in returns between weekdays (Monday through Friday) and weekends (Saturday and Sunday). In many studies, researchers have observed that stock returns on Mondays, especially in the morning, are historically lower on average compared to other weekdays (Osborne, 1962; Cross, 1973; Lakonishok and Levi, 1982; Gibbons and Hess, 1981).

[12] This effect is observed in the stock market; therefore, it won't pose an issue for our estimations.

It is important to note that calendar effects do not always hold. These effects vary across different assets, markets, and countries. Some anomalies may not be present in agribusiness studies, as they differ from stocks (Karali, 2012; Qadan *et al.*,2021; Massa *et al.*, 2021; Indriawan *et al.*, 2021). We outline the anomalies that could potentially exist in the Brazilian Live Cattle futures market and detail our strategies in the next section.

4. Methodology

In this section, we introduce the mapping information strategy along with statistical and econometric tools. Our goal is to access public information channels within the livestock market. Then, we select the most suitable ones for our study (further explained in the section). Afterward, we identify the effects of these publications on the future returns of live cattle prices.

As we are dealing with information in a highly digital market, our strategy involved accessing various electronic sources for information about the cattle market. To achieve this, we focused on five specific categories: i) Homepages of Agricultural Associations and Cooperatives; ii) Websites and Online Platforms; iii) Livestock Auction Platforms: iv) Public Analysis Reports; v) International sources of information. In this way, we have mapped most of the information available in this market.

As presented in section 3.0, under the Market Efficiency Hypothesis, futures prices are construed as the conditional expectation of spot prices at contract maturity. Over the years, researchers have applied Event Study methodology using cumulative abnormal returns (CAR) or the GARCH (Generalized Autoregressive Conditional Heteroskedasticity) model to verify the effect of announcements on commodity futures volatility (Karali *et al.*, 2019; Isengildina-Massa *et al.*, 2021, Sun and Wen, 2023).

As mentioned earlier, our study intends to verify the effect of a livestock announcement on the live cattle futures price returns. As the social benefits are not directly observable, one way to answer these questions is to examine the behavior of future returns given a change in the information in the reports (Huang *et al.*, 2021).

Then, the best choice for us is to apply Event Study, as it allows us to investigate the impacts of news announcements on asset values (Bowman,1983; Jacobs *et al.*, 1988; MacKinlay, 1997; Kolari *et al.*,2018; Heyden *et al.*, 2021; Xie *et al.*,.2022; Foerderer *et al.*, 2022). We also use the Event Study methodology to search for the cumulative abnormal returns (CAR). Also, we estimate the conditional volatility model (GARCH) to gather volatility spikes on daily data.

This section is subdivided into three subsections, each related to the specific objectives outlined in section 1.5. Thus, in section 4.1, we describe the strategies used to search for information in the cattle market. In 4.2, we present detailed procedures for applying the Event Study. With the aim of investigating whether the information mapped in 4.1 alters the expectations of BGI returns, we introduce an application of the

CAR method. Finally, in 4.3, we seek to apply the GARCH model to identify unexpected changes in BGI market volatility.

4.1 Search the Brazilian live cattle market information

To identify whether the information contained in agricultural reports alters the dynamics of the live cattle market, it was necessary to gather relevant information sources. From this collection, we were able to develop specific criteria for selecting the reports to be analyzed. Then, to achieve our first objective of searching the private and public information of the Brazilian beef market, we conducted a document analysis of these sources.

Document analysis is a qualitative research method that involves the systematic review and interpretation of documents to extract relevant information, understand contexts, and generate insights. These documents can be of various types, including official reports, academic articles, government documents, historical records, media publications, among others (Lendel and Varmus, 2011). This approach facilitated the systematic collection and analysis of pertinent information (Siegner *et al*., 2018).

Our strategy to identify primary sources of information involved analyzing each phase of the cattle cycle and identifying relevant livestock reports. However, we ensured that the documents gathered were officially recognized. According to Siegner *et al*. (2018), a document is a written statement officially recognized as proof of an event, fact, or status, such as certificates and contracts. It also encompasses data files generated by word processors, such as electronic reports and digital files (Jemna, 2016).

Therefore, we collected the documented information from the sources made available by the Centro de Tecnologia da Carne Bovina (CiCarne), which summarizes the main electronic resources available for data and information retrieval in this market. We systematically categorized the market into five groups of information: i) Homepages of Agricultural Associations and Cooperatives; ii) Websites and Online Platforms; iii) Livestock Auction Platforms; iv) Public Analysis Reports; v) International sources of information. We present various public, semi-public, and private sources in each group.

Given the quantity of documents gathered, it was necessary to establish criteria for selecting the documents to be analyzed in this study. We developed three criteria aligned with the research objectives: i) publicly available information, ii) national

source, and iii) proprietary source. We selected proprietary sources to indicate our intention to analyze information from public institutions that collect and publish the data. For example, we excluded from our empirical analysis open-source websites that rely on third-party information for dissemination.

4.2 An Event Study application for the Brazilian live cattle futures market

In this subsection, we outline the step-by-step execution of the Event Study proposed by Campbell, Lo, and MacKinlay (1997).

4.2.1 Definition of an Event Study: The first step

The Event Study methodology finds extensive application in financial and economic studies. It functions as a valuable tool for assessing the impact of a particular event on the value of a financial instrument or market performance. The methodology involves gathering data on price returns of the financial instrument both before and after the selected event. Subsequently, a statistical analysis is employed to determine whether the event significantly influenced the price of the financial instrument (Campbell, Lo, and MacKinlay, 1997).

Examples of events include the publication of corporate reports, announcements of mergers and acquisitions, regulatory decisions, agribusiness announcements, interest rate changes, and other relevant macroeconomic events. Our study centers on the release dates of three significant reports: *AgroMensal* (CEPEA, 2023) and *Agromensal* (CONAB, 2023), both with monthly frequency, and Pesquisa de Abates (IBGE, 2023), which has quarterly disclosure. From this, we delineate estimation and event windows. The estimation window comprises returns from the days preceding the report's release. In the event window, we observe returns on the actual day of the report's release.

In practical terms, the Event Study window covers one day prior to and one day after the Event Study. This extended is designed to capture any information leaks. Additionally, given that certain reports are released after regular trading hours, the actual influence of this information on prices may not be evident until the subsequent day (Campbell, Lo, and MacKinlay, 1997). This approach can influence well-informed decision-making, providing insights into how specific events impact the market and influence the prices of financial instruments (Karali et al., 2019; Isengildina-Massa, 2021).

Fama (1970) was among the pioneering authors to undertake an Event Study, even though he was not the first to publish it. His empirical study showcased the efficiency of market prices, providing supporting evidence for the semi-strong form of the Efficient Market Hypothesis (EMH). However, it was Campbell, Lo, and MacKinlay (1997) who played a key role in popularizing the presentation and utilization of Event Study studies.

According to Kothari and Warner (2007), there are two main reasons to apply the Event Study methodology. One is corporate: the company can make decisions based on the abnormal responses observed during an Event Study and then take measures to safeguard the firm's wealth. The other serves to test market efficiency. If abnormal returns persist after an announcement, it can allow for the execution of unfair operations in the market. Being inconsistent with the EMH. The most general form of the null and alternative hypotheses is represented in Equation (6).

$$\begin{cases} H_0: f(R_{BGI}|I_t) - f(R_{BGI}) = 0 \; for \; all \; I_t \\ H_A: f(R_{BGI}|I_t) - f(R_{BGI}) \neq 0 \; for \; all \; I_t \end{cases} \quad (6)$$

where R_{BGI} is the return on BGI futures prices in an Event Study period of interest; I_t is a signal from information structure announced in the Event Study period that potentially affects BGI; $f(R_{BGI}|I_i)$ is the distribution of R_{BGI} conditional on the information signal I_t from information structure. Equation (6) shows that if the signal I_t possess relevant information, the distribution of the BGI returns conditioned on the I_t should differ from the marginal distribution.

4.2.2 The selection criteria: The second step

In this subsection, we explain the data. We use the daily returns of live cattle futures prices (BGI). We utilize the closing prices to calculate the returns of live cattle futures prices from January 2, 2017, to June 28, 2023 from the Brazilian Exchange. The literature states that the use of the closing price is the most recommended because it reflects all available information during trading hours and is assumed to represent the end-of-day value of the stock best (Harris, 1989; Berkman *et al.*, 2011; Jiahui Ying, Yu Chen, Jeffrey H Dorfman, 2019). Our study period covers a complete cycle of the cattle chain, which, according to EMBRAPA (2020), typically lasts between 5 to 6 years.

The BGI contracts outline the trading of male bovines, mandating a minimum weight of 16 net arrobas and imposing an age limit of 42 months. Each contract has a size of 330 net arrobas and is quoted in Brazilian reais per net arroba. Additionally, the maturity date for BGI contracts is scheduled for the last business day of each month (B3, 2023). We opted for the nearby contract, as detailed in section 3.0, as it better reflects the market dynamics and tends to be the most liquid.

The trading sessions of future markets on Brazilian Exchange B3 start at 9:00 a.m. and end at 4:30 p.m. Brasilia time for the "normal" market. The B3 also allows after-hours trading since not all market participants can act accurately during business hours. Therefore, the Exchange allows negotiations on the "aftermarket" between 5:05 pm and 6:00 pm Brasilia time. Our collected data corresponds to the “normal” market. The trades conducted in the after-market can be captured by close-to-close returns, which we adopted and explained in section 4.2.3.

Another relevant exchange in cattle market trading is the Chicago Mercantile Exchange (CME), which trades cattle contracts between Monday and Friday from 8:30 a.m. to 1:05 p.m. US Central Time (11:30 a.m. to 4:05 p.m. Brasilia time) for regular market hours. It also allows after-market trading from Sunday 5:00 p.m. to Friday 5:45 p.m. US Central Time (11:30 a.m. to 4:05 p.m. Brasilia time).

Regarding the reports, we utilize three different publications. Two are monthly, and one is quarterly. The goal is to analyze distinct points in time, and as these reports do not share the same information structure, one report may contain data do not present in the others. The monthly report "*AgroMensal*" from CEPEA encompasses information about prices, costs, market analysis, climate, and both national and international markets. This report is published by CEPEA, a public institution affiliated with the University of São Paulo (USP). While there isn't a specific release date, it is typically published in the first week of the month before 5:00 p.m.

The *AgroConab*, a mensal report released by CONAB, is also a public institution. It contains comparative prices of final stocks, information on the off-season, exports, and imports. It does not have a specific date for publishing, and it is commonly around the 15th and 20th of the month at 4 pm Brasília time. The public institution IBGE releases the "*Pesquisa Trimestral de Abates,*" a quarterly report about slaughtering animals such as heifers, cows, and bulls. The disclosure almost always occurs around the morning of the first week of each quarter. It is usually used for

interpreting the cattle cycle in the market. Through it, it is possible to identify whether the cycle is bullish or bearish.

Next, we proceed to establish the Event window. Since we have three different reports, each of them (*AgroCepea, AgroConab*, and *Pesquisa Trimestral*) will correspond to a distinct event. Selecting an Event Study window is crucial to avoid issues such as anticipation, information leakage, and the complete absorption of information (Beltratti and Paladino, 2013; Aspris *et al*., 2017; Bohmann and Patel, 2020). Additionally, if there is information leakage, the Event Study window may fail to capture the actual impact of the report. Moreover, different commodities may assimilate information at varying rates (Christiansen; Ranaldo, 2007; Karali, 2012; Isengildina-Massa *et al*., 2021). Therefore, the response may not be instantaneous to the report's release but could occur around minutes, hours, or even days. Following the literature (Mattos and Siqueira, 2015; Siqueira *et al.,* 2017; Karali *et al*., 2019; Massa *et al*., 2021), we use the following estimation and Event Study window as Figure (4):

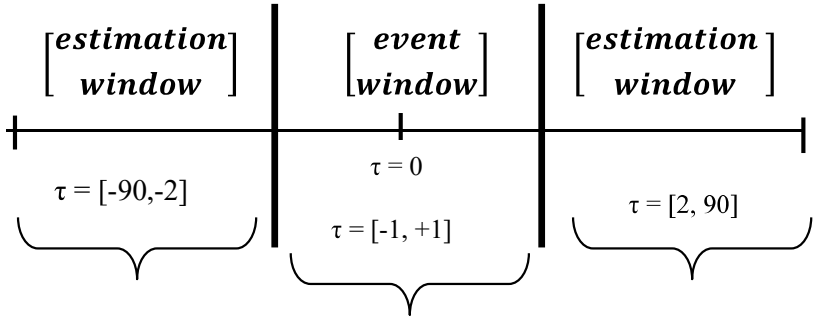

Figure 4: The Event Study outline

where τ=0 represents the release of the report, τ = [-90, -2] and τ = [2, 90] are the estimation window and τ = [-1, +1] the event window. Some literature uses -5 days after and +5 before (Karali *et al*., 2019; Isengildina-Massa *et al.,* 2021). Other uses the 1 day before and 1 after (Capraole and Plastun, 2021) or -7 days before and +14 after (Moghadam et al.,2013). This determination depends on the data frequency under consideration.

The literature argues that choosing between short and long periods is a tradeoff. In short intervals, the information may not be fully captured, while in long intervals, some noise may be introduced (Drienko and Sault, 2013; Caporale and Plastun, 2021).

Meznar *et al.* (1994) and Beitel *et al.* (2001) reduce the window size for [-1, +1] days to eliminate the effects of another Event Study that happens simultaneously.

Indeed, consensus on the optimal estimation window remains unclear. Peterson (1989) suggests that estimation periods should span from 100 to 300 days for daily studies and 24 to 60 months for monthly studies. Corrado and Zivney (1992) conducted statistical tests using pre-event estimation periods of 239, 89, and 39 days. Their findings indicated that the 89 and 39-day windows were insufficient to capture abnormalities, while the 239-day window was considered excessively large, potentially introducing irrelevant content into the analysis. Consequently, they advocate for an estimation window of approximately 100 observations. Ullah (2021) also explored various estimation windows, ultimately selecting the [-90, +90] window as the most suitable choice.

We opted for an estimation window of approximately [-90, +90] days. This choice was not only based on its use in the literature Ullah (2021) but also because it is close to 100, as recommended by Corrado and Zivney (1992). Furthermore, one of the reports analyzed has a quarterly frequency *(Pesquisa Trimestral)*. Therefore, to maintain consistency in the analyses, we chose this estimation window. For the event window, we kept it as [-1, +1] to avoid mixed information. Additionally, we included an analysis with the window [-3, +3] for a dataset providing weekly information. The aim is to identify if there is any abnormality during the week of the report.

- The "*Pesquisa Trimestral de Abates"* from IBGE is released in the first week of each quarter, meaning there are four publications in a year. Here, τ=0 signifies the release of *"Pesquisa Trimestral de Abates"*. The period from τ=[-90,-2] and τ=[2, 90] corresponds to the estimation window and τ=[-1, +1] the event window. Later, we modified the Event Study window to [-3, +3], covering three days before and three days after the release.
    - For the *AgroMensal* from CEPEA and *AgroConab* from CONAB, we use the same Event Study window, first with τ= [-1,1] and after τ= [-3,3] and τ= [-90, -2], τ= [2, 90] as the estimation window. It is not convenient to adopt a one-month estimation window because there are not enough observations to perform the statistical tests, and the interpretation would be not viable due to the lack of test power. We understand that the information published each month does not extend throughout the next month. For example, the information in

AgroMensal for May will be absorbed by the market in at most one week, considering the low liquidity of the Brazilian market. Therefore, its information will not influence agents' decisions in June since they know a new report will be released that same month. However, we still excluded reporting days from other months to avoid mixed information. For example, when analyzing the report released in February, disclosure days in January and March were omitted. This procedure was consistently applied throughout the entire sample.

4.2.3 Normal and abnormal returns: The third step

After establishing the estimation and the Event Study window, following the literature (Campbell, Lo, and Mackinlay, 1997; Moghadam; Schmidt; Grier, 2013), the next step is to calculate the abnormal returns. Abnormal return (AR) describes the difference between the actual return on an investment and the expected or average return. The expected return is typically estimated based on various factors, including the historical performance of the investment, market conditions, and relevant benchmarks or indices (Mackinlay, 1997). One way to analyze Event Study is by checking for cumulative abnormal returns (CAR). The strategy compares mean returns over the Estimation Window with returns over the Event Study window.

To make it more intuitive, imagine a normal day in the live cattle futures market. The market participants have their expectations, hedgers are trying to protect, speculators are taking risks, and arbitrators are taking advantage of gaps. The returns in those days in the market probably remain the same trend. However, a livestock report releases informed that the calf herd would be smaller than expected. In this case, the information arrived at alters the market participants because it differs from their expectations before the announcement. As a result, the returns on the day (and around it) may not follow the same trend as before. They can be abnormal.

In this way, if the returns on the announcement day differ from the average days when there was no announcement, the reports could affect prices (Mackinlay, 1997). We follow the literature (Karali *et al.*, 2019; Massa et al, 2021) and calculate the live cattle returns (RBGI) using closing prices. The $RBGI_t$ return series gives the daily price change at close from date $t\text{-}1$ to t, reflecting market reactions to livestock new information between the end of the trading sessions for two consecutive days (Isengildina-Massa *et al.*,2021).

To search for abnormal returns, first, we calculated the commodity return, as in Equation (7):

$$R_{BGI,t} = ln\left(\frac{BGI_t}{BGI_{t-1}}\right) * 100 \quad (7)$$

where BGI_t is the market closing price on date *t*; BGI_{t-1} s is the market closing price on the previous date *t-1,* and *ln* is the natural logarithm function. The $RBGI_t$ return series gives the daily price change at close from date *t-1* to t, reflecting market reactions to livestock new information between the end of the trading sessions for two consecutive days (Isengildina-Massa *et al.*,2021).

The estimation of abnormal returns is defined as the difference between the actual ex-post return of the live cattle returns minus the expected return, defined as in the following Equation (8):

$$\varepsilon_t^* = R_t - E(R_t|I_t) \quad (8)$$

where ε_t^* is the abnormal return (AR_t) of live cattle at time t, R_t is the realized log return of live cattle on period *t* (Equation 5) and $E(R_t)$ is the normal return for time *t*, and I_t t is the conditioning information for the normal performance model. There are some choices for modeling the normal return $E(R_t|I_t)$. The two more common are the constant mean return and market models.

In the first case, it assumes that the mean return of the live cattle is constant through time. On the second, it assumes a stable linear relation between the market return and the live cattle return (Mackinlay, 1997). According to Corrado (2010), the constant model may give a naive result, and a more sophisticated procedure uses the market model. Knowing that, we chose to use the second model as the following Equation (9):

$$E(R_t) = \alpha + \beta RM_t + \varepsilon_t \qquad with \qquad E(\varepsilon_t)\ var(\varepsilon_t) = \sigma_{\varepsilon_t}^2 \quad (9)$$

where RM_t is the market proxy or portfolio that, in our study, corresponds to the returns for the live cattle average prices of CEPEA/B3 spot prices, calculated and divulgated by Cepea[13]. Also, we use the S&P GSCI Live Cattle Index[14], calculated and released by

[13] Cepea publishes the average prices from five regional markets: *Araçatuba*, São José do Rio Preto, Bauru/Marília, Presidente Prudente, and Vale do Paraíba.

[14] Goldman Sachs Commodity Live Index considers the world production for the Weighting Method

Goldman Sachs Cattle Index. β α and $\sigma_{\varepsilon_t}^2$ are the parameters of the market model. We can see that the abnormal return is the disturbance term of the market model (MacKlinay, 1997). Substituting Equation (9) into Equation (8), we have the abnormal return in Equation (10) and (11):

$$\varepsilon_t^* = R_t - (\alpha + \beta RM_t + \varepsilon_t) \quad (10)$$

$$AR_t = R_t - NR_t \quad (11)$$

where AR represents abnormal returns, R_t the realized, and NR the estimated normal returns through the market proxy.

4.2.4 Estimation procedure: The fourth step

After we define the proxies and select the estimation model, we move on to the fourth step: conducting the estimation. We perform the estimation using the data within the estimation window. Typically, we exclude the day of the Event Study from the model estimation, as its inclusion could impact the expected behavior of the estimated parameters (Campbell, Lo, and MacKinlay, 1997). This subsection presents our estimation strategies since we have some limitations.

As we have two monthly reports, it is impractical for the estimation window to occur within only 30 days. Therefore, we aggregated data over three months and analyzed the report's impact. For example, to analyze the effect of the report released on Jun 28, 2023, our estimation window comprised the days from Apr 25, 2023, to Jun 18, 2023, totaling 92 days. We excluded the report days from previous months (04/23/2023 and 05/23/2023) from the sample to avoid potential changes in the expected estimations and so on for our entire dataset. We did not encounter this issue with quarterly data.

Our objective is not to verify the impact of a mix of information but to each report in isolation. Out of our sample, only the day 2023/06/23 coincided with the publication of two reports: the *AgroConab* report from CONAB and the *Pesquisa de Abates Trimestrais* from IBGE. We excluded this day from the sample. Eliminating the effects of another Event Study that happens simultaneously is challenging, making it difficult to determine the impact of one Event Study on returns. We follow Meznar *et al.* (1994) and Beitel *et al.* (2001) and reduce the window size for [-1, +1] days. The

authors mention that decreasing the estimation and Event Study window contributes to decreasing the bias of other information.

In the literature on Events Study for commodities prices, some authors have related the presence of the time maturity effect (Anderson, 1985; Fama and French, 1988; Irwin *et al.*, 1996; Adjemian, 2012; Dorfman and Karali, 2015; Ying *et al.*, 2019; McKenzie and Ke, 2021; Phan *et al.*, 2022). As maturity approaches, returns exhibit heightened variability, particularly towards the end of the period (Samuelson, 1965; Milonas, 1991; Karali, 2012; Qadan *et al.*, 2021).

Its phenomenon can give rise to a comparability issue, as the increased return variability near maturity can potentially overlap with the effects of the report. Samuelson (1965), who first analyzed the maturity effect, states that future price changes exhibit increasing variability as contract maturity nears. It occurs because, as maturity nears, the futures price is forced to react to any new information since, upon maturity, it must exactly equal the cash price (Milonas, 1991).

In most cases, futures return series are constructed, with contract rollover occurring about one week before maturity (Massa *et al.*, 2021). Following the literature, the returns around the maturity will be replaced for the second nearby contract price (Dorfman and Karali, 2015; Ying *et al.*, 2019; Massa *et al.*, 2021; Indriawan *et al.*, 2021). According to the literature, it is a way to avoid naïve comparisons with the maturity and announcement of abnormal returns (Dorfman and Karali 2015).

We suggest implementing a contract rollover strategy to mitigate the impact of maturity on live cattle returns calculations and ensure the integrity of comparisons between abnormal and normal returns. The Brazilian live cattle contracts expire every month on the last business day. We will execute a contract rollover strategy, transitioning from the close maturity contracts to the second nearby contracts.

There are other calendar anomalies in our Event Study. However, the literature addresses them using dummy variables. Therefore, strategies for handling these other anomalies will be presented in the 4.3 Section.

4.2.5 Testing procedure: The fifth step

After estimating abnormal returns, we move on to the testing phase. We will examine whether report days are statistically different from days without announcements. In this

case, H_0 (the null hypothesis) suggests that the Event Study has no impact on the behavior of returns.

Before conducting hypothesis testing, the abnormal returns (CAR) on the Event Study window must be calculated. Doing that, inferences become more robust (Mackinlay, 1997; Corrado, 2010). Hypothesis testing can be performed on both AR and CAR. However, tests exclusively for individual returns are not required for the analyses (Mackinlay, 1997).

