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INTERNATIONAL JOURNAL ON FOOD SYSTEM DYNAMICS

Int. J. Food System Dynamics 14 (1), 2023, 88-94

DOI: https://dx.doi.org/10.18461/ijfsd.v14i1.E6

Agricultural commodities price dependence on Brazilian financial market

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Received June 2022, accepted November 2022, available online January 2023

ABSTRACT

This study aims to identify whether there is dependence between agricultural commodities traded on the Brazilian market. We used the bivariate copula method over a ten-year period to assess the extreme effects on the returns of the following commodities: soybean, wheat, Arabica coffee, and Robusta coffee. The relationship directly affects the dependence between Arabica and Robusta coffees commodities. While the relationship between wheat, Arabica and Robusta coffees, and soybean is positively dependent. Economic growth, market dynamics, and the prices of an agricultural commodity tend to increase the price of other commodities.

***Keywords**: Agricultural commodities; Price volatility; Bivariate copulas.*

1 Introduction

"Commodity" is used to define food products in their raw form and with productive homogeneity, whose large-scale production generates greater profitability (Pinheiro and Senna, 2017). Global changes can affect agricultural commodity prices, especially in developing countries, which are more exposed to sudden changes in the food prices (Cabrera and Schulz, 2016; Araújo et al., 2020).

Commodities can experience negative or positive price changes depending on market reactions. Negative changes are related to climatic forces, political issues, or macroeconomic fluctuations, which can generate international trade disputes (Daskalaki and Skiadopoulos, 2011). Agricultural commodities are considered a type of commodities in the context of world population growth and economic expansion of emerging countries. One example is the participation of agribusiness in the Brazilian Gross Domestic Product (GDP). Furthermore, these commodities may represent an important demand in developed countries (Yahya et al., 2019).

Economy actors make market and macroeconomic predictions to determine the volatility of the prices of these products (Ye et al., 2021), seeking to mitigate uncertainties in negotiations and policies related to the agricultural market (Su et al., 2019). The variations in this market are of global importance, it concerns to inflation rates, interest rates, and trade balance (Zhang and Ding, 2021). Economic events can interfere with the price of production costs. Among these costs are the commodities used as inputs for several supply chains. Moreover, these events can generate negative effects such as social costs (Shahzad et al., 2018). Variations in the prices of other commodities, such as oil, can influence this scenario, they can represent losses for investors in this market (Shahzad et al., 2018).

Relevant changes in the global market for these products took place from 2003 to 2008, creating interest in analyzing their pricing (Kilian and Zhou, 2018). Some markets had an accelerated growth in business volume, such as China from 2001 to 2010. This country stood out as one of the largest commodity markets in the world, which affected the assets of other countries and investment decisions worldwide (Hammoudeh et al., 2014).

Commodity price shocks can be explained by real declines in the world economy (Kilian and Zhou, 2018), macroeconomic uncertainties (Huang et al., 2021), environmental regulation (Harding et al., 2021), national monetary policies (price level and inflation rates) (Coletti et al., 2021), and oil and energy prices (Agnello et al., 2020). This is the main relevance of this subject, and the market need this information to act accurately.

In this context, dependence on commodities can generate crises and reactions in the economy. Agricultural commodities have strategic commercial value. This market is influenced by the sector in which the products are inserted, and these products can be traded on the stock market. In the case of agricultural commodities, some are traded on the Intercontinental Exchange (sugar, cotton, coffee, cocoa, canola), and others on the Chicago Exchange (wheat, soybean, soybean oil, corn).

The analysis of dependence between commodities is an important component to base investment decisions on. Its purpose is to identify better options, risks, and possible impacts of macroeconomic variations. This paper identifies whether there is dependence between agricultural commodities traded on the Brazilian financial market. The research is justified by the relevance of the agricultural commodities market to the world economic context, especially by its representation in the Brazilian trade balance.

2 Theoretical Background

Brazil is a country with abundant natural resources, enabling the food production for domestic supply and large-scale agricultural exports (Fry-Mckibbin and Souza, 2018; Hey and Morozini, 2018; Agrostat, 2021). Certain changes in the international prices, for example soybean and maize, can induce or be induced by the international price of other products, such as oil (Shahzad et al., 2018). Low returns in the oil market may account for low returns in the market for metals, such as gold and silver, affecting rice marketing (Shah and Dar, 2021).

Commodity market spillover periods happen more frequently in the short term, caused by shocks in the financial market, in conjunction with commodity market variables (Shah and Dar, 2021). Financial market variables influence the spillover in the commodity market. However, uncertainty can be mitigated with analysis of risk management and asset portfolio hedging (Reboredo et al., 2021). On the other hand, turmoil and declines in financial markets lead to the need for investors to seek to diversify assets to reduce the risks of market instability. Commodity investment is one of the alternatives to achieve portfolio diversification (Arouri et al., 2010; Conover et al., 2010; Daskalaki and Skiadopoulos, 2011).

Commodity returns vary, and their fluctuations may or not correlate with other assets in the capital market (Nguyen and Prokopczuk, 2019). To improve predictability, investors should consider a perspective with different time horizons,

as well as explore the potential and diversity of the range of commodities and financial assets (Shah and Dar, 2021). Stock market performance is a key context of analysis for investors to understand the potential of results of commodities in a period. Also, greater or lesser risks of investments in commodities can be hedged with other classes of financial assets and derivatives, for the first case, and through shares, for the second one (Reboredo et al., 2021).

Price volatility in the commodities market correlates with time variation, asymmetry, and sensitivity to potential crises. It becomes necessary to study internal relationships of commodities and the possible effects of these connections (Nekhili et al., 2021). The price changes can alter the demand for agricultural fuels, implying changes in international prices. Examples of these cases are soybean and maize, which can modulate the international oil price (Al-Shahzad et al., 2018).

Another example is crude oil, which is an essential input for transport and processing in the agricultural sector, often putting pressure on production costs. Crude oil has a higher risk spillover effect on agricultural commodities than other products such as natural gas, since the average level of spillover from the oil and gas markets is higher for maize and soybean than for other agricultural commodities (Ji et al., 2018). Faced with this concern and even with potential crises in the world market, oil and natural gas do not respond negatively to all crises, varying in response to historical demand and availability of market supplies (Ahmed and Sarkodie, 2021).

3 Materials and Methods

This study comprises applied quantitative research with secondary data. The analysis of copulas, autoregressive conditional heteroscedasticity (ARCH), with identification of errors in certain time intervals, and dependence structure between four agricultural commodities were performed. The commodities are soybean, wheat, and Arabica and Robusta coffees. The variables choice was due to data availability and previous relations with variation of oil and energy. To perform the tests and show the results it was included the use of R statistical software to identify extreme effects on commodity prices.

The study used data on agricultural commodities, taken from the Center for Advanced Studies on Applied Economics - Department of Economy, Administration and Sociology, Luiz de Queiroz College of Agriculture, University of São Paulo - (Cepea-Esalq/USP, 2021). For the estimation, the study considered daily prices from July 2009 to June 2019, which generated approximately 2,482 observations for each agricultural commodity. The analysis was performed with data from before the COVID-19 pandemic, the data after 2019 was not used on account of the pandemic instabilities.

In the assessment of the dependence structure between return series, the copula approach allows evaluating the dynamic dependence structure between different periods, as well as tail dependence (Berger and Uddin, 2016). Copula models had