Define CAR (τ_1, τ_2) as the sample cumulative abnormal return (CAR) from τ_1 to τ_2 where T1$\leq \tau_1 \leq \tau_2 \leq$ T2. The CAR from τ_1 to τ_2 is the sum of the included abnormal returns. As presented in Equation (12):

$$CAR_i(\tau_1, \tau_2) = \sum_{t=\tau_1}^{\tau_2} AR_{i,t} \qquad (12)$$

where, CAR_i represents the cumulative abnormal returns over the Event Study window $[\tau_1; \tau_2]$ for a report, *i* indicates; *t* is the period and $AR_{i,t}$ is the mean abnormal return for live cattle for a report *i* on period *t.*

To check whether normal and abnormal returns are statistically different, we follow the literature (Mackinlay, 1997; Moghadam *et al.*,2013; Moon *et al.*, Kočenda and Moravcová, 2018; 2020) and estimate the statistical parametric test, Z ~ N (0,1). We calculate the Z-score and compare it to a critical value from a standard normal distribution to determine whether the CAR is statistically significant at a chosen significance level (1%, 5%, and 10%). The Equation (13) presents the equation:

$$Z = \frac{CAR_{BGI}(\tau_1, \tau_2)}{var(CAR_{BGI}(\tau_1, \tau_2))^{\frac{1}{2}}} \qquad (13)$$

The formula for the Z-test for CAR typically involves comparing the observed cumulative abnormal returns to the expected returns under the null hypothesis (H0). Under the null hypothesis, live cattle reports have an insignificant impact on live cattle future returns. The cumulative abnormal returns will be nonnegative:

$$\begin{cases} H_0: No\ report\ impact\ on\ returns \\ H_A: Report\ impact\ on\ returns \end{cases}$$

4.3 GARCH estimations for the report's impacts on BGI prices returns

Another way to assess the impact of reports is by analyzing volatility. Commodities futures prices are conditional expectations of spot prices at contract maturity. When new information about some commodity alters the perceptions of many market participants about supply and demand conditions, it will likely increase volatility in futures prices. This heightened volatility arises as market participants adjust their expectations (Mattos *et al.*, 2015; Lana *et al.*, 2017; Kolari *et al.*,2018).

One limitation of Cumulative Abnormal Returns (CAR) is that it depends on estimating abnormal returns using a simple regression that assumes a normal distribution. However, financial returns present skewed distributions and nonlinear dynamics invariance, and these characteristics make the OLS regression inappropriate for those types of analysis (Yang and Brorsenm 1994). Greene (2000) affirmed that GARCH-type model parameter estimates are more efficient than OLS when the conditional second moment and the distribution of returns are leptokurtic.

Even our effort to minimize the bias of the CAR results can still be improved. Therefore, we consider it essential to analyze the Event Study by estimating volatility models. Checking the impact of livestock reports on Brazilian live cattle futures prices by means (CAR) and variance (GARCH) analysis promotes a complete Event Study analysis for our study.

The family models ARCH and GARCH treat the variance as fluctuating variables to be modeled, being adequate estimators of future return movements (Tsay, 1988; Garcia *et al.*, 1997). Mckenzie *et al.* (2003) conducted several simulations to analyze the Event Study with the constant, OLS, and GARCH models. Their results showed that the GARCH (1,1) was consistently the most powerful model.

The GARCH (p, q) is ideal for examining the effects of new information since it explicitly allows for capturing movements in both the mean and conditional variance of price. Thus, following the literature (Isengildina *et al.*, 2006; Adjemian, 2012; Karali, 2012; Karali *et al.* 2019; Isengildina-Massa *et al.*, 2020; Cao *et al.*,2022), we present the GARCH family model to achieve our goals.

4.3.1 An application of the GARCH model in the BGI daily returns on announcements and non-announcement days

An indication of the impact of the information is if the price volatility in the report's days is greater than average on non-report days. To investigate our third specific objective, we model a GARCH-M[15] by adding dummy variables to capture the effects of the reports, where 1 represents report days and 0 otherwise. The Equations (14) - (16) measure this:

$$R_{BGI,t} = \varphi x_t + \varepsilon_t \tag{14}$$

$$h_t^2 = \omega + \sum_{i=1}^{q} \alpha_i \varepsilon_{t-i}^2 + \sum_{j=1}^{p} \beta_j h_{t-j}^2 + \tau_1 D_{AgroMensal} + \tau_2 D_{AgroConab} + \tau_3 D_{PesquisaAbatesIBGE} \tag{15}$$

$$\varepsilon_t | I_t \sim N(0, h_t) \tag{16}$$

where RBGI*t* is the return of live cattle futures prices, *xt* is an exogenous vector of variables that includes the past realizations of R_{BGIt}, εt is a random error, *ht* is the conditional standard deviation of εt, and I_t is the information set φ, γ, ω , αi, βj, and τ are the unknown parameters[16] to be estimated, and *t* is a time index. Since our objective is to search for the impacts of reports on live cattle volatility, we added the effect of the report in the variance equation by including the dummy variables $\tau_1 PesquisaAbate$; $\tau_2 AgroConab$; $\tau_3 AgroCepea$ corresponds to the report's effects, one on days when reports are published and 0 otherwise.

One of the advantages of using GARCH models is that they enable the minimization of anomalies in the Efficient Market Hypothesis (EMH). The anomalies that we control are the Monday and Holidays effect and month seasonality. Recall that we have avoided the maturity effect by rolling over the contract.

For the month effect our goal was not to add seasonal dummies for every month of the year but only for those that exhibited some seasonal behavior. We calculated seasonal indices to determine which months might carry this component. The methodology adopted follows Hoffman (1998) and involves the use of the centered 12-month moving geometric mean, as described in Equation (17):

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[15] See Aradhyula, S. V., Kesavan, T., & Holt, M. T. (1992) for another example.

[16] To ensure a well defined process, parameters , ω, α, and β_i must be non-negative.

$$g_t = \frac{1}{12}(0.5X_{t-6} + X_{t-5} + \cdots + X_t + \cdots + X_{t+5} + 0.5\,X_{t+6}) \quad (17)$$

g_t represents the centered moving geometric mean in month t; X_t corresponds to the series for which we are constructing the indices, in our case, BGI; *t* denotes the month in which we center the mean. We centered this study in January 2022 and constructed indices for all variables.

We estimate the seasonal indices by dividing the variable X_t, in our case the BGI_t by its respective geometric mean (gt). Afterward, we plot a graph of the constructed indices. If the indices substantially differ from 1, being at least 5% above or below in some months, they will modify the trend value, indicating that the seasonal components affect the series (Soares *et al.*, 1991; Hoffmann, 1998; Parmezan and Batista, 2016).

Then our GARCH estimation changes to Equation (18) to (20):

$$RBGI_t = \varphi x_t + \varepsilon_t \quad (18)$$

$$h_t^2 = \omega + \sum_{i=1}^{q} \alpha_i \varepsilon_{t-i}^2 + \sum_{j=1}^{p} \beta_j h_{t-j}^2 + \sum_{k=1}^{4} \delta_k Day_k + \delta_l g_t + \tau_1 D_{AgroMensal} + \tau_2 D_{AgroConab} + \tau_3 D_{PesquisaAbatesIBGE} \quad (19)$$

$$\varepsilon_t | I_t \sim N(0, h_t) \quad (20)$$

the previous parameters and variables remain unchanged. We are adding Day_k as the dummy variables for each day of the week (1 for Monday and zero otherwise) and g_t as the dummy equal to 1 for the months indicated by the seasonal index and 0 otherwise and being δ_k are the unknown parameters.

4.3.2 An open-to-close CAR robustness analyses for the report's impact on returns in the Brazilian live cattle market

This section presents two alternative robustness approaches for CAR and GARCH estimations, drawing upon some of the models' limitations. Neither of our models enables the analysis of a causal effect. The principal challenge in CAR lies in confirming whether the report generated abnormal returns.

The choice of the Event Study window is fundamental to avoiding some problems, such as anticipation and information leakage (Beltratti and Paladino, 2013;

Aspris *et al.*, 2017; Bohmann and Patel, 2020). Hence, one strategy (described in the project) was added to the Event Study window a day before and after its publication. However, employing this strategy with daily data does not guarantee the elimination or reduction of bias. It is because shifting the Event Study window one day before publication can introduce returns contaminated by information from other markets (Beitel *et al.*, 2001; Liu *et al.*, 2020).

According to a seminal paper, Francis *et al.* (1992) assert that correctly calculating returns is essential because other market information can become mixed. Close-to-close return only considers an asset's closing price on consecutive days, disregarding price fluctuations during the day. It can fail to capture important information about intraday volatility Adjemian (2012).

Hence, if the report becomes available after the stock exchanges close, it is prudent to utilize close-to-open (overnight) returns. Alternatively, when reports get published during the market's trading hours, researchers typically prefer to test an Event Study using open-to-close (trading day) returns (Francis *et al.*, 1992). Mattos *et al.* (2015) employed this method to assess the report's impact on grains. Hence, to improve the robustness of our findings, we also incorporate this return metric as in Equations (21):

$$R_{BGI,t} = ln\left(\frac{oBGI_t}{cBGI_t}\right) * 100 \tag{21}$$

where oBGI_t is the open market price on date *t,* $cBGI_t$ is the market closing price on date *t,* and *ln* is the natural logarithm function.

4.4 Data

The future prices of the Brazilian cattle market are represented by the Future of Live Cattle with Financial Settlement (BGI), traded on the B3 and collected from BARCHART. Given that BGI has contracts for every month of the year, we chose to use the prices of the first open contract, with rolling based on trading volume. The market proxy "INDICATOR DO BOI GORDO CEPEA/B3" reflects spot market prices for lean cattle and was obtained from CEPEA. A second market proxy, the GSCI index for lean cattle, corresponds to a sub-index specific to the American cattle market and

was collected from BARCHART. The data used for analysis includes daily prices, starting on January 2, 2017, and ending on June 28, 2023.

The reports used as sources of information are disseminated by reputable institutions such as *Instituto Brasileiro de Geografia e Estatística (IBGE)*, *Centro de Estudos Avançados em Economia Aplicada - CEPEA Esalq/USP (CEPEA)*, and *Companhia Nacional de Abastecimento (CONAB)*. IBGE provides quarterly information, covering data on the number of animal slaughters in Brazil, including cattle and cows, and indicating the phase of the cattle cycle. These reports were directly collected from IBGE. On the other hand, AgroCepea, with monthly periodicity, offers data on spot prices for cattle and calves, as well as information on domestic and international demand, obtained from CEPEA. This report also explains market fluctuations. AgroConab, also with monthly frequency, encompasses information on prices and exports, collected from CONAB. It is important to note that all the analyzed reports are from national public sources, collected and processed by the sources themselves. In total, 27 reports from IBGE, 46 from CEPEA, and 14 from CONAB were considered. It is emphasized that CONAB started disclosing market information from 2021, and during the election campaign period from September to December, reports were not released.

5. Results

5.1 Search for the Brazilian live cattle market information

This section presents the study's results to investigate the information channels in the live cattle market in Brazil. The first of our objectives is to map the information on the Brazilian live cattle market. We aim to present various sources of information that provide data on prices, actualization on cycles, importation, exportation, basis prices, and the number of herds in the Brazilian cattle market. By examining these information channels, we expected to gain insights into the market dynamics and assess their impact on market participants' decision-making processes (Isengildina-Massa *et al.*, 2016; Alturki and Kurov, 2021; Huang *et al.*, 2021).

One of the most significant challenges we faced in writing this thesis was the search for relevant and unprecedented information. It is essential to understand that the novelty of the information enables the testing of the market efficiency hypothesis. The literature studies we cited relied on USDA announcements, the most reliable and original source of information on commodity markets much awaited by national and international market participants.

In the case of Brazil, we found a different scenario. While several government agencies and institutions are responsible for providing information, they often disseminate it in a raw form, as seen in the cases of SECEX and IBGE. Initially, this information may be a conglomerate of numbers and values that may not provide any knowledge effect to the reader. That is why many news agencies work on interpreting this data according to the Brazilian and global context.

Some public reports incorporate processed data from both third-party sources and their sources, such as CEPEA and Conab's AgroMensal. However, these reports are limited by the delay in information processing, as it takes time to transform raw data into comprehensive reports. That is where private reports can hold an advantage, as they can promptly process and disseminate this information to their subscribers.

Unfortunately, we did not have access to reports from private agencies. Although news agencies, especially those specializing in agribusiness, analyze data and provide interesting information, it is impossible to determine whether the information in these texts is new compared to private sources.

Challenged with the prevailing situation, an extensive "field research" initiative was launched to engage industry producers from both public and private enterprises and to gather information from slaughterhouses, despite encountering challenges. Initial contact was made with public agencies such as EMBRAPA Gado de Corte and EMBRAPA Gado de Leite, CEPEA, and CONAB through telephone calls and email. Additionally, a technical visit to EMBRAPA Gado de Leite, situated in the municipality of Coronel Pacheco in Minas Gerais, was conducted to acquire information and insights into the initiation of the cattle cycle, starting with the birth of calves.

Upon completing the field research, the subsequent step involved an in-depth examination of electronic information sources to evaluate the study's hypothesis, which suggests a correlation between agricultural reports and future live cattle prices. The process entailed systematically mapping data from existing public reports, noting their frequency in days and hours. Each report's objectives, shared information, and distinctive elements were thoroughly assessed. The resulting compilation categorizes these online resources into sections, including public and private reports, association and cooperative pages, and websites featuring agricultural content.

1) **Homepages of Agricultural Associations and Cooperatives:** serve as essential information channels in the live cattle market. These organizations often provide market reports, including information on cattle prices, supply and demand dynamics, and industry updates. Market participants can access these homepages to stay informed about market conditions and make informed decisions. We selected these principals' homepages of agricultural associations and cooperatives:

i) **Confederação da Agricultura e Pecuária do Brasil (CNA) (www.cnabrasil.org.br):** Aims to represent, organize, and strengthen Brazilian rural producers. It also advocates for their rights and interests, promoting the economic and social development of the agricultural sector (CNA, 2023). Its webpage features a news channel. However, the focus is primarily on highlighting CNAs' activities in various sectors and their involvement in influencing government departments and ministries to protect the interests of producers (CAN, 2023).

ii) **Associação Brasileira das Indústrias Exportadoras de Carnes (ABIEC) (www.abiec.com.br):** is a prominent industry association representing Brazilian meatpacking companies exporting beef and other meat products. ABIEC works closely with government agencies to advocate for policies that support the growth and competitiveness of the meat industry in Brazil. The association also emphasizes the importance of promoting the quality and safety of Brazilian meat products in international markets to build consumer trust and confidence. Once a year, between May and June, ABIEC releases a report rich in information on the bovine market. It is a public report with its own and government sources, such as IBGE. The reports were essential for this thesis's beef chain history section (ABIEC, 2023).

iii) **Associação Brasileira de Frigoríficos (ABRAFRIGO) (https://www.abrafrigo.com.br/)** is a prominent industry association representing Brazil's meatpacking companies. ABRAFRIGO plays a crucial role in advocating for policies that support the growth and competitiveness of the meatpacking sector in Brazil. It collaborates closely with government agencies, industry stakeholders, and international organizations to address challenges and opportunities within the meatpacking industry. It also focuses on animal health, food safety, and compliance with international standards to ensure the quality and safety of Brazilian meat products for export markets (ABRAFRIGO,2023).

iv) **Federação das Associações Rurais do Estado de São Paulo FAESP and, Fundo de Desenvolvimento Da Pecuária Do Estado De São Paulo – FUNDEPEC-SP (www.faespsenar.com.br).** This website explicitly covers agricultural and livestock unions in São Paulo. It provides daily news updates from various sectors, including grains, beef cattle, dairy cattle, environment, and fruit farming. The website also offers training courses in these fields. While the site presents some price indicators, its source primarily comes from Cepea (FAESP, 2023).

v) **Associação Brasileira do Agronegócio (ABAG) (https://abag.com.br/associadas/):** It is an association that brings together

all links in the value chain, from the field to the industry, distribution, and services, playing a crucial role in strengthening the agro-industrial system and fostering relationships with the government, private sector, professional organizations, and educational institutions (ABAG, 2023). As examples of members, we can mention prominent organizations such as Embrapa, Bayer, Yara, Cargill, and Coaxupe. The website does not provide precise information about the bovine sector, although it presents some news. Its primary objective is to showcase its actions with ministries and secretariats in Brazil to its members and cooperatives as the CAN (ABAG, 2023).

vi) **Associação Brasileira de Supermercados (ABRAS) (www.abras.com.br):** aims to bring wholesale supermarkets together and inform them about the sector. It also provides courses and addresses supermarket management strategies. What is interesting about our study is that the webpage presents categorized information, including a category for meats that encompasses beef. Additionally, the association creates an Abrasmercado index that tracks the fluctuations in Brazilian household consumption and expenditure, with beef being one of the index's components (ABRAS,2023).

2) Websites and Online Platforms: Websites and online platforms dedicated to the Brazilian cattle market are prominent sources of information for market participants. These platforms offer comprehensive data on cattle prices, trends, and market analyses. Major agricultural news portals, industry associations, and government agencies maintain websites that provide real-time updates on market conditions, including price fluctuations and market news. These platforms also offer historical data, allowing users to track market trends and conduct analyses.

i) **BeefPoint (www.beefpoint.com.br):** is a leading online portal that provides news, market analysis, and information about the Brazilian beef industry. It covers topics such as cattle prices, production, and industry trends. It is an example of a site that compiles raw indicator information. Beefpoint uses

information from third-party sources, such as CEPEA, B3, DATAGRO, Valor Econômico (BeefPoint, 2023).

ii) **Scot Consultoria (www.scotconsultoria.com.br):** operates as a reputable consulting and market intelligence company focusing on the Brazilian livestock sector. The website offers market reports, analysis, and price information related to cattle and beef. It is a semi-public source of information, offering a significant amount of data for free. However, it features two reports with limited access available only to subscribers, "Tem Boi na Linha," published daily around 12h, and Boi&Cia, a weekly report; unfortunately, the precise disclosure time for Boi&Cia was not disclosed to us. Scot Consultoria relies exclusively on self-sourced information and abstains from using third-party data. The company collects, processes, and disseminates information, serving as the primary source for its reports. Initially, this information is disclosed exclusively to its subscribers, and subsequently, specific details, like price quotations, become publicly accessible (Scot, 2023).

iii) **Nelore.org (www.nelore.org.br):** is dedicated to the Nelore breed of cattle, one of Brazil's most prominent beef cattle breeds. The website provides information about breed standards, genetics, and events related to Nelore cattle (Nelore Org, 2023).

iv) **Boi Na Linha (www.boinalinha.com.br):** is an online platform specializing in cattle auctions and trading, enabling users to explore future cattle auctions and access market information. It operates as a company partnered with the public ministry to conserve the Amazon, thoroughly observing the eradication and monitoring of slave and child labor. Its information is concentrated in the North region and is not sourced from third-party platforms.

v) **Portal DBO (www.portaldbo.com.br):** It is a semi-public information portal focused on the Brazilian agribusiness sector. It covers various aspects of the cattle market, including news, technical articles, and market analysis

expert insights, incorporating data curated from reputable sources like Cepea. Additionally, they have proprietary information exclusive to their platform. However, to have access to this information, a subscription is necessary. The DBO represents the initials of the names of the brothers who founded the company, Daniel Bilk e Odemar (DBO, 2023).

vi) **Datagro (www.datagro.com/)** is a private company that provides agricultural market intelligence and analysis. It collects and analyzes data from various sources, including official government agencies, industry associations, and private entities. Datagro processes the data and offers valuable insights, reports, and forecasts, highly regarded by professionals and stakeholders in the agricultural sector (Datagro, 2023).

vii) **Rural business (www.ruralbusiness.com.br)** operates as a private agency to subscribers with exclusive access to strategic information concerning agriculture and livestock. The content available on the platform is entirely proprietary and sourced exclusively by Ruralbusiness, which maintains a policy of non-interference from buyers, sellers, governments, or any other external entities or agencies. This approach ensures the integrity and independence of the information provided to its privileged subscribers (RuralBusiness, 2023).

viii) **Agrolink (www.agrolink.com.br)** is an online platform in Brazil that provides agricultural information, news, and resources to farmers, agribusiness professionals, and stakeholders in the agricultural sector. The platform covers a wide range of topics related to agriculture, including crop cultivation, livestock, agricultural technology, market prices, weather updates, and industry trends. The site uses its own and third-party sources, such as Embrapa, Scot, and Cepea, to compose its news. In addition, the site features exclusive content for subscribers (Agrolink, 2023).

ix) **Agromove (www.blog.agromove.com.br/)** is a startup that provides a tool platform that delivers the price trend and the probability of a fall or rise in

the arroba of the cattle, the calf, and the prices of corn and soybeans. The platform can find the best time to buy or sell the inputs the producers and farms need, but unfortunately, it is private (Agromove, 2023).

3) **Livestock Auction Platforms:** Livestock auction platforms are another critical channel for obtaining market information. These platforms facilitate the buying and selling of cattle through online auctions, providing participants with real-time price data and transaction details. Market participants can track recent auction results, assess price trends, and evaluate market sentiment.

   i) **Pecuária.com.br (www.pecuaria.com.br)**: an online marketplace dedicated to the Brazilian livestock industry. It offers livestock auctions and advertisements for buying and selling cattle, horses, and other livestock.

   ii) **Correa da Costa (www.correadacosta.com.br/):** is a Mato Grosso do Sul company at Campo Grande. It aims to facilitate the purchase and sale of livestock production, permanently offering good business options to the market.

   iii) **Canal do Boi (www.sba1.com/)** offers a wide range of programming related to the livestock sector, including discussions on agricultural practices, market trends, industry insights, and expert opinions. It plays a crucial role in connecting farmers, ranchers, livestock traders, and other stakeholders in the cattle industry, fostering communication and knowledge exchange within the community. The channel's dedicated coverage of livestock auctions is particularly beneficial for buyers and sellers, as it allows them to access real-time information on prices and make informed decisions.

4) **Public Analysis Reports:** Research firms, financial institutions, and universities produce reports and publications that offer detailed insights into market trends, price forecasts, and analysis of supply and demand dynamics. These reports often incorporate statistical models, economic indicators, and expert opinions, providing valuable information to market participants. We seek

to test our hypothesis directly with this information channel. The bovine market, although not as liquid as soy or corn, contains different sources of information. However, understanding who primarily holds the information, whether public or private entities, is impossible.

i) **Pesquisa Trimestral de Abate de Animais (https://www.ibge.gov.br/estatisticas/economicas/agricultura-e-pecuaria.html):** The IBGE collects and disseminates a wide range of data, including agricultural and livestock statistics. The "Pesquisa Trimetral de Abate de Animais" is a quarterly report crucial for tracking the production and supply of meat in the country and is an essential resource for market analysts, researchers, and policymakers. When the IBGE releases these surveys, it does not take long for the media to process and report the survey results in more detail. That is because this report informs how the livestock cycle is in Brazil. It contains information on the slaughter of matrices, the number of animals in pasture, and the offer of calves. Based on this information, the market tends to move by tracing its strategies. The survey is released every three months, starting in March, around the second week (ABIEC, 2021; IBGE, 2022).

ii) **Cepea Agromensal (https://www.cepea.esalq.usp.br/br):** is a monthly publication by CEPEA that focuses on economic analysis of the agricultural sector. The publication includes market analysis, price trends, and other relevant information on various agricultural commodities, including grains, livestock, and other products. However, it is released in a very faithful periodicity, in the first week of each month. There is a limitation in this report. It was released with a delay of one month. Thus, the Agromensal for October, for example, contains information about September.

iii) **Secretaria de Comércio Exterior (Secex) (http://comexstat.mdic.gov.br/pt/home):** is an agency under the Brazilian Ministry of Economy responsible for managing and regulating

foreign trade activities in Brazil. It supervises the country's imports and exports, ensures compliance with international trade regulations, and promotes foreign trade policies. Regarding live cattle exports, Secex regulates and monitors trade to ensure compliance with international trade regulations and sanitary requirements. Secex collaborates with relevant government agencies, such as the Ministry of Agriculture, Livestock, and Food Supply (MAPA), to ensure that exported animals meet the necessary health and safety requirements. It is a rich database but with high difficulty of understanding. The data presented does not suffer any processing. Reports and agencies work on this data to make it more understandable. However, it is impossible to determine if the private reports present the information upfront to their subscribers.

iv) **Instituto de Economia Agrícola (IEA) (www.iea.agricultura.sp.gov.br):** is a vital research institution that operates in São Paulo. It conducts economic analysis and research related to agriculture and rural development in São Paulo. The institute generates valuable information, data, and studies to support policymakers as agricultural and rural statistics related to crop production, livestock, land use, and agricultural inputs. It also provides market analysis and price monitoring for various agricultural commodities, helping farmers and policymakers understand market trends and dynamics. A considerable portion of the information is provided free of charge. Nevertheless, the IEA offers subscription-based information, such as historical prices, specialized web services, and electronic yearbooks.

v) **Instituto Mato-Grossense de Economia Agropecuária (IMEA) (www.imea.com.br):** is an important research institution based in Mato Grosso, Brazil. The institute provides market analysis and price monitoring for various agricultural commodities pr Mato Grosso, including soybeans, corn, cotton, cattle, etc. The institute produces reports and publications focusing on the agribusiness sector, offering

insights into its regional and national economic contributions. IMEA provides an important report for our research. The "Bovino Cultura de Corte" is a weekly report published every Monday at 5:00 PM Brasilia time. The information comes from IMEA's sources, presenting the basis differential, animal slaughter, and market insights for both domestic and international markets provided by specialists. Although it provides information specific to a particular state, Mato Grosso, the report also includes comparisons with other states, such as São Paulo. Additionally, Mato Grosso is a benchmark in this sector, being the largest Brazilian state for cattle breeding (IBGE, 2022).

vi) **Companhia Nacional de Abastecimento (Conab) (www.conab.gov.br)**: in Brazil The Conab Agromensal report offers comprehensive data and analysis on various agricultural commodities, including grains, oilseeds, and livestock. It provides insights into production estimates, market prices, domestic consumption, and export and import volumes for different agricultural products. The Conab presents information from government sources, the Brazilian entity that most resembles the USDA (United States Department of Agriculture) in disseminating data and analysis on agricultural production and the grain market. Although the report is widely known and highly regarded in the grain industry, it is important to note that disclosures related to livestock, including information on production and the cattle market, are relatively recent, starting in 2021. Nonetheless, despite the limitation of recent disclosures, the report holds significant importance for our research.

vii) **AnualPec** report published by Informa Economics FNP is a paid report that likely includes comprehensive data on various aspects of the livestock industry, such as cattle production, sheep and goat farming, swine production, poultry farming, and other livestock-related activities. It covers the number of animals, production volumes, market trends, prices, and other relevant indicators.

5) **International sources of information:** While Brazil is the largest beef exporter, the supply and demand of other competitor countries in this sector are also important sources. Acquiring knowledge of the foreign market and understanding the production and cycle of its competitors allows the information processed in Brazil to be comprehensive.

   i) **The United States Department of Agriculture (USDA) (https://www.nass.usda.gov/):** provides various reports on cattle and the U.S. livestock industry. These reports offer valuable insights and data on cattle production, prices, trade, and other relevant information for farmers, ranchers, traders, and policymakers. Some of the key USDA reports related to cattle include the Cattle on Feed Report, Cattle Inventory Report, National Weekly Cattle and Beef Summary, and Livestock Slaughter Report.

   ii) **Beef + Lamb New Zealand (www.beeflambnz.com/)**: This organization represents New Zealand's sheep and beef farmers and provides valuable market insights, economic analysis, and industry data related to beef and lamb production and exports.

   iii) **Meat & Livestock Australia (www.mla.com.au/):** is the marketing and research organization for the Australian red meat and livestock industry. It provides comprehensive market information and analysis on the beef, lamb, and goat industries. They offer price trends, demand forecasts, and market insights to help industry participants make informed decisions.

   iv) **World Agricultural Supply and Demand Estimates (WASDE) Report:** The WASDE report includes forecasts and estimates of global livestock production, consumption, and trade, including cattle.

These information channels provide market participants with up-to-date, reliable, and comprehensive information about Brazil's live cattle market and the world. By leveraging these channels, market participants can make well-informed decisions,

manage risks effectively, and contribute to the overall efficiency and transparency of the market. They are valuable resources for industry professionals and stakeholders to stay informed about the current state of the cattle market, help make informed decisions, understand market trends, and plan for the future.

In standard circumstances, the pricing of live cattle is typically formed on equilibrium between supply and demand, both subject to the influence of various endogenous and exogenous factors within the livestock segment. Internally, climatic and technological conditions and profitability considerations impact supply (Carvalho and De Zen, 2017; da Fonseca Boechat and Parré, 2018).

Conversely, demand is contingent upon exogenous elements such as income levels, export dynamics, and the reputability of industry participants (Pancera and Alves, 2020). In addition, cattle are an economic asset, providing a relatively secure alternative for storing value (Shikida *et al.*, 2016).

From a historical perspective, it can be observed that, on many occasions, this second aspect has played a role as important, if not more important, than meeting consumption needs. Information has become increasingly precise and rapidly disseminated as the market has evolved. Understanding where to find the primary sources of information is fundamental for comprehending our study and providing insights on which reports are best to analyze. The following section presents our empirical results.

5.2 Descriptive statistics

In this section, we present the descriptive statistics for the price and return series of Brazilian live cattle futures (BGI) traded on the B3 stock exchange. We initiate by offering potential explanations for the moments of sharp declines and increases in the historical BGI prices. The Figure 7 illustrates the price history of BGI, with our analysis covering from January 1, 2017, to June 28, 2023.

At the beginning of the series, in 2017, there is a notable drop in BGI's future prices, possibly attributable to the "*Operação Carne Fraca*" conducted by the Brazilian Federal Police in March 2017. It was an investigation designed to break a suspected network of corruption that implicated federal agricultural inspectors and companies in the meat processing industry, including some of Brazil's largest meat producers, such as *José Batista Sobrinho, JBS.* The investigation revealed a series of illicit practices, including corruption of inspectors to obtain fraudulent sanitary certificates, product

adulteration, and the sale of expired meat, among other irregularities. These actions exposed food safety and harmed the reputation of Brazil's meat industry (Datagro, 2018).

The *Carne Fraca* Operation had a significant impact both domestically and internationally. Many countries suspended imports of Brazilian meat due to product quality and safety concerns (Quevedo-Silva, 2020). The investigation also led to the notice and arrest of several public officials and corporate executives. In response to the operation, the Brazilian government announced measures to strengthen the oversight and regulation of the country's food industry (Silva *et al.*, 2021).

In general, 2018 was a year of recovery for the cattle market. Despite that, there were still some challenges and fluctuations in the market during the year. In May, Brazil experienced a truckers' strike. Which affected cattle and inputs transportation, leading to logistics and meat distribution challenges, resulting in price fluctuations and beef supply issues. In response, there was significant downward pressure on cattle prices in June when prices reached the lowest value of the year. Consequently, the demand for replacement cattle decreased (CEPEA, 2019).

Also, in 2018, Brazil immunized 98.33% of its cattle herd against foot-and-mouth disease. With this successful vaccination campaign, the country received the World Organization for Animal Health (OIE) certification as free from the disease, enhancing its international sanitary visibility (MAPA, 2018). This had a significant impact on the international market. The increase in exports in the second semester of the year resulted from more competitive prices and trade agreements. Compared to the year of the *Carne Fraca* scandal in 2017, the cattle sector showed an improvement of 11.77% in its exports in 2018 (CEPEA, 2019).

In 2019, African swine fever rapidly spread in China, significantly discarding its swine herd. As China is the world's largest producer and consumer of pork, this sanitary crisis impacted the consumption habits in China. This created significant opportunities for Brazil to export animal protein (CNA, 2019). This scenario led China to increase its meat imports, producing a record of Brazilian beef exports in 2019. In 2019, exports to China reached 494,078 tons, a growth of 53.2% compared to 2018 (Agência Safras, 2020).

Nevertheless, the prices have also increased, influenced by the decline in the proportion of female cattle in the slaughter process. Then, a transition from a low cattle cycle to a high one, where producers retain female cattle due to favorable market prices

(IBGE, 2020). Therefore, the cattle market experienced high prices in 2019 due to the records of Brazilian beef exports and the limited availability of animals ready for slaughter (CEPEA, 2020). The Figure 5 shows the future prices of BGI used in our research.

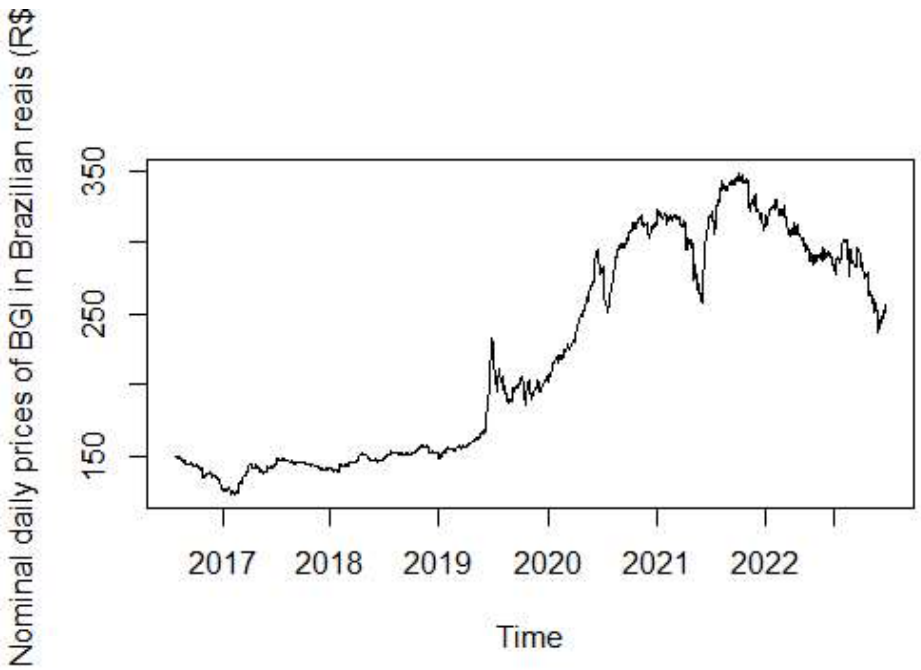


Figure 5: Daily futures prices of Brazilian cattle, between January 2, 2017, to June 28, 2023

The year 2020 proved to be atypical for Brazil and the world. Various sectors of the economy faced challenges because of the unfolding COVID-19 pandemic, which significantly disrupted the daily routines and meat consumption habits of the Brazilian populace. Notably, the unemployment rate surged from 11.3% to 14.3%, impacting a substantial portion of the population with income losses (CNA, 2021). Despite these domestic challenges, the Brazilian agribusiness exports demonstrated resilience, avoiding significant negative impacts from the global health crisis.

China was the only major global economy to experience growth in 2020, resulting in increased income for its population and a subsequent shift in consumption habits. Consequently, China's share in beef purchases remained high, surpassing 40% in 2020, a significant increase from the 25.3% recorded in 2019 (CEPEA, 2021). With strong external demand, a limited supply of animals, and the dollar appreciation, cattle prices in 2020 reached record levels in Brazil (ABRAFRIGO, 2021).

In 2021, we witnessed a persistent upward trajectory in prices, primarily attributed to a shortage of animals for domestic market supply. This trend was influenced by factors such as the ongoing cattle cycle and inadequate rainfall in key production areas across the country. The elevated price level of cattle continued to surpass R$ 300.00[17] per arroba (CEPEA, 2022). However, the dynamics shifted with a notable decline in 2021 due to concerns regarding bovine spongiform encephalopathy (BSE). In September of that year, China imposed a suspension on imports from Brazil following the identification of two atypical cases of BSE. This event had a substantial adverse impact on the reputation and perceived quality of Brazilian meat, resulting in a significant reduction in prices (EMBRAPA, 2022). The interplay of these factors highlights the volatility and susceptibility of the Brazilian cattle market to both domestic and international influences.

In 2022, a noticeable shift in the market dynamics became evident as the previously escalating trend in prices began to reverse. Despite achieving record export figures, the domestic demand failed to match these heights. It's worth noting that a substantial portion, approximately 75%, of the beef produced in Brazil is intended for the domestic market. With a slow demand for beef domestically, prices experienced a decline (CEPEA, 2023). Nevertheless, we posit that a more profound force is influencing this market reversal.

Additionally, 2022 marked the initiation of the cattle low cycle, as highlighted by Scott Consultoria (2022). Within this cycle, producers tended to increase the culling of breeding females for slaughter instead of retaining them for reproductive purposes. This strategic decision resulted in an augmented supply of animals available for slaughter. The repercussions of this cycle of low prices extended into the first semester of 2023 due to the ongoing low cycle in cattle farming (CEPEA, 2023). This intricate interplay of factors illustrates the intricate nature of the Brazilian cattle market and its susceptibility to various internal and external influences.

Figure 6 illustrates the returns of BGI futures traded on B3. Notably, discernible volatility clusters emerge in 2017, 2019, 2021, and 2023. These clusters denote specific periods during which the volatility of financial assets exhibits marked variations. The implications of high volatility in a market are distinct, presenting challenges for participants, including investors, businesses, and consumers. Unexpected and

[17] One "arroba" corresponds to 15 kilograms, so 300 "arrobas" are equivalent to 4500 kilograms.

substantial price swings can yield significant gains or losses within a short timeframe, raising uncertainty.

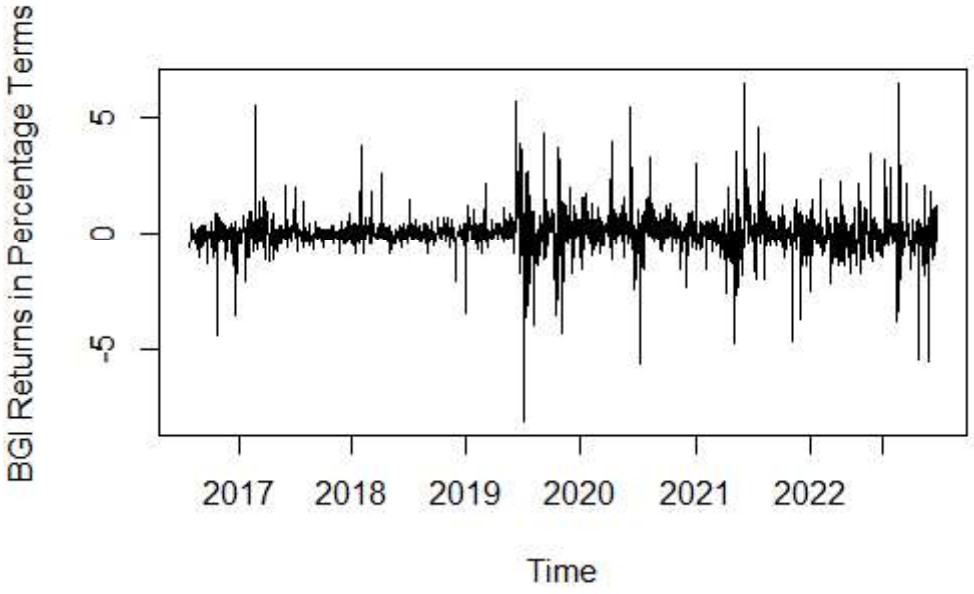


Figure 6:BGI Returns in Percentage Terms between January 2, 2017, to June 28, 2023

These clusters may be associated with the information from the reports we are investigating. Any of them can alter the behavior of returns due to unexpected information. Therefore, when we observe these clusters, the market may seize opportunities to achieve abnormal gains and high returns, provided investors are willing to take on this level of risk.

The 2017 volatility cluster may be aligned with the evolving of the *"Operação Carne Fraca"* scandal. The revelation of irregularities in the meat industry had profound effects on market sentiment, leading to pronounced fluctuations in asset prices. Investors faced heightened uncertainty during this period. Volatility cluster in 2019 coinciding with the onset of the COVID-19 pandemic. The rapid spread of the virus globally triggered widespread economic disruptions, resulting in increased market uncertainty. Investors faced challenges adapting to the evolving situation, leading to pronounced fluctuations in asset values.

Another apparent volatility cluster appears in 2021, paralleling concerns over the "*vaca louca*" disease. The news surrounding cases of Bovine Spongiform Encephalopathy (BSE) contributed to a surge in market uncertainty, impacting investor confidence and precipitating a notable increase in volatility during this period. In 2023,

we identify a volatility cluster associated with the repercussions of a downturn in the cattle cycle. Fluctuations in supply and demand dynamics, coupled with external factors, contribute to heightened market turbulence. Investors navigating this period face challenges as the market adjusts to the complexities of the cattle cycle's downturn.

Table 3 provides descriptive statistics for the daily futures prices of cattle (BGI) traded on B3, along with its returns. These statistics offer valuable insights into market behavior, guiding us in making informed inferences. With a mean of 220.82, we can infer that, on average, daily futures prices of cattle tend to cluster around this value. However, the fact that the median is 201.85, lower than the mean, implies a right-skewed distribution of prices. This suggests the presence of some higher values that apply a rising influence on the mean.

Table 3: Descritive statistics of BGI prices and returns between January 2, 2017, and June 28, 2023.

	Live cattle future prices	**Log Return live cattle future prices**
Mean	220.8229	0.0333
Median	201.8500	0.0000
Maximum	348.7500	6.4805
Minimum	123.0600	-8.0604
Variance	5556.7830	0.8818
Standard deviation	74.543833	0.9390
Skewness	0.219079	-0.0246
Kurtosis	-1.626674	13.9445
Jarque-Bera (p-value)	$2.2e\text{-}^{16}$	$2.2e\text{-}^{16}$
Number observations	1607	1606

Source: Elaborated by the author using research data

With a variance of 5556.78, it becomes evident that the BGI futures prices exhibit a considerable degree of variation around the mean, which was 220.82. This large variance highlights the dynamic nature of the market, with prices displaying a broad range of fluctuations. The corresponding standard deviation of 74.54 suggests that, on average, daily BGI futures prices deviate by approximately 74.54 units from the mean. It constitutes a considerable value, taking the mean as a reference parameter.

The skewness positive value of 0.2190 suggests a slight positive skewness, indicating that the right tail of the distribution is a bit longer. This implies that there may be some higher values attracting the mean to the right. A value of -1.6266 indicates negative kurtosis, meaning the distribution is relatively plane and larger than the normal

distribution. It indicates that the data has shorter tails and a lower probability of extreme values occurring. It is commonly referred to as a platykurtic distribution.

These measures indicate the presence of variability in the future market of cattle, with a bias towards higher values. Additionally, both skewness and kurtosis suggest that these variables deviate from a normal distribution, which should be taken into consideration in data modeling. However, it's essential to highlight that the modeling will be conducted on BGI returns.

Concerning the log returns of BGI, a mean of 0.033 suggests an average percentage growth, while a median of 0.00 implies an equal distribution of positive and negative returns. The variance of 0.88% and a standard deviation of 0.93% indicate a moderate dispersion around the mean, both values being below 1%. This implies that, on average, BGI returns do not exhibit significant percentage variations relative to the mean throughout the analyzed period.

Regarding the log return of skewness, the negative value (-0.024%) indicates a left-skewed (negative) distribution. It suggests that the number of days with returns below the average is higher than those above. Therefore, this negative skewness result informs us of a tendency for negative returns throughout the return series of BGI.

A kurtosis value of 13.94% suggests a leptokurtic data distribution, meaning the data has a more pronounced concentration around the mean and heavier tails. This suggests a higher probability of the occurrence of extreme values, both positive and negative, compared to a normal distribution. Overall, the returns are more stable than prices at the level. However, they exhibit different characteristics from a normal distribution that we will consider in the remaining modeling.

Our objective is to examine whether livestock reports influence the future price of live cattle. To achieve this, we conducted a descriptive statistical analysis by dividing the data into six distinct subsets. These subsets include days with the release of reports from IBGE on BGI returns, days without IBGE reports, days with reports from CEPEA, days without CEPEA reports, days with reports from CONAB, and days without CONAB reports. The descriptive statistics for each of these subsets are presented in Table 4.

Table 4: Log BGI returns descritive statistics for reports and no reports days between January 2, 2017, and June 28, 2023.

Measures	Statistics in IBGE reports days	Statistics in IBGE no reports days	Statistics in CONAB reports days	Statistics in CONAB no reports days	Statistics in CEPEA reports days	Statistics in CEPEA no reports days
Mean	0.3343	0.0282	-0.0166	0.0337	0.0362	0.0332
Median	0.1357	0.0000	0.0000	0.0000	-0.0218	0.0151
Maximum	3.7124	-8.0608	2.0523	-8.0608	2.5092	-8.0608
Minimum	-1.9324	6.4805	-1.0698	6.4805	-1.9375	6.4805
Variance	1.1604	0.8757	0.6030	0.8842	0.5947	0.8912
Sdt deviation	1.0772	0.9357	0.7765	0.9403	0.7711	0.9440
Skewness	1.1751	-0.0611	0.8468	-0.0300	0.7226	-0.0383
Kurtosis	2.3859	14.248183	0.9720	13.9826	1.6560	14.0616
N obs.	27	1589	15	1601	52	1564

Source: Elaborated by the author using research data

While we cannot assert definitively that the reports cause volatility or abnormal returns based on Table 4, we observe notable differences in certain measures, as in (Isengildina-Massa *et al.* (2008); McKenzie and Ke, 2022). The variance on report days for all reports is higher than on days without announcements, with particular emphasis on the IBGE, whose release is *"Pesquisa Trimestral de Abates"*. This specific report presented the most intriguing results.

The mean on IBGE report days surpasses the overall mean of returns in the sample. Furthermore, a median lower than the mean suggests that on days of this report, BGI log returns tend to have values above the mean. The standard deviation of IBGE is the only one among the reports that increases on disclosure days. In all skewness statistics on report days, there is a greater concentration of values in the higher range of the sample.

These observations indicate that, while causality cannot be conclusively established, the reports, especially the IBGE report, are associated with distinct patterns in BGI log returns. Further analysis is recommended to better understand the nature of this association and its implications in the cattle market. In the following sections, we present the results of inference based on the adopted models.

5.3 Cumulative abnormal returns for BGI future prices

This section presents the results of the CAR modeling for the log returns of BGI. In the following subsection, 5.3.1, we present the outcomes using the log returns of the spot indicator for live cattle CEPEA/B3 as market proxy. In section 5.3.2, the CAR results are based on the utilization of the GSCI-Live Cattle index as our market proxy.

5.3.1 Cumulative abnormal returns for BGI future prices spot indicator for live cattle CEPEA/B3

The BGI future prices and spot indicator for live cattle CEPEA/B3 prices show a high correlation, with a coefficient of 0.997, as shown in the Figure (9) in the 8.1 Appendix Section. Therefore, we consider it a suitable proxy for representing the market under study.

Caution is necessary when attributing abnormal returns exclusively to the examined reports, as our earlier findings have underscored the presence of private

information within this market. Nevertheless, the identified abnormal returns hint at a potential correlation between these variables. Table 5 presents the results of the CAR analysis, employing the event window [-1, 0, +1].

Table 5: CAR results in a [-1, 0, +1] Event Study window between January 2, 2017, and June 28, 2023.

Event Day	AR			CAR	p-valor	t-value
	-1	0	1			
Panel A1: Significance CAR days of IBGE reports 27 events were studied, 2 were significant, and 25 were not significant						
2020-03-19	1.270	3.680***	0.730***	5.680	0.005***	2.833
2021-03-18	-1.120***	-0.270	-0.900***	-2.290	0.043**	-2.019
Panel A2: **Significance CAR days of CEPEA reports 46 events were studied, 3 were significant, and 43 were not significant**						
2017-06-02	-3.410***	0.160*	0.250**	-3.000	0.004***	-2.848
2021-11-05	1.990*	2.730***	2.060***	6.780	0.015**	2.425
2022-08-09	-1.270*	-0.890*	-0.510*	-2.670	0.064*	-1.859
Panel A3: Significance CAR days of Conab 14 events were studied, 0 were significant, and 14 were not significant.						

Source: Elaborated by the author using research data
Note: *Z*-statistic for the mean abnormal return. $*p<.10$, $**p<.05$, $***p<.01$. Non-significant results in the appendix. Results with spot indicator for live cattle CEPEA/B3

We did not identify any discernible patterns. In certain analyses, we observed instances where returns from the previous day [-1] exceeded those on the actual event day, such as on 2022-08-09 (-1.2700) and 2017-06-02 (-3.4100). This observation underscores two relevant considerations: i) the market may have already assimilated the information beforehand; ii) other factors or information might have influenced the analysis.

When the event window is extended to [-3, 0, +3] days, we observe that certain dates, such as September 10, 2020, and September 10, 2021, become significantly abnormal in response to the release of the IBGE report. We cannot definitively attribute the abnormality solely to the report. Nevertheless, the expand event window has revealed that a considerable portion of abnormal returns is concentrated on the actual disclosure day, as indicated by the higher absolute value of the parameter. However, certain dates showing significance might be associated with other events, such as 2019-12-05 and 2021-10-06. This is because a few exhibits higher absolute abnormal returns at -3 or +3 days, which raises the possibility that another Event

Study could influence the analysis, thereby introducing contamination. The results are presented in Table 23 in Section 8.2 of the Appendix.

As previously discussed, it is not definitive to attribute these returns solely to the information in the reports. Nevertheless, in our quest for deeper insights into each abnormal return date, we meticulously examined the respective reports to identify key market highlights on the specified event day:

- **03/19/2020** ***Pesquisas Trimestrais do Abate de Animais IBGE***

  On the specified date, the IBGE's research indicated a decline in the slaughter of mature cattle and increased exports attributed to the devaluation of the Brazilian currency. The study further notes that this phenomenon can be categorized as a peak in the livestock cycle, wherein prices remain disposed to escalation owing to the scarcity of slaughtered animals and the appreciation of calves.

  > "'We are currently in what is known as a high phase in cattle farming following a period of low activity. The price per arroba has increased, and calves, one of the primary production inputs, are scarce and appreciated. This implies that those who own female cattle are retaining them to produce more calves' explains the research supervisor, Bernardo Viscardi" (IBGE, 2020, our translation).

  Examining the data relating to the event day on March 19, 2020, conspicuous elevations in variations were observed compared to the preceding and subsequent days. Both intraday variation and the overall range exhibited a notable increase of 4.16%. These findings are showed in Table 6:

Table 6: Price behavior within the event window [-1, 0, 1]

Date	Open Price	Max Price	Min Price	Close Price	Var % Day	Range	Behavior
03/18/2020	186.00	189.05	183.10	186.40	0.22%	3.25%	
03/19/2020	185.30	193.00	185.30	193.00	4.16%	4.16%	
03/20/2020	192.95	196.00	192.95	196.00	1.58%	1.58%	

Source: Elaborated by the author using research data

- **03/18/2021** ***Pesquisas Trimestrais do Abate de Animais IBGE***

The animal slaughter research conducted by IBGE continued to indicate an upward trend in the Brazilian livestock cycle. "The result represents the second consecutive year of decline, following the scenario of animal retention observed since the beginning of 2020" (IBGE, our translation).

It is notable that the event day exhibited the smallest fluctuations, both intraday and in the range, compared to the event window. The negative returns align with the reported news, underscoring a plausible correlation between the observed price behavior and the information disclosed. While studying the information from the reports and news of that day, we noticed the presence of a news item from *Agência Safras* private report.

Despite the scarcity of animals, which would have pushed prices upward, the scenario was marked by a lockdown due to the COVID-19 pandemic (Agência Safra, 2021). This led to the closure of restaurants and collective leave in some Brazilian meatpacking plants, such as Minerva (IMEA, 2021). In addition, the country's economic fragility shifted the population's consumption towards cheaper protein sources like chicken and suine (ABRAFRIGO, 2021). The economic instability and uncertainty might have influenced the futures market, putting downward pressure on prices. The summary of these findings is presented in Table 7.

Table 7: Price behavior within the event window [-1, 0, 1]

Date	Open Price	Max Price	Min Price	Close Price	Var % Day	Range	Behavior
03/17/2021	313.45	314.25	310.10	311.1	-0.75%	1.34%	
03/18/2021	311.90	312.85	310.80	311.55	-0.11%	0.66%	
03/19/2021	312.60	313.80	309.00	309.75	-0.91%	1.55%	

Source: Elaborated by the author using research data

- **06/02/2017** ***Agromensal Cepea***

  The June report marks the largest decline since the series began in 1997. Two main factors explain this: a surplus due to increased female slaughter and low demand, compounded by the lasting effects of *Carne Fraca* Operation. The sector's primary industry, implicated in the scandal, weakened, giving competitors greater bargaining power over producers.

  > "After the *Carne Fraca* operation and recent political and economic developments resulting from the plea bargain, the leading industry in the sector significantly reduced the volume of slaughtered animals.

> Consequently, the need to fill production scales for competing industries was promptly met, granting these entities more negotiation power with the producers. This scenario was exacerbated by the fact that primary production is comprised of a high number of cattle ranchers with little coordination in joint marketing and considerable heterogeneity in the offered product. This characterizes them as economic agents who are price takers. Meanwhile, the intermediary link in the chain, more concentrated and organized, managed purchases to the extent of not flooding the wholesale market." (Cepea, 2017, our translation)

Indeed, the "*Carne Fraca"* scandal significantly disrupted the cattle market. JBS, the implicated company, triggered widespread uncertainty affecting both the cattle industry and the financial market. Notably, on the specific report day, intraday variations were minimal, with a smaller range compared to surrounding days. We attribute the abnormal returns during this period to general news.

For example, on June 1, 2017, *Valor Econômico* reported *Carne Fraca* operation suspicions involving the former Regional Superintendent of the Ministry of Agriculture in Goiás, Francisco Carlos de Assis (Valor Econômico, 2017). On June 5, reflecting weekend information, Scott Consultoria noted JBS's purchasing challenges. The JBS unit in Ponta Porã-MS took collective vacation, and the government aimed to mitigate the situation through tax exemptions. In essence, the CEPEA report may not be the primary driver of abnormal returns, but rather a reflection of broader market uncertainties. Table 8 reflects the prices during these days.

Table 8: Price behavior within the event window [-1, 0, 1]

Date	Open Price	Max Price	Min Price	Close Price	Var % Day	Range	Behavior
06/01/2017	129.30	129.30	128.11	128.20	-0.85%	0.93%	
06/02/2017	128.20	128.49	128.00	128.17	-0.02%	0.38%	
06/05/2017	128.50	128.90	128.00	128.36	-0.11%	0.70%	

Source: Elaborated by the author using research data

- **11/05/2021** ***Agromensal Cepea***

Our findings indicate a positive CAR (2,73%), in line with the insights provided by the Cepea report. The market displayed strong activity on that day despite the pause in exports to China. This was largely due to a reduced animal supply.

> "Despite the ongoing suspension of beef shipments to China (which has been observed since the beginning of September), the cattle prices were propelled by the contraction in the supply of cattle for slaughter."(Cepea, 2021, our translation).

Based on the behavior of the futures market in November, it was evident that it capitalized on the appreciation. According to *Cepea Agromensal* (2021), on the year-end surge in demand from slaughterhouses. Then, the producers opted to retain their livestock on pasture, facilitated by favorable weather conditions. Indeed, the report also highlights heightened demand from slaughterhouses, driven by the intention to reinforce their inventory for the year-end sales period.

The *Scott Consultoria* also added that prices increased due to the arrival of the salary payment period. Quotations resumed their upward trend in response to increased demand, as stated by analyst Jéssica Olivier from Scott (Scott Consultoria, 2021). Table 9 reflects the prices during these days.

Table 9: Price behavior within the event window [-1, 0, 1]

Date	Open Price	Max Price	Min Price	Close Price	Var % Day	Range	Behavior
06/04/2021	273.00	278.75	271.00	277.45	1.63%	2.86%	
06/05/2021	277.60	285.45	277.50	284.50	2.49%	2.86%	
06/08/2021	284.90	289.90	283.55	289.40	1.58%	2.24%	

Source: Elaborated by the author using research data

- **08/09/2022 *Agromensal Cepea***

The cumulative abnormal return displayed a negative value (-2.670%), aligning with the sentiment dominant in the market then. According to the report, live cattle prices did not advance further due to the compromised income of Brazilians.

> “Given the high inflation, a significant portion of the Brazilian population is facing budget constraints. As a result, many consumers are seeking proteins with more competitive prices, such as pork, poultry, and eggs, at the expense of beef”. (Cepea, 2022 our translation).

During this period, it was evident that futures market prices were declining. However, further insights from *Scott Consultoria*, now publicly available but previously undisclosed, have come to our attention. According to the information provided by Scott, it was revealed that meat processing companies were strategically

curbing their demand for live cattle, aiming to exert a downward influence on prices (Scott Consultoria, 2021).

This scenario emphasizes the constant challenge of discerning which information takes precedence in shaping market dynamics. Once again, the complexities of information dissemination accentuate the potential for significant market impact, especially when the disclosed information diverges from initial expectations. Table 10 reflects the prices during these days.

Table 10: Price behavior within the event window [-1, 0, 1]

Date	Open Price	Max Price	Min Price	Close Price	Var % Day	Range	Behavior
08/08/2022	316.50	316.95	311.95	312.30	-1.30%	1.60%	
08/09/2022	311.55	312.45	308.50	309.45	-0.70%	1.28%	
08/10/2022	309.15	309.65	307.25	307.85	-0.40%	0.78%	

Source: Elaborated by the author using research data

5.3.2 Cumulative abnormal returns for BGI future prices with GSCI proxy

In this subsection, we introduce the CAR results utilizing the GSCI Live Cattle index as a proxy, specifically disaggregated for live cattle. Like the approach in Section 5.3.1, the CAR results will undergo a disaggregated analysis. Notably, our analyses will exclusively focus on new abnormal return dates; it is worth noting that dates identical to those found in Table 5 do not necessitate a fresh analysis, as they have already been comprehensively addressed in Section 5.3.1.

The CAR market model assumes that R_{mt} acts as a proxy for the overall market. However, existing literature (Han *et al*., 2016; Ramiah *et al*., 2019), suggests the consideration of an index or alternative variable that more accurately reflects the market. Despite the GSCI Live Cattle index serving as an indicator for cattle, it is important to note that it is not exclusive to the Brazilian market. With a correlation of 0.533, notably lower than the CEPEA/B3 indicator Figure (10) in Appendix 8.1 Section its alignment with the Brazilian market is limited. Despite this limitation and the absence of a more fitting proxy, we proceeded with the GSCI Live Cattle index for our analysis. Table 11 provides the CAR results utilizing the GSCI proxy.

Table 11: CAR results in a [-1, 0, +1] Event Study window between January 2, 2017, and June 28, 2023.

Event Day	AR			CAR	p-value	t-value
	-1	0	1			
Panel A1: Significance CAR days of IBGE reports 27 events were studied, 3 were significant, and 24 were not significant.						
2017-12-14	-2.720**	-0.650	-0.810	-4.180	0.026**	-2.223
2018-03-21	-0.270	-1.180**	-2.540***	-3.990	0.019**	-2.328
2020-12-10	0.860**	3.300***	0.610	4,770	0.007***	2.720
Panel A2: Significance CAR days of Cepea reports 46 events were studied, 4 were significant, and 42 were not significant.						
2017-06-02	-3.410***	0.160	0.250*	-3.000	0.004***	-2.847
2021-09-03	-0.009***	0.011***	0.039***	0.0414	0.007***	2.684
2021-11-05	1.990	2.730**	2.060**	6.780	0.015**	2.424
2022-08-09	-1.270*	-0.890	-0.510	-2.670	0.064*	-1.850
Panel A3: Significance CAR days of Conab 14 events were studied, 1 were significant, and 13 were not significant.						
2023-02-23	-3.850***	0.280	-3.280***	-6.850	0.000***	-4.597

Source: Elaborated by the author using research data. Note: *Z*-statistic for the mean abnormal return. $*p<.10$, $**p<.05$, $***p<.01$. Non-significant results in the appendix. Results with GSCI proxy.

In the disaggregated analysis of the IBGE reports, we found no evidence that abnormal returns were directly influenced by IBGE information. This is evident as abnormal returns accumulated negative values on December 14, 2017, and March 21, 2018, while national news in the reports highlighted record slaughter numbers and a heated or stable demand.

On December 10, 2020, the report indicated the worst results in production and slaughter since 2016. Therefore, abnormal return outcomes contradict the information presented in IBGE releases when considering the GSCI proxy, suggesting the possibility that other variables or, likely, international information may have affected the market.

- **2022/09/08 *Agromensal Cepea***

The abnormal return displayed a positive value (0.0138), not aligning with the sentiment dominant in the market then. According to the report, live cattle prices did not advance further due to the weak domestic demand.

> The pressure mainly arises from weak domestic demand for meat, which has led meatpacking companies to restrict purchases of batches of animals for slaughter. Furthermore, the supply of fattened cattle ready for slaughter has been increasing slightly in many regions." (Cepea, 2022, our translation).

As our proxy pertains to the international market, we seek information for this date in the international market. However, according to the USDA, demand in the American market was also declining (USDA, 2022).

If we analyze the context of the dates, we will notice a holiday on 07/09. These positive values may relate more to the holiday effect than the report. In fact, some private reports provided positive information. For example, *Scot Consultoria* reported that meat packing companies in the State of São Paulo improved their purchase offers for live cattle on September 8 (Thursday), offering an additional R$ 2.00 per arroba (Scot Consultoria, 2022).

Agência Safras reports that the holiday interrupted the negotiations, making the market less fluid. It reduces the time it takes to slaughter cattle, which is essential for creating the opportunity for price increases for cattle (Safras & Mercado, 2022).

We continue facing the challenge of identifying who released the news first, public, or private reports. We observed a holiday effect that disrupted the market dynamics for this specific day. Furthermore, we observed the presence of private information that the public report did not include. Table 12 reflects the prices during these days.

Table 12: Price behavior within the event window [-1, 0, 1]

Date	Open Price	Max Price	Min Price	Close Price	Var % Day	Range	Behavior
09/06/2022	306.00	309.00	305.50	308.00	0.65%	1.15%	
09/08/2022	308.20	312.15	307.30	311.80	1.17%	1.58%	
09/09/2022	311.65	314.35	311.55	313.25	0.51%	0.90%	

Source: Elaborated by the author using research data

•**2023/02/23** ***Agromensal Conab***

On the date is negative, leading us to believe that some unfavorable news impacted the market. Indeed, the CONAB report presented a worrisome scenario for both producers and slaughterhouses. At the time, China's demand was declining due to the recovery of its domestic protein production. "China, the largest importer, has been decreasing its demand due to the recovery of its domestic animal protein production."(CONAB, 2023. Our translation).

Analyzing the price fluctuations on that date a significant price decline was visible within the futures market. This trend might connect to another notable detail emphasized in the report. The report highlights the current state of the 2023 livestock cycle, marked by a phase of reduced activity and an excess of animal supply. As a result, livestock producers are choosing to keep their animals on pastures. Additionally, they are taking steps to slaughter breeding animals to achieve price stability and eventual growth. Table 13 reflects the prices during these days.

Table 13: Price behavior within the event window [-1, 0, 1]

Date	Open Price	Max Price	Min Price	Close Price	Var % Day	Range	Behavior
02/22/2023	302.05	302.05	290.00	290.85	-3.71%	4.16%	
02/23/2023	291.00	293.65	289.00	292.10	0.38%	1.61%	
02/24/2023	292.75	292.80	281.55	282.60	-3.47%	4.00%	

Source: Elaborated by the author using research data

5.3.3 An open-to-close CAR robustness results for the report's impact on returns in the Brazilian live cattle market

In Section 4.3, we describe the method for analyzing the robustness of the CAR model. This section presents the robustness results using the open-to-close return. Once again, disaggregated analyses will be conducted only for the new abnormal return dates. This return calculation technique captured more abnormal returns compared to the close-to-close method.

Given that reports are typically released during B3's operating hours, this calculation method may prove more parsimonious in capturing information, as indicated. However, we emphasize that by using the close-to-close method, we aim to access the after-market, as we do not have access to traded prices during that period. The results are presented in the Table 14.

Table 14: Open-to-Close CAR results in a [-1, 0, +1] Event Study window between January 2, 2017, and June 28, 2023.

Event Day	AR			CAR	p-valor	t-value
	-1	0	1			
Panel A1: Significance CAR days of IBGE reports 27 events were studied, 5 were significant, and 22 were not significant						
2017-03-15	-0.003	-0.007	0.002	-0.009	0.032**	-2.144
2018-03-21	0.002	0.003	0.002	0.007	0.063*	1.856
2019-06-13	-0.003	-0.006	-0.000	-0.010	0.076*	-1.774
2021-03-18	0.011	0.004	0.012	0.028	0.004***	2.864
Panel A2: Significance CAR days of Cepea reports 46 events were studied, 7 were significant, and 40 were not significant						
2019-04-05	-0.337	-0.084	-0.457	-0.879	0.098*	-1.654
2020-09-08	-0.010	-0.006	-0.005	-0.022	0.036**	-2.086
2020-12-04	0.012	0.007	0.017	0.037	0.011**	2.528
2021-11-05	-0.016	-0.026	-0.017	-0.059	0.001***	-3.289
2022-04-06	0.808	0.047	0.919	1.775	0.019**	2.346
2022-08-09	0.014	0.004	0.005	0.024	0.012**	2.502
2022-09-08	-0.542	-1.187	-0.362	-2.092	0.052*	-1.940
Panel A3: Significance CAR days of Conab reports 14 events were studied, 2 were significant, and 12 were not significant						
2023-02-23	3.719	-0.383	3.405	6.740	0.000***	5.749
2023-05-23	-1.997	-2.464	0.902	-3.559	0.005***	-2.809

Source: Elaborated by the author using research data. Note: *Z*-statistic for the mean abnormal return. $*p<.10$, $**p<.05$, $***p<.01$. Non-significant results in the appendix. Results with GSCI proxy.

- **2019/04/05** ***Agromensal Cepea***

In this report, CEPEA highlighted significant price fluctuations, with the decline being attributed to the increased supply of animals. It is noteworthy that the period from April to June is characterized by the weaning process, consequently leading to a surge in the availability of animals, peaking in May (CEPEA, 2019, our translation). Table 15 illustrates the price dynamics during these days.

Table 15: Price behavior within the event window [-1, 0, 1]

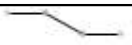
Date	Open Price	Max Price	Min Price	Close Price	Var % Day	Range	Behavior
04/04/2019	155.60	156.15	155.60	156.15	0.35%	0.35%	
05/04/2019	156.25	156.40	156.20	156.40	0.10%	0.13%	
08/04/2019	156.75	157.45	156.75	157.45	0.45%	0.45%	

Source: Elaborated by the author using research data

- **2022/04/06 *Agromensal Cepea***

In this report, Cepea explained that prices remained robust due to the limited supply of animals and high external demand, stating, "The support comes from strong external demand and the tight supply of animals for slaughter" (CEPEA, 2022, our translation). Table 16 illustrates the price trends during these days.

Table 16: Price behavior within the event window [-1, 0, 1]

Date	Open Price	Max Price	Min Price	Close Price	Var % Day	Range	Behavior
04/05/2022	326.45	326.65	324.05	324.10	-0.72%	0.80%	
04/06/2022	323.70	324.45	321.35	323.75	0.02%	0.96%	
04/07/2022	325.30	326.00	322.05	322.70	-0.80%	1.23%	

Source: Elaborated by the author using research data

- **2022/04/06 *Agromensal Cepea***

According to the report, live cattle prices did not advance further due to the weak domestic demand.

> The pressure mainly arises from weak domestic demand for meat, which has led meatpacking companies to restrict purchases of batches of animals for slaughter. Furthermore, the supply of fattened cattle ready for slaughter has been increasing slightly in many regions."(Cepea, 2022, our translation).

Tabela 17 apresenta o comportamento dos preços durante esses dias.

Table 17: Price behavior within the event window [-1, 0, 1]

Date	Open Price	Max Price	Min Price	Close Price	Var % Day	Range	Behavior
09/06/2022	306.00	309.00	305.50	308.00	0.65%	1.15%	
09/08/2022	308.20	312.15	307.30	311.80	1.17%	1.58%	
09/09/2022	311.65	314.35	311.55	313.25	0.51%	0.90%	

Source: Elaborated by the author using research data

- **2023/05/23 *AgroConab***

The report indicated a decline in prices due to the downturn in the cattle cycle, compounded by the repercussions of the China embargo. "As a consequence of the embargo, the volume exported to China decreased by 26% compared to the previous month. The current low point in the livestock cycle indicates an increase in slaughtering, driven by the culling of females" (CONAB, 2023). Table 18 illustrates the price trends during these days.

Table 18: Price behavior within the event window [-1, 0, 1]

Date	Open Price	Max Price	Min Price	Close Price	Var % Day	Range	Behavior
05/22/2023	251.00	257.00	250.70	255.60	1.83%	2.51%	
05/23/2023	255.15	263.00	253.80	260.90	2.25%	3.62%	
05/24/2023	260.10	261.60	256.65	257.60	-0.96%	1.93%	

Source: Elaborated by the author using research data

The abnormal returns' results suggest the existence of correlations between the information from the reports and the market. When using the national proxy, we observe that returns exhibit expected behaviors in relation to the news; when the news is negative, returns tend to be negative. However, we cannot make the same inference with the GSCI proxy, as the results obtained do not always align with the news information. Indeed, one would reasonably expect better alignment between the national variables. Although Brazil holds a significant position in the international market, justifying the use of this proxy, we believe that if international reports were analyzed with this proxy, the results would also show a better correspondence.

The results from section 5.3 show some abnormal returns. However, Fama (1970) argues that when the market is efficient in its semi-strong form, abnormal returns are random. Our results do not show consistent patterns in the returns. For example, we did not find that a particular report produced abnormal returns in the same month across all the years analyzed. Additionally, some abnormal returns were observed in the [-1] and [+1] day windows, indicating a lack of consistent behavior

patterns. In pursuit of more accurate results, the next section investigates the behavior of variance when news is disclosed.

5.4 Analysis of the effect of reports on the volatility of BGI using GARCH modeling

In this section, we present the results of the volatility analysis. Our objective was to employ GARCH family models to determine if there is more volatility on reporting days. The use of this methodology also assists us in using variables that control for external effects and reduce omitted variable bias (Isengildina *et al.*, 2006; Michael K. Adjemian, 2012; Lehecka, 2014).

The results of the correlation functions (ACF and PACF) for the BGI log return indicated the presence of serial correlation at lags 1, 2, 3 and 6[18] (see GARCH Appendix). Therefore, we fitted an ARMA (1,1) model, which achieved the best fit according to the Akaike Information Criterion (AIC) criteria, it was determined that this model outperformed the other potential estimations. The ARMA (1,1) model for BGI log returns has eliminated the issue of serial correlation, as confirmed by the standardized residuals autocorrelation functions (ACF and PACF) and the Box-Ljung test (p-value = 0.2358).

Next, we analyzed the ARCH effect through the autocorrelation functions of ARMA (1,1) squared residuals and ARCH and Box-Ljung tests. Both the functions, the test Box-Ljung (p-value $2.2e^{-16}$) and the LM test for effect ARCH ($2.0e^{-16}$) indicated the presence of the ARCH effect. Therefore, we proceeded with the estimation of the GARCH-M model.

We estimated different models with different variations, such as EGARCH, TARCH, and GARCH-M. For EGARCH and TARCH models, as reports dummy variables were added, the asymmetry parameters lost significance, preventing us from justifying the choice of these models. For the GARCH-M, the additional parameter in the mean equation also did not show significance, and then we discarded that model variation. We also checked for long memory, which, based on the Hurst exponent (0.4558), indicates short memory. Therefore, we proceeded to estimate a simple GARCH model among all the specifications.

[18] All detailed results are in the GARCH Appendix.

In the estimations for the GARCH model, we consider the use of the t-distribution since our sample exhibits excess kurtosis, as recommended by Lange et al. (1989), Kim and White (2004). Using the t-distribution, can lead to more robust estimates and more realistic confidence intervals, as it considers the greater variability in the distribution's tails (Mckenzie *et al.*, 2023).

The impact of reports was examined by incorporating dummy variables into the variance equation, aiming to determine whether the release of these reports contributes to increased data variability. Accordingly, report dates are denoted by a value of 1, otherwise 0. Additionally, we introduced dummy variables for the months of May and October, historically recognized for experiencing higher market liquidity in the Brazilian market.

To account for the Monday effect, a variable representing Monday was introduced, taking the value of 1 on Mondays and 0 otherwise. In Table 19, we present our estimations: Panel A) without external regressors, Panel B) with a vector of exogenous variables containing only the dummies for reporting days (DIBGE, DCepea, DConab) in the variance equation, Panel C) the dummy variables for May and October, also included in the variance equation, Panel D) the dummy variable for Mondays. Table 19 presents the ARMA-GARCH results.

Table 19: ARMA-GARCH Models for the BGI log return

(continue)

	Variables	Std. Error	t value	Pr(>|t|)
Panel A: Model without external regressors				
		Mean Equation		
Ar (1)	0.997	0.000	2620.008	0.000 ***
Ma (1)	-0.991	0.000	-8023.631	0.000 ***
		Variance Equation		
Intercept	0.000	0.000	3.816	0.000 ***
$\boldsymbol{\alpha}$ (1)	0.416	0.159	0.192	0.009**
$\boldsymbol{\alpha}$ (2)	0.583	0.005534	21.9621	0.002**
Panel B: Model with the days of report as external regressors				
		Mean Equation		
Ar (1)	0.934	0.089	10.385	0.0000***
Ma (1)	-0.913	0.103	-8.788	0.0000***

Table 20: ARMA-GARCH Models for the BGI log return

(conclusion)

		Variance Equation		
α (1)	0.061	0.021	2.829	0.004**
β (1)	0.961	0.003	246.921	0.000***
IBGE	0.000	0.000	1.908	0.056*
Cepea	0.000	0.000	1.355	0.175
Conab	0.000	0.000	1.872	0.061
Panel C: Model with report days and May and October months as external regressors				
		Mean Equation		
Ar (1)	0.929	0.001	990.408	0.000***
Ma (1)	-0.907	0.000	-3523.501	0.000***
		Variance Equation		
α (1)	0.041	0.030694	206.5622	0.000***
β (1)	0.957	0.012614	130.0689	0.000***
IBGE	0.000	0.000	2.336	0.019*
Cepea	0.000	0.000	1.081	0.279
Conab	0.000	0.000	1.976	0.051*
MayOct	0.000015	0.000	194.814	0.000***
Panel 4: Model with report days, May and October months, and Monday as external regressors				
		Mean Equation		
Ar (2)	0.933	0.081	1099.5353	0.000***
Ma (2)	-0.913	0.094	-4640.498	0.000***
		Variance Equation		
α (1)	0.061	0.002	14.647	0.000***
β (1)	0.938	0.009	62.177	0.000***
IBGE	0.000	0.000	0.370	0.243
Cepea	0.000	0.000	0.565	0.737
Conab	0.000	0.000	1.408	0.986
MayOct	0.000	0.000	5.210	0.510
Monday	0.000	0.000	1.839	0.000*

Source: Elaborated by the author using research data. Note: Z-statistic for the parameters. $*p<.10$, $**p<.05$, $***p<.01$. α is the coefficient of the autoregressive terms of squared residuals and β is the coefficient of the autoregressive terms in conditional variance.

We observe that the models demonstrate significant volatility persistence, as the sum of alpha and beta is close to 1. The market takes several days to stabilize following a shock. As external regressors are added, the persistence tends to increase. This leads us to believe that returns react to new information entering the market. Starting from Panel B, we sought to accept or reject our hypothesis by incorporating report dummies. According to this estimation, only information released by IBGE is considered significant at the 10% level. The information that IBGE provides regarding animal slaughter is invaluable. It accurately reflects the stage of the livestock cycle we are in (MAPA, 2023).

In Panel C, we added the dummy variables for the harvest and offseason. As explained throughout this research, May and October mark the cattle market. May signifies the end of the rainy season and the beginning of the dry season, while October marks the return of rainfall. May is the month of cattle harvest when the animal supply is at its peak. In contrast, October is characterized by the return of rain, higher retention of animals in pastures, and lower supply. Furthermore, during these months, we sought to identify the presence of seasonality in other periods. As described in section 4.3, we calculated seasonal indices; however, the results pointed to the absence of this component. The findings are presented in the Table 21 in section 8.1 of the Appendix.

Hence, there is a tendency for increased trading volume and speculation, consequently generating volatility in these months (Oliveira, 2017; Carvalho and Felema, 2021). Our results indicate that these months are statistically different from the other months of the year in the cattle market. Indeed, the volume of contracts traded in May and October is either higher or changes the trend, showing an increase in volume compared to previous months. Regarding the response of reports, IBGE remained significant at the 10% level.

However, when we introduced the Monday dummy in Panel D, the response showed that none of the public reports analyzed in this study affected the volatility of BGI returns. The months also turn to non-significant. We note that Monday is statistically different at the 10% level from the other days of the week, likely due to the Monday effect. Table 20 summarizes the significant results from Table 19.

Table 21: Summary of the significance of the variables in the ARMA-GARCH models for BGI's log returns

Model 1	Significative?
Ar (1)	Yes
Ma (1)	Yes
$\boldsymbol{\alpha}$ (1)	Yes
$\boldsymbol{\alpha}$ (2)	Yes
Model 2	
Ar (1)	Yes
Ma (1)	Yes
$\boldsymbol{\alpha}$ (1)	Yes
$\boldsymbol{\beta}$ (1)	Yes
IBGE	Yes
Cepea	No
Conab	No
Model 3	
Ar (1)	Yes
Ma (1)	Yes
$\boldsymbol{\alpha}$ (1)	Yes
$\boldsymbol{\beta}$ (1)	Yes
IBGE	Yes
Cepea	No
Conab	No
MayOct	Yes
Model 4	
Ar (1)	Yes
Ma (1)	Yes
$\boldsymbol{\alpha}$ (1)	Yes
$\boldsymbol{\beta}$ (1)	Yes
IBGE	No
Cepea	No
Conab	No
MayOct	No
Monday	Yes

Source: Elaborated by the author using research data.

Indeed, this result was expected. The Brazilian cattle market possesses specific characteristics that help explain this outcome. Due to the use of technologies from studies organized by Embrapa and Public Universities, the cattle herd has grown, transitioning from the fourth-largest herd in the world in 1990 to the largest in 2015 (IBGE, 2016). Since then, we have remained at this level, surpassing the number of slaughtered animals each year. In 2009, the average slaughter of animals was 185,000 heads per year, while in 2022, 29.80 million cattle were slaughtered (ABIEC, 2009, 2023; IBGE, 2008). However, this evolution of the cattle market in terms of numbers has also been accompanied by market concentration on the part of demanders, primarily most slaughterhouses.

Since 2018, Forbes Brazil has published the Agro100 list of the 100 largest companies in the Brazilian agribusiness sector. Cattle-related companies hold prominent positions, with JBS ranked first, Marfrig Global Foods fifth, and Minerva fifteenth, when compared across all sectors (Forbes Brazil, 2022). The three companies mentioned above are the top three players in the cattle market. JBS's market share corresponds to 32.39% of the Brazilian market, followed by Marfrig (18.80%) and Minerva (13.41%). Together, Marfrig and Minerva still fall below JBS's market share (Foreign Trade Balance and Trade Statistics, 2022). Only three companies account for over 65% of the meat market in Brazil. We understand that this concentration among demanders is characterized as an oligopsony (Moita, 2014; Loiola *et al.*, 2019). This high concentration leads to a verticalized management, allowing large firms to have greater administrative and financial capacity to gather information (Isengildina-Massa, 2016).

In fact, several authors confirm the high market concentration concerning slaughterhouses in Brazil (Rodovalho, 2010; Moita and Goloni, 2020; Pinheiro *et al.*, 2015; Marques *et al.*, 2017; da Fonseca, 2018; Persona *et al.*, 2019). However, this characteristic is not unique to the Brazilian market. Karali *et al.* (2019), studying the effect of cattle market reports on future prices, identified that around the 2000s, the impact of reports disappeared in the United States.

Hoffman (1980) and Grunewald (1993) studied the effect of reports on future prices of beef and pork in the United States. Both analyzed the same report, Cattle on Feed, with the only difference being that Hoffman examined prices for the first expiration, while Grunewald examined prices for the first, second, and third expirations. Both authors found that the reports influenced future prices. The study by

Isengildina *et al.* (2006) already signaled that cattle prices no longer reacted to reports. Karali (2012) found some reaction in beef prices in the United States. However, this author disaggregated the reports, identifying that some of them affected prices.

Isengildina-Massa *et al.* (2016) studied the volatility of returns on future prices of different commodities concerning USDA report publication. Their findings showed that among all commodities, only cattle showed that reports had no impact. Furthermore, they found that the impact of reports on the cattle market started to decline in the 2000s. Companies with vertical coordination enjoy greater control over production planning within their operations. It reduces market volatility and enhances supply predictability (Isengildina-Massa, 2016). We have been experiencing the same situation in Brazil. The market concentration in the cattle sector may be a crucial factor in the limited impact of these reports.

The research of Isengildina-Massa *et al.* (2019) identified that traditional volatility models do not capture the effects of reports in concentrated markets. However, these effects still exist. Using a surprise test methodology, the authors found that reports still impact the market, but the magnitude of the surprise effect has decreased. The analyzed surprise represents the difference in price expectations between analysts from private and public companies. Based on this result, the authors conclude that market analysts have become more adept at anticipating USDA information in more concentrated and less variable cattle and swine markets.

Since our cattle market exhibits similar concentration characteristics, it is plausible that market analysts may also anticipate information. However, we cannot definitively state this without statistical confirmation. Unfortunately, we cannot measure the surprise for the Brazilian market as we do not have access to private sources. Furthermore, the Brazilian futures market for commodities remains relatively illiquid compared to others. This low liquidity also hinders the ability of information to influence price expectations, as indicated by the Efficient Market Hypothesis (EMH).

Our results, in line with those presented in the literature, do not diminish or exclude the need for and role of public reports in the market. We do not contend that the reports have lost all their informational significance. It is possible that markets still react to the information contained in these reports. However, such reactions may not be discernible through the relatively simple price volatility tests commonly employed in the existing literature, including the study by Isengildina-Massa *et al.* (2016).

However, we highlight to policymakers the possibility that public reports may not be distributed efficiently. In a concentrated market, public information risks ceasing to be a public good as rivalry emerges between the public and private sectors. This creates a scenario where one group provides information services while another purchases them. However, within this context, achieving market efficiency becomes challenging. As previously discussed, if the market is inefficient, ensuring a level playing field may not be possible. Consequently, prices may not accurately reflect supply and demand, leading to unfair prices for consumers and less reliable information for investors.

6. Conclusion

This study analyzed the impact of information from three national agricultural reports (Pesquisa Trimestral de Abates, AgroConab, and AgroMensal) on the formation of abnormal returns and volatility in the futures prices of Brazilian live cattle on the B3 Stock Exchange. Our research hypothesis was that the Brazilian cattle market is semi-efficient based on the analysis of these three public reports. The study employed Event Study methodology, Cumulative Abnormal Returns (CAR), and GARCH methodologies. Our sample covers the years 2017 to 2023, with 87 reports analyzed.

While high market concentration may compromise market efficiency, the recent increase in BGI contracts liquidity can enhance it. Additionally, Brazilian live cattle, a derivative product from a complex market, represents an extremely relevant commodity both nationally and internationally. The analysis of market efficiency, specifically in its semi-strong form, has not yet been explored in this context. This study aimed to fill the gap in the Brazilian live cattle literature.

Our results indicate the non-rejection of this hypothesis. Although we identified some abnormal returns, we cannot assert that they follow a consistent pattern with Fama's (1970) definition of semi-strong form efficiency. Additionally, the GARCH analysis allowed us to isolate certain external effects, such as the Monday effect. The non-rejection of our hypothesis suggests that cattle commodity prices already reflect all available public information, making it difficult for investors to achieve abnormal returns based solely on this data.

Public information in agribusiness is an asset that benefits the market, government, and producers, playing a pivotal role in building a more efficient, resilient, and sustainable sector. For the market, accurate and timely information is essential for price setting, investment decisions, and risk management, allowing participants to adapt to ever-evolving conditions. Government authorities rely on reliable agribusiness data to formulate agricultural policies, regulations, and strategic plans.

Additionally, public information enhances transparency and trust within the sector, attracting investments and spurring economic development. Access to information is vital for producers to optimize production, efficiently manage resources, and address challenges like climate change and global market dynamics.

Hence, policymakers need to be mindful of the value of information to the market, striving to establish a comprehensive dataset that is disseminated promptly.

Transparency can increase investor confidence, improve market liquidity, and attract more capital to the sector. For producers and agribusiness companies, understanding market efficiency can help them better plan their operations and make more informed decisions about production and sales. For policymakers, evidence of market efficiency suggests that policies focused on improving the quality and accessibility of information can be beneficial, promoting a more resilient and sustainable environment for all market participants.

The limitations of this study include the database used, which does not contain all public reports released in Brazil. Additionally, there are private agencies that provide reports for a fee, which were not considered in our analysis. More accurate information can also be obtained using intraday data. We recommend that future studies analyze private reports and utilize intraday data to achieve more robust and detailed results.

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8. Appendix

8.1 Descriptive appendix

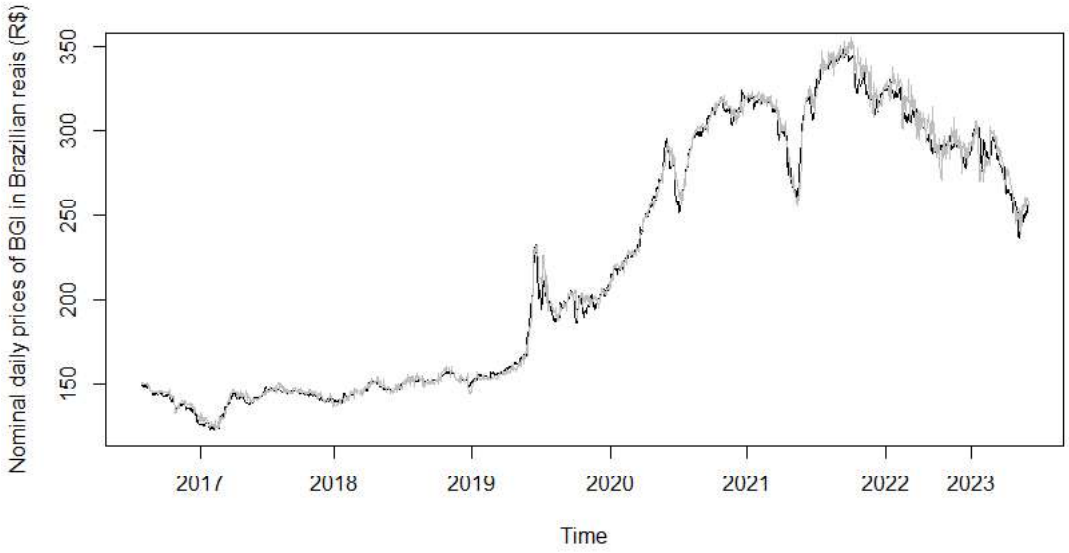


Figure 7: Brazilian live cattle future daily prices and CEPEA/b3 spot prices between 2017 and 2023

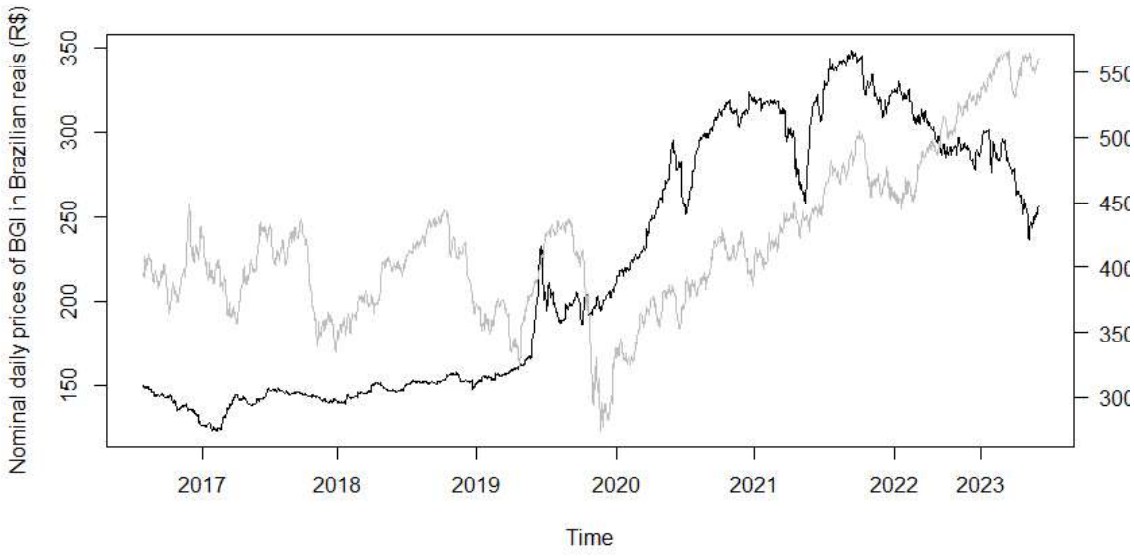


Figure 8: Brazilian live cattle future daily prices and GSCI index between 2017 and 2023

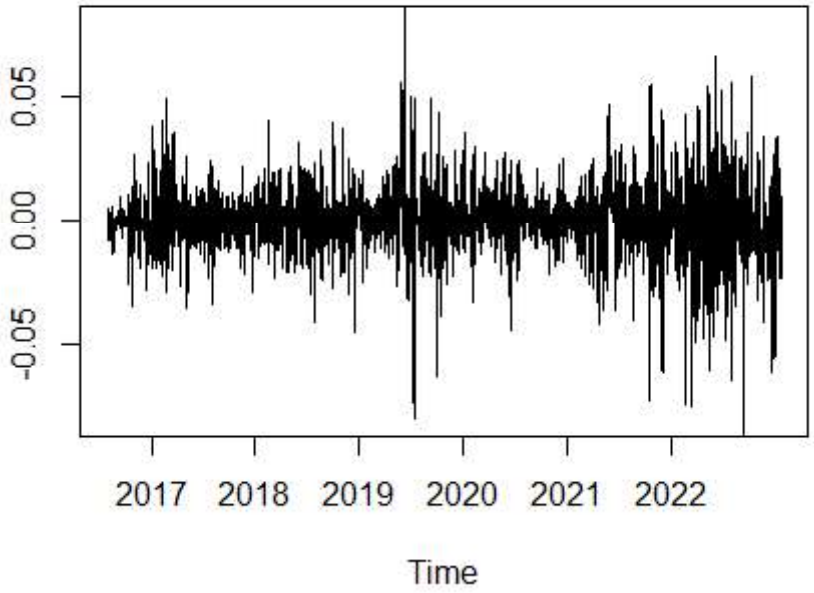


Figure 9: CEPEA/B3 live cattle spot returns between 2017 and 2023

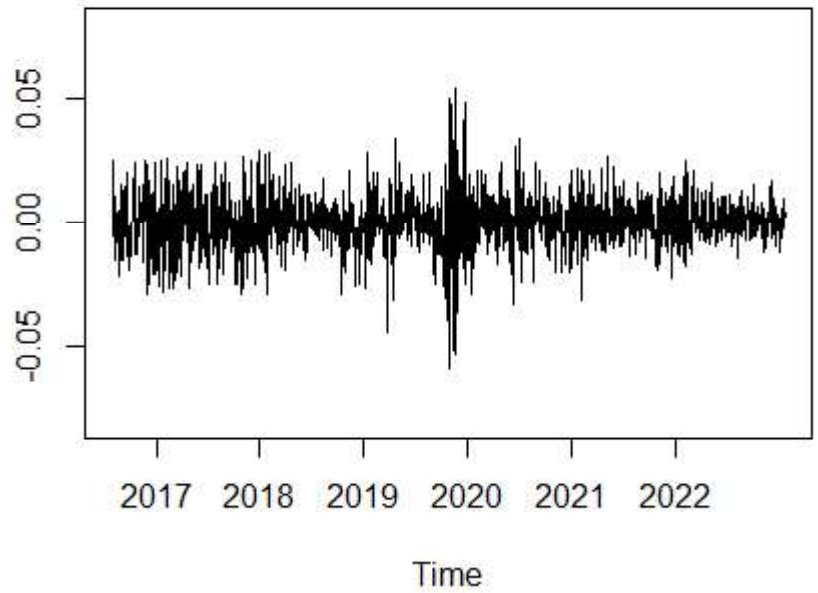


Figure 10: GSCI returns between 2017 and 2023

Table 22: Seasonality index

Month	Seasolanity indices
January	1,025
February	1,032
March	1,027
April	1,005
May	0,972
June	0,970
July	0,976
August	0,982
September	0,991
October	0,969
November	1,028
December	1,023

Source: Elaborated by the author using research data

8.2 CAR appendix

Table 23: CAR results in a [-1, 0, +1] Event Study window between January 2, 2017, and June 28, 2023.

Event Day	AR			CAR	p-valor	t-value
	-1	0	1			
Panel A1: Significance CAR days of IBGE reports 27 events were studied, 3 were significant, and 24 were not significant						
2017-03-15	0.430	0.600	-0.550	0.480	0.4219	0.8031
2017-06-14	0.730	0.540	-0.390	0.880	0.8801	0.1504
2017-09-14	-0.960	-0.540	-0.420	-1.920	0.5826	-0.5495
2017-12-14	0.330	0.160	-0.140	0.350	0.7698	0.2927
2018-03-21	-0.270	-0.270	-0.170	-0.710	0.3782	-0.8813
2018-06-14	-0.790	-0.010	0.470	-0.330	0.4932	-0.6853
2018-09-12	-0.200	0.320	-0.200	-0.080	0.9425	0.0721
2018-12-12	0.440	-0.020	-0.260	0.160	0.6980	0.3880
2019-03-14	0.280	0.210	0.280	0.770	0.1382	1.4825
2019-06-13	0.710	0.690	0.260	1.660	0.1491	1.4426
2019-09-12	0.170	-0.140	-0.040	-0.010	0.8581	-0.1787
2019-12-12	-3.020	2.430	0.460	-0.130	0.9747	-0.0317
2020-03-19	1.270	3.680	0.730	5.680	0.0084***	2.6348
2020-06-10	-0.840	1.500	0.370	1.030	0.4286	0.7916
2020-09-10	0.570	0.800	-0.380	0.990	0.3143	1.0063
2020-12-10	-0.050	-0.770	-1.590	-2.410	0.2868	-1.0653

2021-03-18	-1.120	-0.270	-0.900	-2.290	0.0279**	-2.1989
2021-06-08	-0.320	0.140	-0.570	-0.750	0.5284	-0.6304
2021-09-10	-2.350	0.080	1.410	-0.860	0.5379	-0.6160
2021-12-08	-0.240	-2.140	-0.090	-2.470	0.3674	-0.9013
2022-03-15	-0.100	-0.610	-0.760	-1.470	0.3251	-0.9840
2022-06-08	-0.110	0.810	0.730	1.430	0.4456	0.7628
2022-09-06	-0.980	0.310	1.370	0.700	0.5696	0.5686
2022-12-07	0.330	-0.580	-0.550	-0.800	0.6022	-0.5213
2023-01-12	-0.240	0.060	0.060	-0.120	0.8932	-0.1342
2023-05-15	-0.380	0.180	-0.900	-1.100	0.6325	-0.4783
2023-06-06	3.380	1.540	1.010	5.930	0.0731*	1.7924
Panel A2: Significance CAR days of Cepea reports 46 events were studied, 6 were significant, and 40 were not significant.						
2017-06-02	-3.410	0.160	0.250	-3.000	0.7613	-0.3037
2017-07-24	0.060	0.400	-0.520	-0.060	0.2428	0.8082
2017-08-25	0.950	0.070	0.750	1.770	0.8082	0.2428
2018-11-08	-0.590	0.250	-0.050	-0.390	0.6894	-0.3997
2018-12-07	-0.030	-0.290	0.180	-0.140	0.7943	-0.2607
2019-04-05	-0.130	0.130	0.650	0.650	0.8155	0.4148
2019-05-08	-0.140	-0.140	-0.040	-0.320	0.7500	-0.3186
2019-06-05	0.380	0.430	-0.150	0.660	0.9164	0.1050
2019-12-05	-3.460	-0.210	2.090	-1.580	-0.6166	0.5375
2020-03-06	0.340	-0.800	-1.680	-2.140	0.4474	-0.7597
2020-04-08	1.460	0.300	0.180	1.940	0.6362	0.5247
2020-05-06	0.430	0.220	-0.960	-0.310	0.8704	-0.1631
2020-06-04	0.770	1.520	-0.280	2.010	0.4520	0.7521
2020-06-04	-1.120	1.100	0.960	0.940	0.4520	0.7521
2020-07-06	0.330	-0.670	-0.520	-0.860	0.5826	0.5495
2020-08-05	0.840	0.590	0.610	2.040	0.3120	-1.0110
2020-09-08	0.960	-0.560	-0.500	-0.100	0.0745*	1.7836
2020-10-06	-0.110	0.080	1.190	1.160	0.9419	0.0729
2020-11-05	-1.300	-0.420	-1.460	-3.180	0.5476	0.6013
2020-12-04	-0.580	0.320	-0.180	-0.440	0.1238	-1.5390
2021-03-09	-0.190	-0.110	-0.040	-0.340	0.7633	-0.3012
2021-04-06	-0.050	-1.010	-0.230	-1.290	0.9380	-0.0778
2021-05-05	0.320	-0.380	0.240	0.180	-1.0128	0.3112
2021-06-07	0.650	0.350	0.520	1.520	0.9868	-0.0165
2021-07-06	0.310	-0.520	0.790	0.580	0.2353	1.1868
2021-08-04	-1.450	0.390	3.320	2.260	0.9132	0.1090
2021-09-03	3.680	-0.340	-2.350	0.990	0.0699*	1.812
2021-10-06	1.990	2.730	2.060	6.780	0.6491	0.4551
2021-11-05	0.030	-0.660	-0.230	-0.860	0.0303**	2.1659
2021-12-06	-0.500	-2.490	-0.050	-3.040	0.7606	-0.3047
2022-01-05	-0.460	-0.300	-0.810	-1.570	0.2223	-1.2206
2022-02-03	-0.550	-1.110	-0.380	-2.040	0.8944	0.1328
2022-03-07	-0.720	0.090	-0.710	-1.340	0.2020	-1.2760
2022-04-06	-0.330	0.120	-0.020	-0.230	0.3975	-0.8460
2022-05-05	1.710	0.180	-0.070	1.820	0.7119	-0.3693
2022-06-06	-1.270	-0.890	-0.510	-2.670	0.2992	1.0381
2022-08-09	0.430	1.340	0.260	2.030	0.0588*	-1.8899

2022-09-08	-0.740	-0.430	0.380	-0.790	0.1276	1.5236
2022-10-06	1.460	0.010	-1.130	0.340	0.5139	-0.6527
2022-11-07	0.330	-0.580	-0.580	-0.830	0.8045	0.2476
2022-12-07	-0.930	-0.350	-0.890	-2.170	0.5971	-0.5285
2023-01-04	0.710	0.110	0.510	1.330	0.1475	-1.4484
2023-02-03	-0.860	-0.120	-2.010	-2.990	0.3876	0.8640
2023-03-07	-0.370	-1.380	0.470	-1.280	0.1912	-1.3070
2023-04-06	0.330	0.600	0.550	1.480	0.5887	-0.5407
2023-05-04	1.630	1.800	1.220	4.650	0.5557	0.5892
2023-06-06	-3.410	0.160	0.250	-3.000	0.0332**	2.1295
Panel A3: Significance CAR days of Conab 14 events were studied, two were significant, and 12 were not significant.						
2021-06-21	-0.610	0.170	-0.110	-0.550	0.8305	-0.2140
2021-07-21	-0.120	-0.310	-0.640	-1.070	0.3300	-0.9741
2021-08-27	1.030	-1.100	0.430	0.360	0.6740	0.4202
2021-09-21	0.360	0.110	-0.640	-0.170	0.6335	0.4768
2022-07-29	0.430	0.450	-2.180	-1.300	0.5235	-0.6380
2022-08-31	-0.070	0.350	-1.090	-0.810	0.6936	-0.3939
2022-09-22	0.340	-1.040	0.150	-0.550	0.7754	-0.2853
2022-11-24	0.540	0.000	0.140	0.680	0.6261	0.4872
2022-12-22	-0.530	-0.360	0.290	-0.600	0.6982	-0.3877

Source: Elaborated by the author using research data

Note: *Z*-statistic for the mean abnormal return. $*p<.10$, $**p<.05$, $***p<.01$. Non-significant results in the appendix. Results with spot indicator for live cattle CEPEA/B3

Table 24: CAR results in a [-1, 0, +1] Event Study window between January 2, 2017, and June 28, 2023

Event Day	AR			CAR	p-valor	t-value
	-1	0	1			
Panel A1: Significance CAR days of IBGE reports						
2017-03-15	-1.000	1.400	1.160	1.560	0.6728	0.4223
2017-06-14	-0.420	-2.160	-0.660	-3.240	0.5615	-0.5806
2017-09-14	2.240	1.040	0.260	3.540	0.1921	-13.045
2017-12-14	-2.720	-0.650	-0.810	-4.180	0.8976	-0.1288
2018-03-21	-0.270	-1.180	-2.540	-3.990	0.0042***	-28.617
2018-06-14	-0.460	3.360	-0.420	2.480	0.4838	-0.7001
2018-09-12	-1.820	2.310	-0.450	0.040	0.7842	0.2739
2018-12-12	-0.290	0.780	-0.230	0.260	0.6641	0.4343
2019-03-14	-0.270	0.910	0.590	1.230	0.4450	0.7637
2019-06-13	1.200	-0.040	0.090	1.250	0.4342	0.7820
2019-09-12	-0.290	0.290	1.990	1.990	0.9405	0.0747
2019-12-12	0.450	-0.290	-0.560	-0.400	0.9063	0.1177
2020-03-19	0.490	-1.360	-0.900	-1.770	0.0084 ***	26.367
2020-06-10	3.550	-2.070	4.990	6.470	0.0006	0.0282

2020-09-10	0.590	0.940	1.000	2.530	0.6931	-0.3947
2020-12-10	0.860	3.300	0.610	4.770	0.1341	-14.981
2021-03-18	-0.320	-0.860	0.030	-1.150	0.0592*	-18.864
2021-06-08	0.670	0.500	-0.970	0.200	0.3074	-10.208
2021-09-10	0.620	0.490	-1.340	-0.230	0.7896	0.2668
2021-12-08	0.010	-0.990	-0.910	-1.890	0.2941	-10.493
2022-03-15	0.800	0.370	0.900	2.070	0.5285	-0.6304
2022-06-08	0.770	-0.750	-0.710	-0.690	0.5256	0.6348
2022-09-06	-0.150	-0.430	0.170	-0.410	0.2945	10.483
2022-12-07	-0.740	-0.010	-0.020	-0.770	0.6461	-0.4592
2023-01-12	-0.240	0.210	-0.290	-0.320	0.6461	-0.4592
2023-05-15	-0.670	-0.030	1.690	0.990	0.7044	-0.3794
2023-06-06	-0.010	0.280	-0.260	0.010	0.1784	13.456
Panel B: Significance CAR days of Conab reports						
2021-06-21	-0.610	0.170	-0.110	-0.550	0.3286	-0.9769
2021-07-21	-0.120	-0.310	-0.640	-1.070	0.6017	-0.5219
2021-08-27	1.030	-1.100	0.430	0.360	0.2324	11.943
2021-09-21	0.360	0.110	-0.640	-0.170	0.9873	-0.0160
2022-07-29	0.430	0.450	-2.180	-1.300	0.6273	0.4855
2022-08-31	-0.070	0.350	-1.090	-0.810	0.2994	10.378
2022-09-22	0.340	-1.040	0.150	-0.550	0.6669	-0.4304
2022-11-24	0.540	0.000	0.140	0.680	0.7613	0.3038
2022-12-22	-0.530	-0.360	0.290	-0.600	0.4752	-0.7141
2023-01-24	-0.390	-0.500	-0.210	-1.100	0.2044	-12.692
2023-02-23	-3.850	0.280	-3.280	-6.850	0.0003***	-35.803
2023-03-17	0.180	0.060	-0.010	0.230	0.9551	-0.0564
2023-05-23	1.950	2.480	-1.950	2.480	0.0257**	22.304
2023-06-20	0.820	-0.420	1.390	1.790	0.4448	0.7641
Panel C: Significance CAR days of Cepea reports						
2017-06-02	-3.410	0.160	0.250	-3.000	0.7204	-0.3579
2017-07-24	0.060	0.400	-0.520	-0.060	0.4974	0.6786
2017-08-25	0.950	0.070	0.750	1.770	10.180	0.3087
2018-11-08	-0.590	0.250	-0.050	-0.390	-0.2868	0.7743
2018-12-07	-0.030	-0.290	0.180	-0.140	0.9369	-0.0792
2019-04-05	-0.130	0.130	0.650	0.650	0.5381	0.6157
2019-05-08	-0.140	-0.140	-0.040	-0.320	0.5222	0.6399
2019-06-05	0.380	0.430	-0.150	0.660	0.0026***	30.119
2019-12-05	-3.460	-0.210	2.090	-1.580	0.3922	-0.8556
2020-03-06	0.340	-0.800	-1.680	-2.140	0.4361	-0.7788
2020-04-08	1.460	0.300	0.180	1.940	0.8382	0.2042
2020-05-06	0.430	0.220	-0.960	-0.310	-0.1613	0.8718

2020-06-04	0.770	1.520	-0.280	2.010	0.3380	0.7353
2020-07-06	-1.120	1.100	0.960	0.940	0.9561	0.0550
2020-08-05	0.330	-0.670	-0.520	-0.860	0.6289	-0.4833
2020-09-08	0.840	0.590	0.610	2.040	0.0667*	18.338
2020-10-06	0.960	-0.560	-0.500	-0.100	0.1589	14.086
2020-11-05	-0.110	0.080	1.190	1.160	0.1589	14.086
2020-12-04	-1.300	-0.420	-1.460	-3.180	0.0584*	-18.929
2021-03-09	-0.580	0.320	-0.180	-0.440	0.9587	0.0518
2021-04-06	-0.190	-0.110	-0.040	-0.340	0.9466	0.0670
2021-05-05	-0.050	-1.010	-0.230	-1.290	0.3934	-0.8536
2021-06-07	0.320	-0.380	0.240	0.180	0.6585	-0.4420
2021-07-06	0.650	0.350	0.520	1.520	13.263	0.1847
2021-08-04	0.310	-0.520	0.790	0.580	0.9514	-0.0609
2021-09-03	-0.910	1.070	3.980	4.140	0.0073***	26.847
2021-10-06	3.680	-0.340	-2.350	0.990	0.6771	0.4164
2021-11-05	1.990	2.730	2.060	6.780	0.0198**	23.302
2021-12-06	-0.930	-0.050	-0.520	-1.500	0.6042	-0.5184
2022-01-05	-0.500	-2.490	-0.050	-3.040	0.3037	-10.284
2022-02-03	-0.460	-0.300	-0.810	-1.570	0.7421	0.3291
2022-03-07	-0.550	-1.110	-0.380	-2.040	0.2974	-10.420
2022-04-06	-0.720	0.090	-0.710	-1.340	0.9206	0.0997
2022-05-05	-0.330	0.120	-0.020	-0.230	0.9003	-0.1253
2022-06-06	1.710	0.180	-0.070	1.820	0.3144	10.061
2022-08-09	-1.270	-0.890	-0.510	-2.670	0.0011***	-32.510
2022-09-08	0.430	1.340	0.260	2.030	0.0193**	23.392
2022-10-06	-0.740	-0.430	0.380	-0.790	0.4510	-0.7537
2022-11-07	1.460	0.010	-1.130	0.340	0.6985	0.3874
2022-12-07	0.330	-0.580	-0.580	-0.830	0.6599	-0.4400
2023-01-04	-0.930	-0.350	-0.890	-2.170	0.5395	-0.6136
2023-02-03	0.710	0.110	0.510	1.330	0.4268	0.7947
2023-03-07	-0.860	-0.120	-2.010	-2.990	0.0976*	-16.566
2023-04-06	-0.370	-1.380	0.470	-1.280	0.5181	-0.6463
2023-05-04	0.330	0.600	0.550	1.480	0.5181	-0.6463
2023-06-06	1.630	1.800	1.220	4.650	0.0749*	17.813

Source: Elaborated by the author using research data

Note: *Z*-statistic for the mean abnormal return. $*p<.10$, $**p<.05$, $***p<.01$. Non-significant results in the appendix. Results with GSCI live cattle index proxy.

Table 25: CAR results in a [-3,+3] Event Study window between January 2, 2017, and June 28, 2023

Event Day	AR							CAR	p-value	Test t
	-3	-2	-1	0	1	2	3			
Panel B1: Significance CAR days of IBGE reports using CEPEA/B3 proxy										
2020-03-19	**1.2700**	**3.6800**	**0.7300**	**5.6800**	**0.0046*****	**2.8330**	**2020-03-19**	**1.2700**	**3.6800**	1.774
2021-09-10	0.033***	-0.011***	-0.020***	0.004***	0.008***	0.004	0.022***	0.040	0.041**	2.047
Panel B2: Significance CAR days of Cepea reports using CEPEA/B3 proxy										
2017-06-02	0.0052***	-0.0344***	0.0042***	0.0010	-0.0093***	-0.0038***	0.0047***	-0.0324	0.019**	-2.3399
2019-12-05	-0.0807***	-0.0196***	-0.0444***	-0.0050	0.0200***	-0.0259***	-0.0108***	-0.1664***	0.000***	-4.5178
2020-11-05	-0.0017*	0.0519***	0.0005	-0.0001	0.0105**	-0.0094***	0.0080***	0.0597	0.001***	3.1041
2021-05-05	0.0009	-0.0242***	-0.0009	-0.0095***	-0.0021*	-0.0047***	0.0094***	-0.0311	0.076*	-1.7726
2021-09-03	0.0017*	-0.0480***	-0.0155***	0.0032***	0.0325***	-0.0059***	-0.0255***	-0.057	0.000***	-5.243
2021-10-06	-0.0457***	-0.0298***	0.0393***	-0.0097***	-0.0243***	0.0161**	-0.0045*	-0.0586	0.028**	-2.1943
2021-11-05	0.0711***	-0.0056	0.0242*	0.0280***	0.0223***	0.0175	0.0349***	0.1924	0.000***	4.9968
2022-04-06	-0.0525***	-0.0039***	-0.0067***	0.0004*	-0.0050***	0.0020**	0.0061**	-0.0596	0.000***	-4.5629
2022-05-05	-0.0364***	0.0160***	-0.0087***	0.0029*	-0.0020	-0.0130***	0.0040***	-0.0372	0.084*	-1.7259
Panel B3: Significance CAR days of Conab reports using CEPEA/B3 proxy										
2021-08-27	-0.0010*	0.0008	0.0022***	0.0014**	0.0016	0.0025**	-0.0467***	-0.0392	0.0005***	-3.4939
2023-02-23	-0.0067	0.0028*	-0.0387***	0.0023**	-0.0326***	-0.0150***	-0.0097***	-0.0976	0.0000***	-4.1841

Source: Elaborated by the author using research data

Note: *Z*-statistic for the mean abnormal return. ∗p<.10, ∗∗p<.05, ∗∗∗p<.01. Non-significant results in the appendix. Results with GSCI live cattle index proxy.

8.3 GARCH appendix

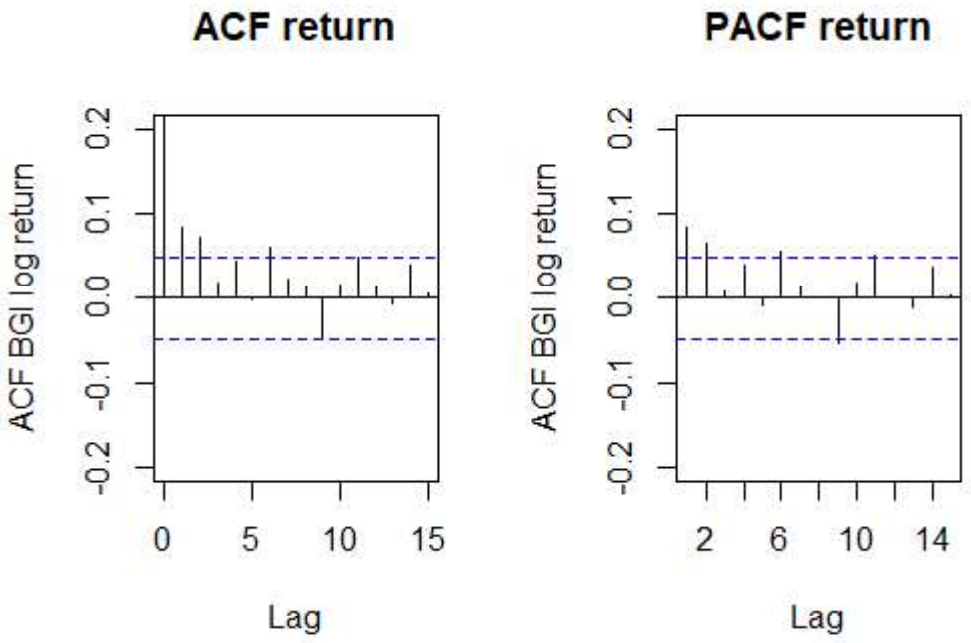


Figure 11: Auto and Partial Correlation Function of BGI log returns

Table 26: ARMA(1,1) model estimate for BGI log returns

	Estimate	Std. Error	z-value	p-valuee
Ar (1)	0.74869	0.12801	5.8485	0.000***
Ma (1)	-0.67371	0.14309	-4.7085	0.000***

Source: Elaborated by the author using research data $*p<.10$, $**p<.05$, $***p<.01$.

Table 27: AIC (Akaike Information Criterion): Criterion for Model Selection

Model	AIC
ARMA (1,1)	-10515.6
ARMA (2,2)	-10515.93
ARMA (1,2)	-10516.62
ARMA (2,1)	-10517.65
ARMA (6,0)	-10517.25

Source: Elaborated by the author using research data

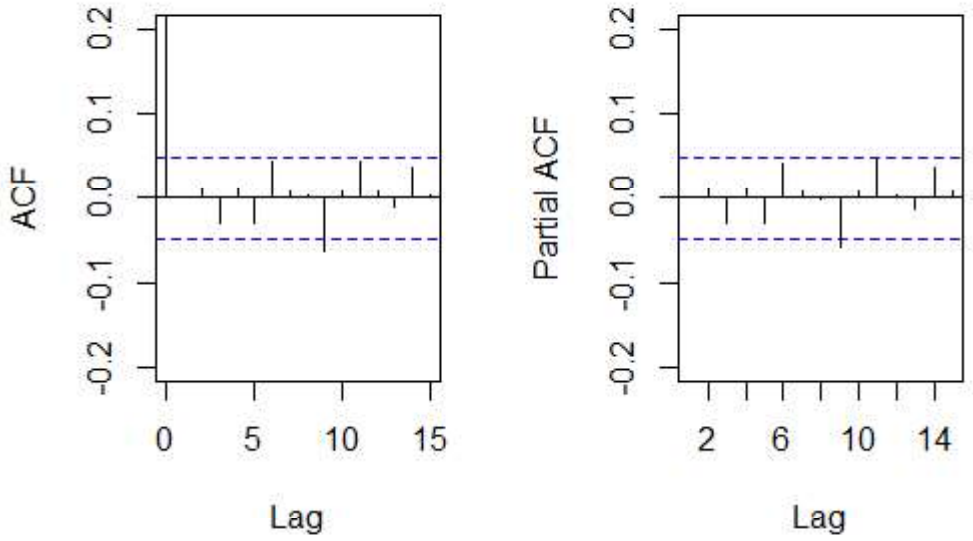


Figure 12: Standard residuals auto and Partial Correlation Function of ARMA(1,1)

Table 28: ARMA (1,1) model fitness tests

Test	Variable	p-value	Result	Implication
Box-Ljung	Standardized residuals	0.2358	Do not reject the H0	Without serial correlation
Box-Ljung	Squared residuals	2.2e-16	Do not reject the H0	There is serial correlation in squared residuals
ARCH LM-test	Squared residuals	2.033e-06	Reject H0	There is an ARCH effect

Source: Elaborated by the author using research data $*p<.10$, $**p<.05$, $***p<.01$.

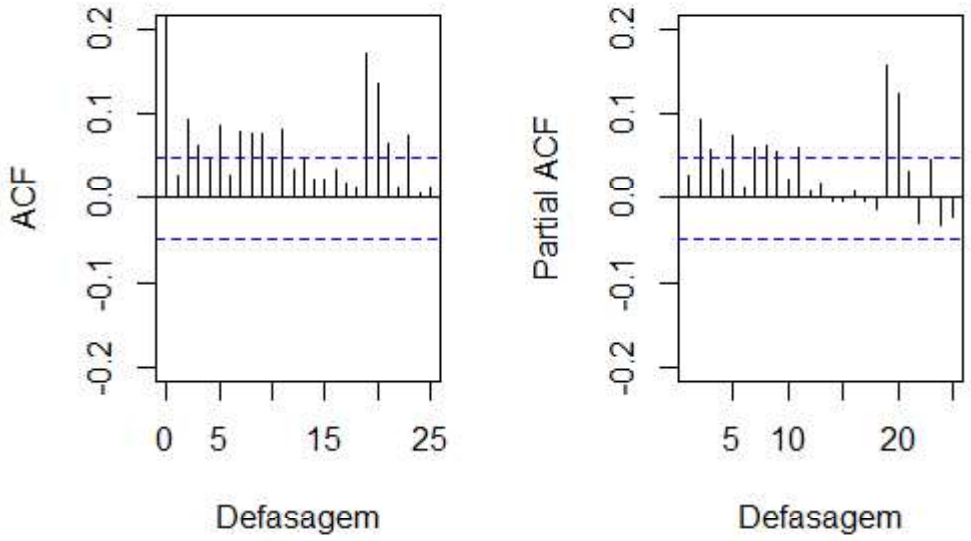


Figure 13: Squared residuals auto and Partial Correlation Function of ARMA(1,1)

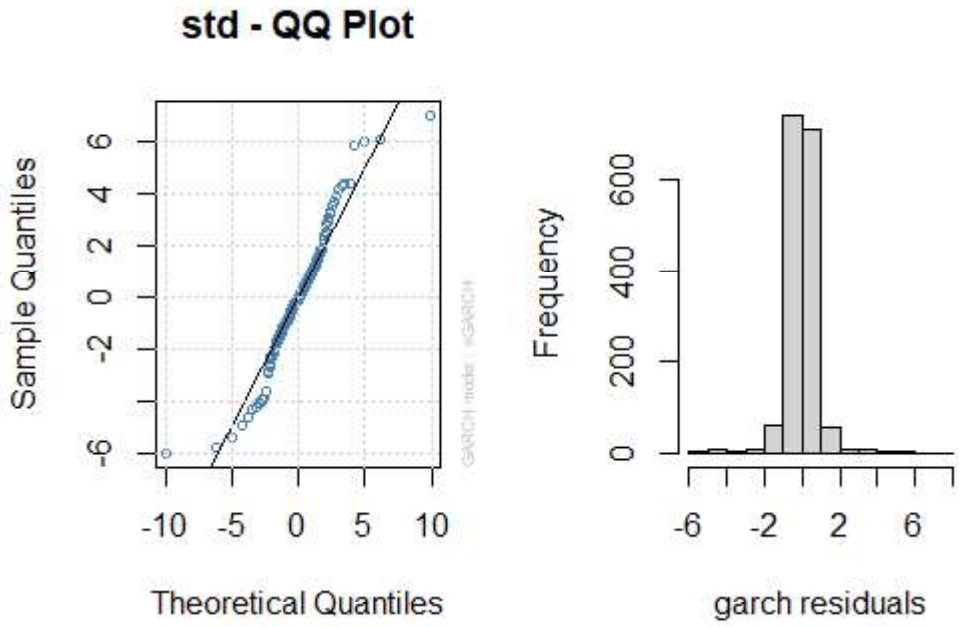


Figure 14: QQPlot Graph and Histogram of Model 1 ARMA(1,1)GARCH(2,0)

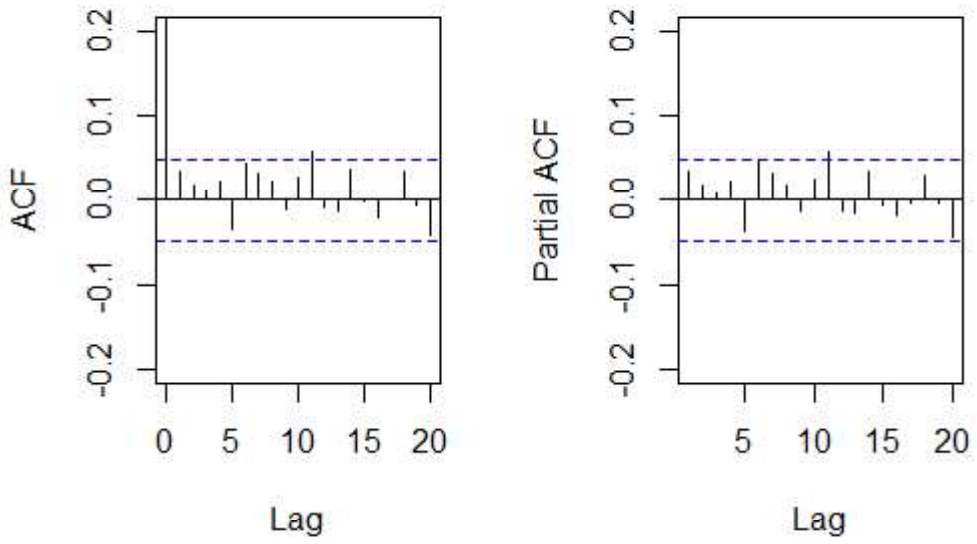


Figure 15: Standard residuals auto and Partial Correlation Function of Model 1 ARMA(1,1)GARCH(2,0)

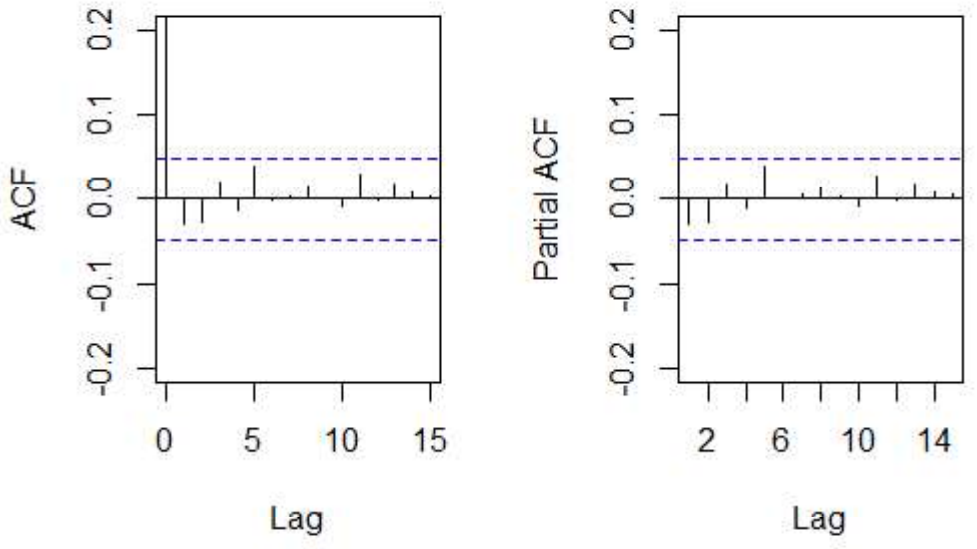


Figure 16:Squared residuals auto and Partial Correlation Function of Model 1 ARMA(1,1) GARCH(2,0)

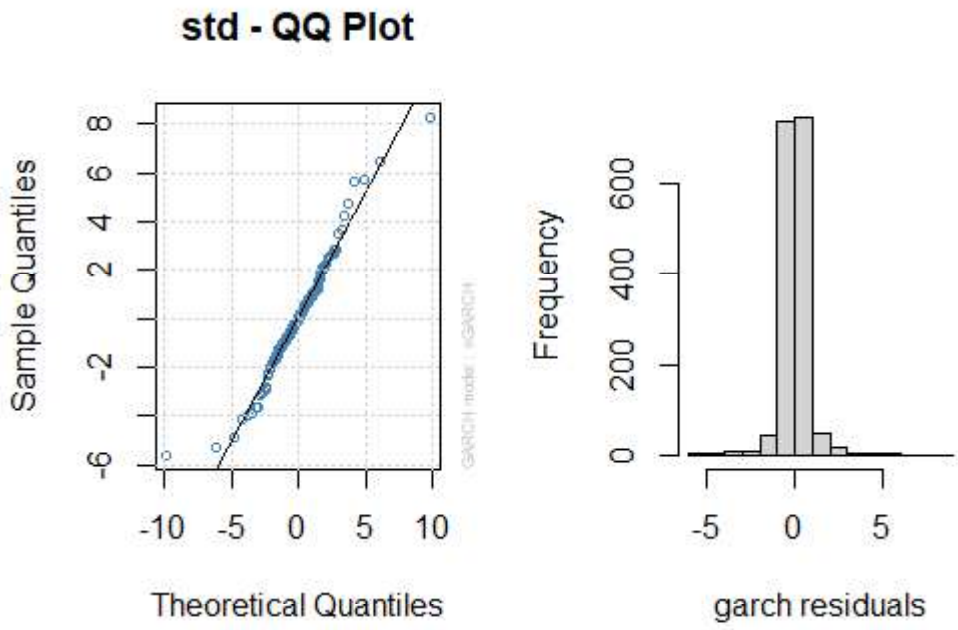


Figure 17: QQPlot Graph and Histogram of Model 2 ARMA(1,1)GARCH(1,1)

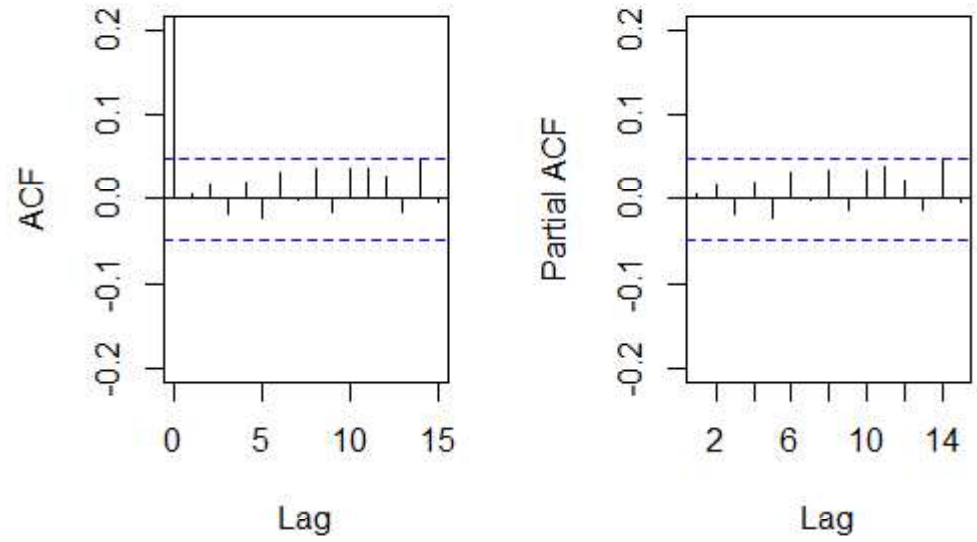


Figure 19: Standard residuals auto and Partial Correlation Function of Model 2 ARMA(1,1) GARCH (1,1)

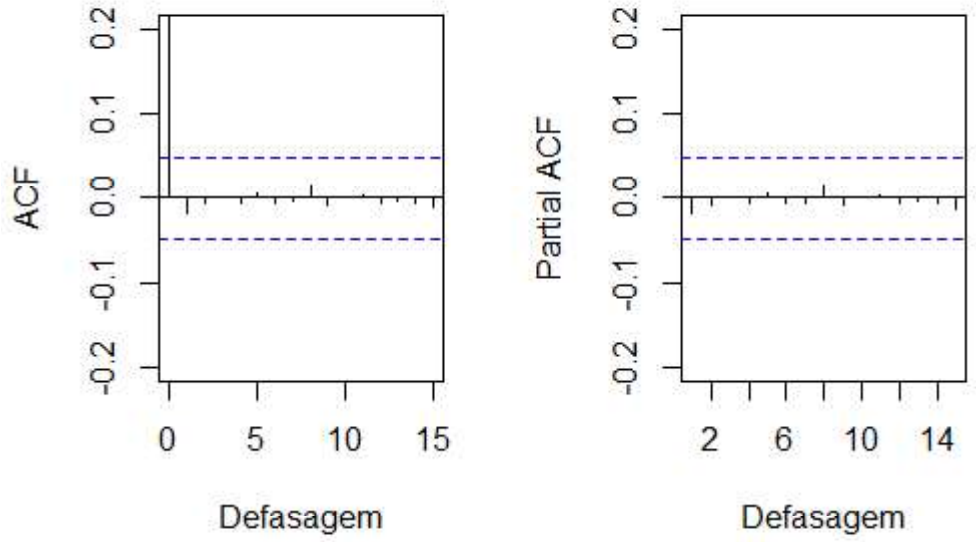


Figure 20: Squared residuals auto and Partial Correlation Function of Model 2 ARMA(1,1) GARCH(1,1)

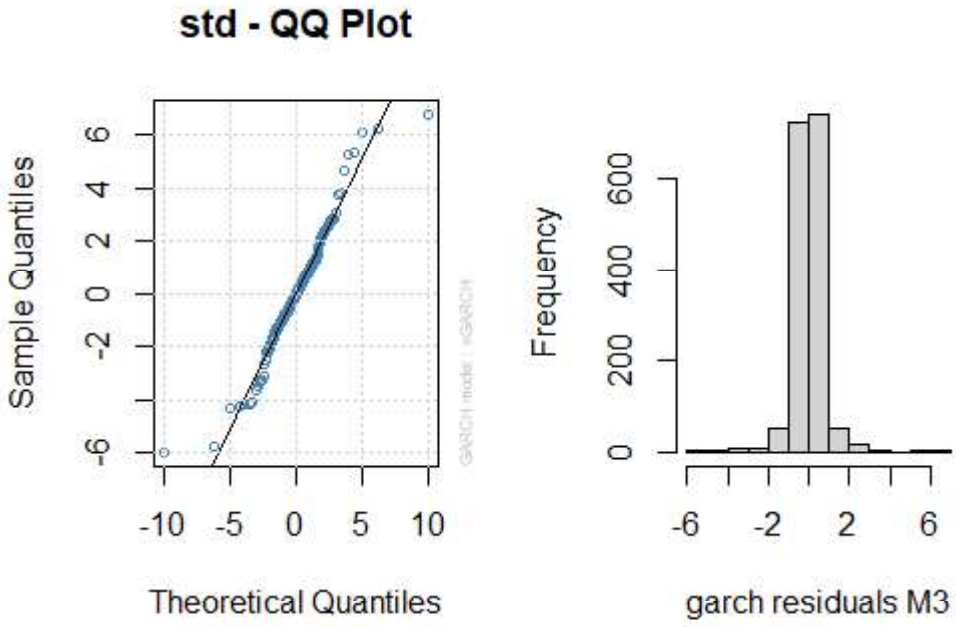


Figure 21: QQPlot Graph and Histogram of Model 3 ARMA(1,1)GARCH(1,1)

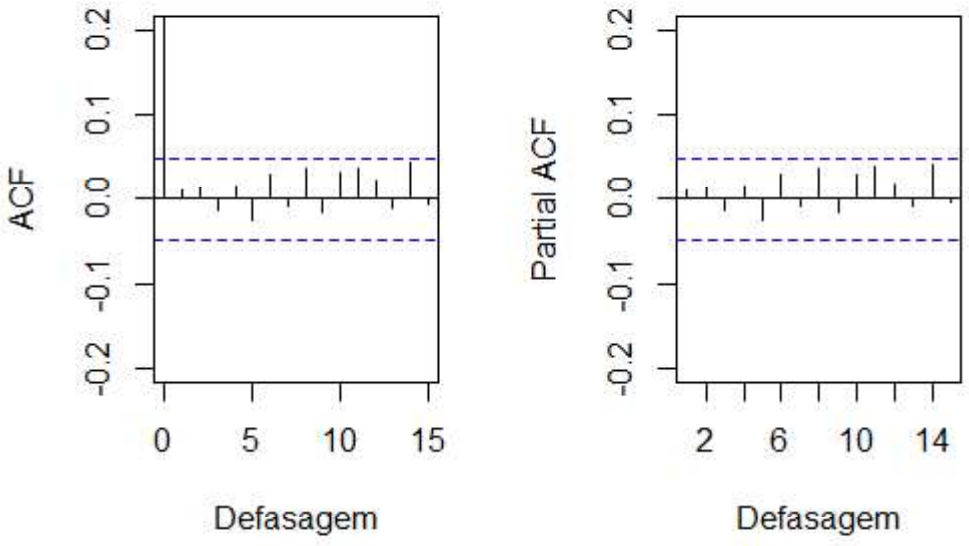


Figure 22: Standard residuals auto and Partial Correlation Function of Model 3 ARMA(1,1) GARCH(1,1)

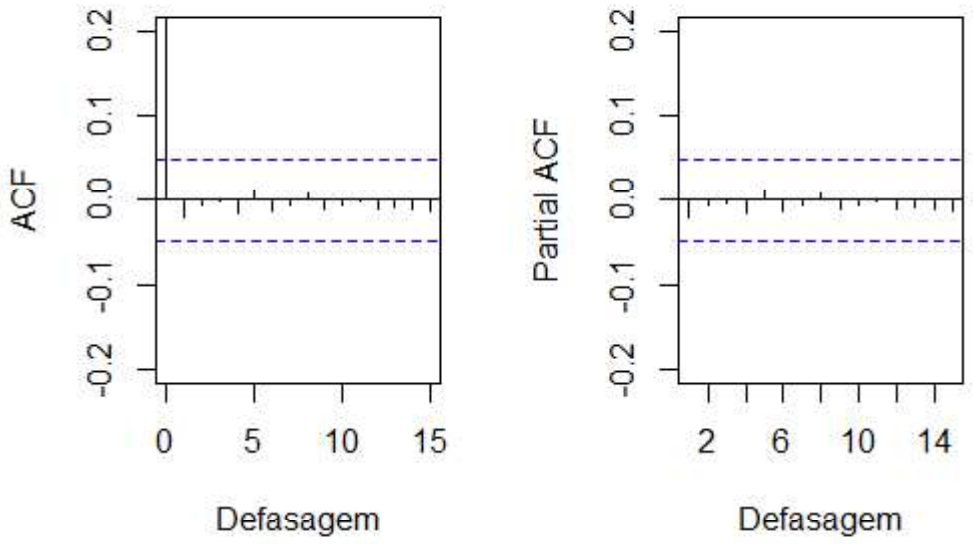


Figure 23: Squared residuals auto and Partial Correlation Function of Model 3 ARMA(1,1) GARCH(1,1)

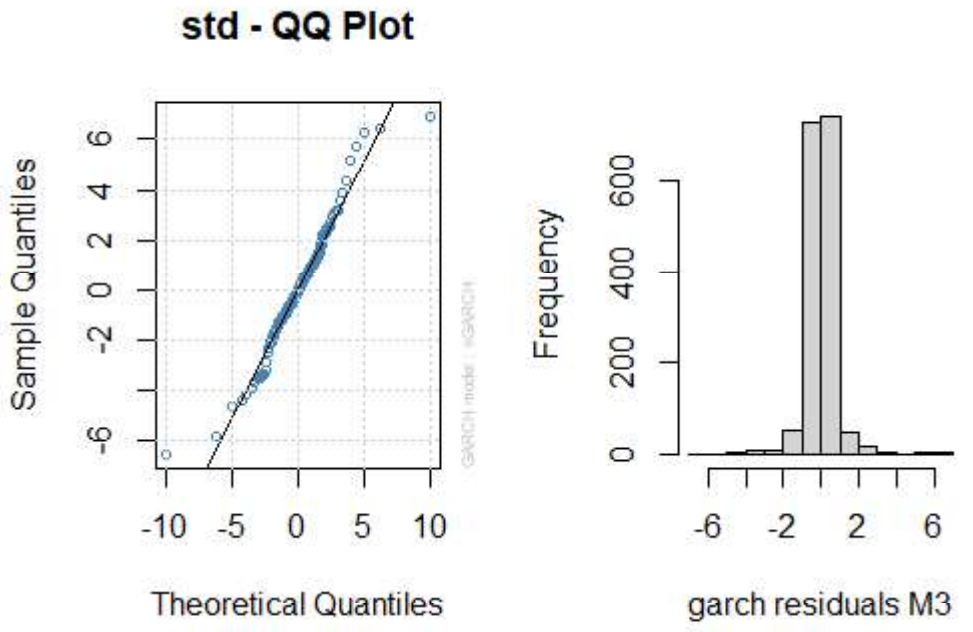


Figure 24: QQPlot Graph and Histogram of Model 4 ARMA(1,1)GARCH(1,1)

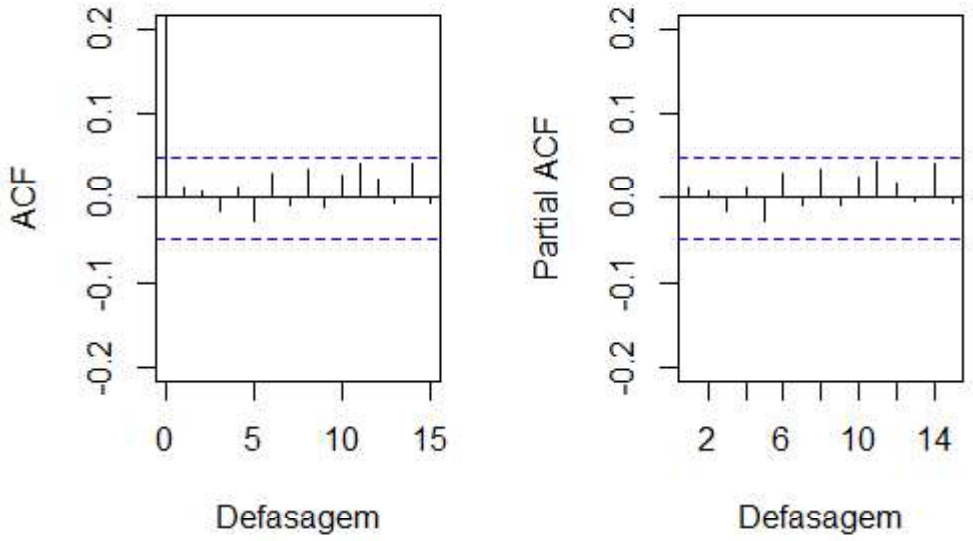


Figure 25: Standard residuals auto and Partial Correlation Function of Model 4 ARMA(1,1) GARCH(1,1)

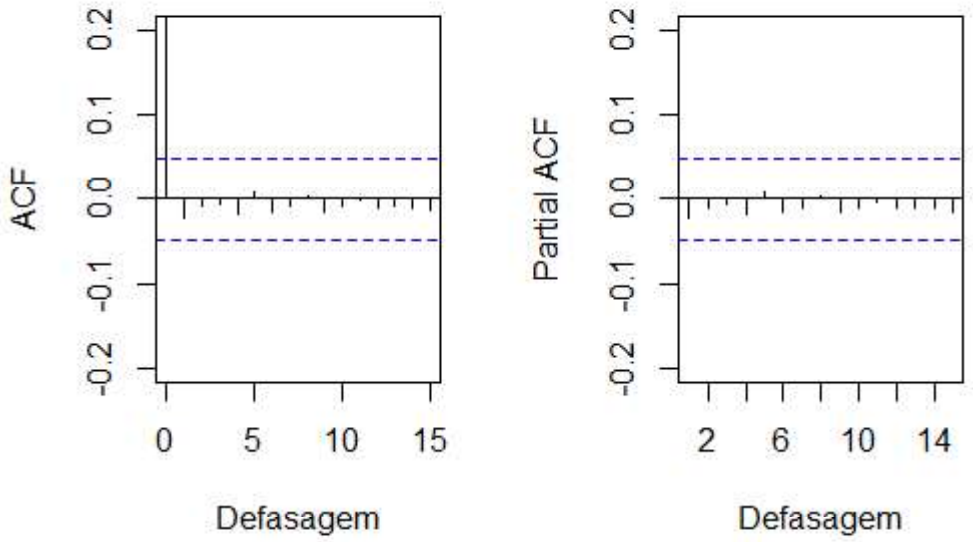


Figure 26: Standard residuals auto and Partial Correlation Function of Model 4 ARMA(1,1) GARCH(1,1)

Table 29: Model (1-4) fitness tests

Model	Test	Variable	p-value	Result	Implication
M1	Box-Ljung	Standardized residuals	0.1062	Do not reject the H0	Without serial correlation
	Box-Ljung	Squared residuals media	0.8661	Do not reject the H0	There is no serial correlation in squared residuals
	ARCH LM-test	Squared residuals	0.9999	Reject H0	There is no ARCH effect
M2	Box-Ljung	Standardized residuals	0.223	Do not reject the H0	Without serial correlation
	Box-Ljung	Squared residuals	0.485	Do not reject the H0	There is no serial correlation in squared residuals
	ARCH LM-test	Squared residuals	0.999	Reject H0	There is no ARCH effect
M3	Box-Ljung	Standardized residuals	0.217	Do not reject the H0	Without serial correlation
	Box-Ljung	Squared residuals	0.410	Do not reject the H0	There is no serial correlation in squared residuals
	ARCH LM-test	Squared residuals	0.999	Reject H0	There is no ARCH effect
M4	Box-Ljung	Standardized residuals	0.387	Do not reject the H0	Without serial correlation
	Box-Ljung	Squared residuals	0.385	Do not reject the H0	There is no serial correlation in squared residuals
	ARCH LM-test	Squared residuals	0.996	Reject H0	There is no ARCH effect

Source: Elaborated by the author using research data

8.4 Sensitive analyses appendix

Table 30: Open-to-Close CAR results in a [-1, 0, +1] Event Study window between January 2, 2017, and June 28, 2023

Event Day	AR			CAR	p-valor	t-value
	-1	0	1			
Panel A1: Significance CAR days of IBGE reports 27 events were studied, 3 were significant, and 24 were not significant						
2017-03-15	-0.3651	-0.7869	0.2174	-0.9346	**0.0330****	-2.1318
2017-06-14	-0.3014	-0.0746	-0.5974	-0.9734	0.2354	-1.1867
2017-09-14	0.7972	0.4776	0.3122	1.5870	0.1362	1.4900
2017-12-14	-0.2016	-0.1301	-0.3394	-0.6711	0.3395	-0.9551
2018-03-21	0.2428	0.3080	0.2212	0.7720	**0.0518***	1.9446
2018-06-14	0.3507	0.0009	-0.4668	-0.1152	0.8034	-0.2490
2018-09-12	0.4665	-0.0369	-0.0604	0.3692	0.4617	0.7361
2018-12-12	-0.4612	0.0005	-0.0275	-0.4882	0.3245	-0.9853
2019-03-14	0.0874	-0.1206	0.0875	0.0543	0.8876	0.1413
2019-06-13	-0.3551	-0.7314	-0.1415	-1.2280	**0.0340****	-2.1202
2019-09-12	-0.3170	0.3539	-0.0395	-0.0026	0.9955	-0.0056
2019-12-12	3.2471	-2.6441	-0.3706	0.2324	0.9152	0.1065
2020-03-19	-0.5815	-4.3744	-1.4963	-6.4522	**0.0001*****	-4.0194
2020-06-10	1.3438	-0.9476	0.0054	0.4016	0.7916	0.2642
2020-09-10	-0.4278	-0.9012	0.3695	-0.9595	0.3751	-0.8869
2020-12-10	0.0571	0.6324	1.6733	2.3628	0.1169	1.5678
2021-03-18	1.1002	0.4014	1.2838	2.7854	**0.0056*****	2.7679
2021-06-08	0.4074	0.0410	0.5755	1.0239	0.2137	1.2435
2021-09-10	2.2090	-0.3276	-1.2174	0.6640	0.3033	1.0294
2021-12-08	0.4207	1.9269	-0.1183	2.2293	0.3191	0.9962
2022-03-15	0.1670	0.5745	0.6037	1.3452	0.2903	1.0575
2022-06-08	0.3129	-0.7965	-0.3638	-0.8474	0.4379	-0.7758
2022-09-06	0.9268	-0.5370	-1.2226	-0.8328	0.38745	-0.8643
2022-12-07	-0.1082	0.6710	0.2329	0.7957	0.5363	0.6184
2023-01-12	0.2936	0.1517	-0.2874	0.1579	0.8587	0.1781
2023-05-15	0.2574	-0.3373	0.8818	0.8019	0.6050	0.5172
Panel A2: Significance CAR days of Cepea reports 46 events were studied, 6 were significant, and 40 were not significant.						
2017-06-02	0.8097	0.0110	0.0544	0.8751	0.1963	1.2923
2017-07-24	-0.0187	-0.4594	0.6942	0.2161	0.7928	0.2626
2017-08-25	-0.3686	-0.0180	-0.9523	-1.3029	0.1569	-1.4156
2018-11-08	0.4597	-0.2315	-0.2586	-0.0304	0.9636	-0.0456
2018-12-07	0.0952	0.4436	-0.0016	0.5372	0.3802	0.8775
2019-04-05	-0.3372	-0.0841	-0.4578	-0.8791	0.0980*	-1.6549
2019-05-08	-0.0089	0.3192	0.1027	0.4130	0.3417	0.9508
2019-06-05	-0.1538	-0.2825	0.2285	-0.2078	0.6470	-0.4579
2019-12-05	3.9521	-0.0958	-2.2789	1.5774	0.3944	0.8517
2020-03-06	-0.6096	0.7544	1.3112	1.4560	0.4960	0.6808
2020-04-08	-1.6910	0.0677	0.4610	-1.1623	0.6438	-0.4625
2020-05-06	-0.2325	-0.0623	0.8105	0.5157	0.8077	0.2434

2020-06-04	0.2084	-1.0053	0.4688	-0.3281	0.8744	-0.1580
2020-07-06	1.8616	-0.9647	-0.5703	0.3266	0.7707	0.2915
2020-08-05	-0.3826	0.2013	-0.2052	-0.3865	0.7093	-0.3727
2020-09-08	-1.0362	-0.6140	-0.4711	-2.1213	0.0502*	-1.9586
2020-10-06	-1.0879	0.4102	0.4690	-0.2087	0.8208	-0.2265
2020-11-05	0.0120	0.0762	-1.3347	-1.2465	0.2182	-1.2314
2020-12-04	1.2559	0.6792	1.7632	3.6983	0.0123**	2.5020
2021-03-09	0.7125	-0.3606	0.3145	0.6664	0.6362	0.4731
2021-04-06	-0.3864	0.0109	0.0732	-0.3023	0.8244	-0.2218
2021-05-05	0.1250	1.1463	0.2515	1.5228	0.1447	1.4586
2021-06-07	-0.3220	0.4556	-0.0939	0.0397	0.9641	0.0450
2021-07-06	-0.4232	-0.4415	-0.4869	-1.3516	0.0774*	-1.7661
2021-08-04	-0.4414	0.2912	-0.3522	-0.5024	0.4603	-0.7383
2021-10-06	-3.8447	0.7604	2.3171	-0.7672	0.5277	-0.6316
2021-11-05	-2.0985	-2.6220	-1.8743	-6.5948	0.0003***	-3.5756
2022-01-05	0.3530	2.1555	-0.1621	2.3464	0.2496	1.1512
2022-02-03	-0.0714	-1.1625	0.8091	-0.4248	0.8041	-0.2480
2022-03-07	0.5609	0.9189	0.1630	1.6428	0.2049	1.2678
2022-04-06	0.8080	0.0478	0.9196	1.7754	0.0190**	2.3461
2022-05-05	0.4428	0.0256	0.1850	0.6534	0.4646	0.7313
2022-06-06	-1.5557	-0.0054	0.2675	-1.2828	0.2183	-1.2310
2022-08-09	1.3691	0.7255	0.5002	2.5948	0.0096***	2.5900
2022-09-08	-0.5422	-1.1878	-0.3626	-2.0926	0.0523*	-1.9403
2022-10-06	0.9146	0.5176	-0.5812	0.8510	0.3780	0.8817
2022-11-07	-0.9945	0.2105	1.1554	0.3714	0.7654	0.2983
2022-12-07	-0.1096	0.6717	0.2651	0.8272	0.5294	0.6290
2023-01-04	0.5467	0.4553	0.8184	1.8204	0.1551	1.4218
2023-02-03	-0.7620	0.1006	-0.5291	-1.1905	0.3383	-0.9575
2023-03-07	0.7229	0.1232	1.6658	2.5119	0.1252	1.5332
2023-04-06	0.1417	0.7690	-0.6565	0.2542	0.8854	0.1441
2023-05-04	-0.3331	-0.5371	-0.2827	-1.1529	0.4736	-0.7167
Panel A3: Significance CAR days of Conab 14 events were studied, two were significant, and 12 were not significant.						
2021-06-21	0.0060	0.0006	0.0071	0.0137	0.1382	1.4824
2021-07-21	0.0012	-0.0006	0.0083	0.0089	0.2540	1.1407
2021-08-27	-0.0110	0.0024	-0.0009	-0.0095	0.1178	-1.5641
2021-09-21	-0.0008	0.0017	0.0071	0.000	0.3805	0.8770
2022-07-29	-0.0063	-0.0027	-0.0051	-0.0141	0.3255	-0.9832
2022-08-31	-0.0018	-0.0045	-0.0150	-0.0213	0.1482	-1.4458
2022-09-22	-0.0060	0.0114	-0.0020	0.0034	0.8162	0.2324
2022-11-24	-0.0061	0.0021	-0.0006	-0.0046	0.7291	-0.3464
2022-12-22	0.0060	-0.0012	-0.0031	0.0017	0.8976	0.1287

Source: Elaborated by the author using research data.

Note: *Z*-statistic for the mean abnormal return. $*p<.10$, $**p<.05$, $***p<.01$. Non-significant results in the appendix. Results with spot indicator for live cattle CEPEA/B3

8.4.2 EGARCH appendix

Figure 27: Results of the ARMA(2,2)EGARCH(1,0) for the study of future returns of BGI

Variable	Estimate	Std. Error	t value	Pr(>|t|)
		Mean Equation		
Ar (1)	0.929	0.036	25.362	0.000***
Ma (1)	-0.911	0.041	-21.733	0.000***
		Variance Equation		
C	-0.195	0.035	-5.597	0.000***
Alpha (1)	0.190	0.035	5.393	0.000***
Gamma (1)	-0.003	0.019	-0.160	0.872
Beta (1)	0.981	0.005	173.707	0.000***
IBGE	-0.003	0.200	-1.180	0.856
Conab	0.386	0.193	2.000	0.045**
Cepea	-0.019	0.151	-0.129	0.897
MayOct	0.002	0.015	1.700	0.089*
Monday	0.379	0.143	2.650	0.008**

Source: Elaborated by the author using research data Note: *Z*-statistic for the mean abnormal return. $*p<.10$, $**p<.05$, $***p<.01$.

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob*
		1	0.012	0.012	0.2335	
		2	0.016	0.016	0.6311	
		3	-0.013	-0.014	0.9193	0.338
		4	0.017	0.018	1.4121	0.494
		5	-0.032	-0.032	3.1040	0.376
		6	0.024	0.025	4.0742	0.396
		7	-0.008	-0.008	4.1898	0.522
		8	0.034	0.033	6.0984	0.412
		9	-0.010	-0.009	6.2625	0.509
		10	0.026	0.024	7.3855	0.496
		11	0.045	0.047	10.634	0.302
		12	0.020	0.015	11.259	0.338
		13	-0.001	0.000	11.262	0.422
		14	0.040	0.038	13.843	0.311
		15	-0.005	-0.004	13.879	0.382
		16	-0.009	-0.010	14.004	0.449
		17	0.001	0.002	14.005	0.525
		18	0.022	0.019	14.775	0.541
		19	0.016	0.016	15.195	0.581
		20	-0.040	-0.044	17.856	0.465
		21	-0.030	-0.031	19.314	0.437
		22	0.012	0.009	19.565	0.485
		23	0.059	0.059	25.309	0.234
		24	-0.013	-0.016	25.586	0.270

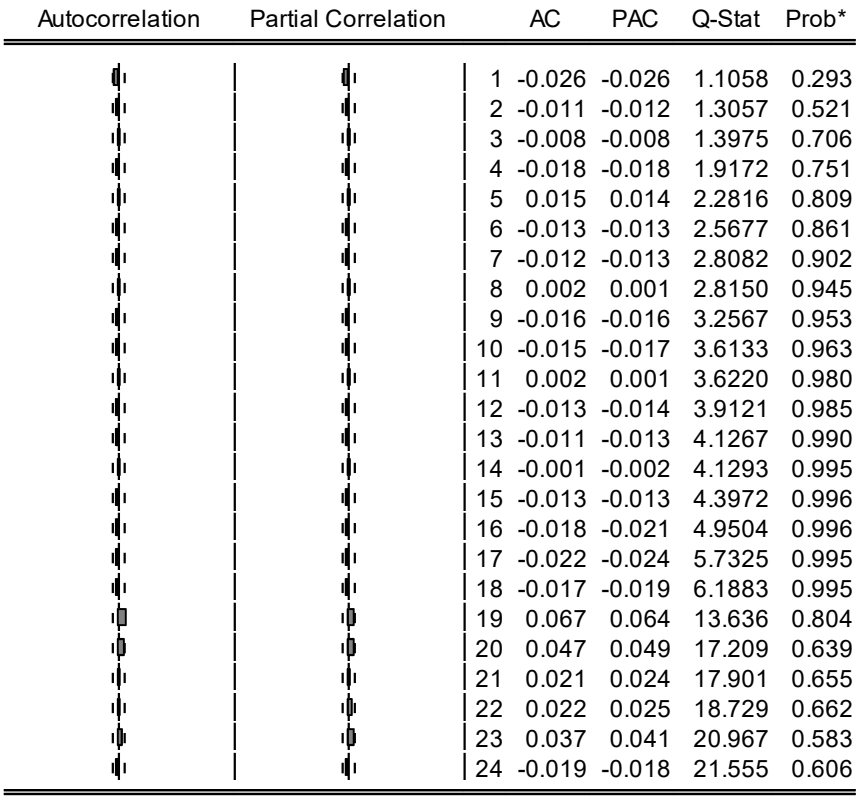
*Probabilities may not be valid for this equation specification.

Figure 28: ARMA (1,1) EGARCH (1,1,1) Complete Model ACF and PACF standard residuals

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob*
		1	-0.026	-0.026	1.1058	0.293
		2	-0.011	-0.012	1.3057	0.521
		3	-0.008	-0.008	1.3975	0.706
		4	-0.018	-0.018	1.9172	0.751
		5	0.015	0.014	2.2816	0.809
		6	-0.013	-0.013	2.5677	0.861
		7	-0.012	-0.013	2.8082	0.902
		8	0.002	0.001	2.8150	0.945
		9	-0.016	-0.016	3.2567	0.953
		10	-0.015	-0.017	3.6133	0.963
		11	0.002	0.001	3.6220	0.980
		12	-0.013	-0.014	3.9121	0.985
		13	-0.011	-0.013	4.1267	0.990
		14	-0.001	-0.002	4.1293	0.995
		15	-0.013	-0.013	4.3972	0.996
		16	-0.018	-0.021	4.9504	0.996
		17	-0.022	-0.024	5.7325	0.995
		18	-0.017	-0.019	6.1883	0.995
		19	0.067	0.064	13.636	0.804
		20	0.047	0.049	17.209	0.639
		21	0.021	0.024	17.901	0.655
		22	0.022	0.025	18.729	0.662
		23	0.037	0.041	20.967	0.583
		24	-0.019	-0.018	21.555	0.606

*Probabilities may not be valid for this equation specification.

Figure 29: ARMA (1,1) EGARCH (1,1,1) Complete Model ACF and PACF standard residuals



Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob*
		1	-0.026	-0.026	1.1058	0.293
		2	-0.011	-0.012	1.3057	0.521
		3	-0.008	-0.008	1.3975	0.706
		4	-0.018	-0.018	1.9172	0.751
		5	0.015	0.014	2.2816	0.809
		6	-0.013	-0.013	2.5677	0.861
		7	-0.012	-0.013	2.8082	0.902
		8	0.002	0.001	2.8150	0.945
		9	-0.016	-0.016	3.2567	0.953
		10	-0.015	-0.017	3.6133	0.963
		11	0.002	0.001	3.6220	0.980
		12	-0.013	-0.014	3.9121	0.985
		13	-0.011	-0.013	4.1267	0.990
		14	-0.001	-0.002	4.1293	0.995
		15	-0.013	-0.013	4.3972	0.996
		16	-0.018	-0.021	4.9504	0.996
		17	-0.022	-0.024	5.7325	0.995
		18	-0.017	-0.019	6.1883	0.995
		19	0.067	0.064	13.636	0.804
		20	0.047	0.049	17.209	0.639
		21	0.021	0.024	17.901	0.655
		22	0.022	0.025	18.729	0.662
		23	0.037	0.041	20.967	0.583
		24	-0.019	-0.018	21.555	0.606

*Probabilities may not be valid for this equation specification.

Figure 30: ARMA (1,1) EGARCH (1,1,1) Complete Model ACF and PACF squared residuals

Heteroskedasticity Test: ARCH

F-statistic	0.330634	Prob. F(12,1590)	0.9839
Obs*R-squared	3.990091	Prob. Chi-Square(12)	0.9836

Test Equation:
Dependent Variable: WGT_RESID^2
Method: Least Squares
Date: 11/22/23 Time: 15:59
Sample (adjusted): 1/20/2017 6/28/2023
Included observations: 1603 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	1.000179	0.126536	7.904302	0.0000
WGT_RESID^2(-1)	-0.026599	0.025076	-1.060697	0.2890
WGT_RESID^2(-2)	-0.012733	0.025085	-0.507594	0.6118
WGT_RESID^2(-3)	-0.009486	0.025084	-0.378187	0.7053
WGT_RESID^2(-4)	-0.018362	0.025082	-0.732061	0.4642
WGT_RESID^2(-5)	0.013168	0.025086	0.524916	0.5997
WGT_RESID^2(-6)	-0.013992	0.025086	-0.557766	0.5771
WGT_RESID^2(-7)	-0.012864	0.025086	-0.512780	0.6082
WGT_RESID^2(-8)	6.72E-05	0.025086	0.002680	0.9979
WGT_RESID^2(-9)	-0.016964	0.025081	-0.676367	0.4989
WGT_RESID^2(-10)	-0.016715	0.025081	-0.666429	0.5052
WGT_RESID^2(-11)	0.000660	0.025083	0.026329	0.9790
WGT_RESID^2(-12)	-0.013730	0.025073	-0.547597	0.5840

R-squared	0.002489	Mean dependent var	0.886905
Adjusted R-squared	-0.005039	S.D. dependent var	3.843957
S.E. of regression	3.853630	Akaike info criterion	5.543985
Sum squared resid	23612.24	Schwarz criterion	5.587613
Log likelihood	-4430.504	Hannan-Quinn criter.	5.560184
F-statistic	0.330634	Durbin-Watson stat	2.000306
Prob(F-statistic)	0.983881		

Figure 31: ARCH Test for the ARMA(1,1) EGARCH (1,1,1) Complete Model

TARCH Appendix

Table 31: ARMA(1,1) TGARCH (1,1,1) Complete Model results

Variable	Estimate	Std. Error	t value	Pr(>|t|)
		Mean Equation		
AR(1)	0.937	0.032	28.424	0.000***
MA(1)	-0.916	0.038	-23.674	0.000***
		Variance Equation		
C	-0.008	0.011	-0.759	0.447
Alpha(1)	0.048	0.017	2803	0.005
Gamma(1)	0.029	0.021	1.381	0.167

Beta(1)	0.936	0.010	91.344	0.000***
IBGE	0.001	0.099	0.011	0.995
CEPEA	0.062	0.080	0.785	0.432
CONAB	0.441	0.230	1.920	0.054
MayOct	0.013	0.009	1.429	0.152
Monday	0.086	0.060	1.416	0.156

Source: Elaborated by the author using research data Note: *Z*-statistic for the mean abnormal return. $*p<.10$, $**p<.05$, $***p<.01$.

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob*
		1	0.014	0.014	0.2991	
		2	0.009	0.009	0.4419	
		3	-0.012	-0.012	0.6822	0.409
		4	0.016	0.017	1.1205	0.571
		5	-0.026	-0.026	2.2291	0.526
		6	0.027	0.027	3.4044	0.493
		7	-0.007	-0.007	3.4832	0.626
		8	0.036	0.035	5.6246	0.467
		9	-0.011	-0.011	5.8331	0.559
		10	0.028	0.026	7.1322	0.522
		11	0.040	0.042	9.7268	0.373
		12	0.021	0.017	10.471	0.400
		13	-0.006	-0.004	10.530	0.483
		14	0.042	0.040	13.414	0.340
		15	-0.006	-0.006	13.477	0.412
		16	-0.010	-0.012	13.654	0.476
		17	-0.002	-0.001	13.664	0.551
		18	0.018	0.015	14.213	0.583
		19	0.013	0.013	14.477	0.633
		20	-0.038	-0.042	16.829	0.535
		21	-0.030	-0.030	18.348	0.499
		22	0.009	0.005	18.489	0.555
		23	0.063	0.063	24.980	0.248
		24	-0.012	-0.016	25.235	0.286

*Probabilities may not be valid for this equation specification.

Figure 32: ARMA (1,1) TGARCH (1,1,1) Complete Model ACF and PACF standard residuals

Heteroskedasticity Test: ARCH

F-statistic	0.202300	Prob. F(12,1590)	0.9984
Obs*R-squared	2.443717	Prob. Chi-Square(12)	0.9984

Test Equation:
Dependent Variable: WGT_RESID^2
Method: Least Squares
Date: 11/22/23 Time: 15:07
Sample (adjusted): 1/20/2017 6/28/2023
Included observations: 1603 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.955648	0.127971	7.467686	0.0000
WGT_RESID^2(-1)	-0.021688	0.025078	-0.864817	0.3873
WGT_RESID^2(-2)	-0.010046	0.025083	-0.400490	0.6888
WGT_RESID^2(-3)	-0.007832	0.025084	-0.312216	0.7549
WGT_RESID^2(-4)	-0.017254	0.025083	-0.687878	0.4916
WGT_RESID^2(-5)	0.007247	0.025086	0.288868	0.7727
WGT_RESID^2(-6)	-0.011290	0.025086	-0.450041	0.6527
WGT_RESID^2(-7)	-0.009907	0.025086	-0.394914	0.6930
WGT_RESID^2(-8)	0.005933	0.025086	0.236524	0.8131
WGT_RESID^2(-9)	-0.011925	0.025083	-0.475446	0.6345
WGT_RESID^2(-10)	-0.007796	0.025079	-0.310859	0.7559
WGT_RESID^2(-11)	0.002636	0.025079	0.105107	0.9163
WGT_RESID^2(-12)	-0.009787	0.025072	-0.390343	0.6963

R-squared	0.001524	Mean dependent var	0.875286
Adjusted R-squared	-0.006011	S.D. dependent var	3.981764
S.E. of regression	3.993714	Akaike info criterion	5.615397
Sum squared resid	25360.10	Schwarz criterion	5.659025
Log likelihood	-4487.741	Hannan-Quinn criter.	5.631596
F-statistic	0.202300	Durbin-Watson stat	2.000172
Prob(F-statistic)	0.998393		

Figure 33: ARCH Test for the ARMA(1,1) TGARCH (1,1,1) Complete Model

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob*
		1	-0.022	-0.022	0.7540	0.385
		2	-0.009	-0.009	0.8855	0.642
		3	-0.007	-0.007	0.9540	0.812
		4	-0.017	-0.017	1.4252	0.840
		5	0.009	0.008	1.5436	0.908
		6	-0.011	-0.011	1.7321	0.943
		7	-0.010	-0.010	1.8799	0.966
		8	0.007	0.006	1.9649	0.982
		9	-0.012	-0.012	2.1970	0.988
		10	-0.007	-0.008	2.2720	0.994
		11	0.003	0.003	2.2915	0.997
		12	-0.010	-0.010	2.4499	0.998
		13	-0.010	-0.012	2.6230	0.999
		14	-0.005	-0.006	2.6626	1.000
		15	-0.013	-0.013	2.9197	1.000
		16	-0.018	-0.019	3.4314	1.000
		17	-0.019	-0.021	4.0329	0.999
		18	-0.017	-0.019	4.5224	0.999
		19	0.091	0.088	17.953	0.526
		20	0.045	0.048	21.235	0.383
		21	0.019	0.022	21.824	0.410
		22	0.015	0.017	22.177	0.449
		23	0.033	0.038	23.995	0.404
		24	-0.017	-0.016	24.488	0.434

*Probabilities may not be valid for this equation specification.

Figure 34: TGARCH Complete Model ACF and PACF squared residuals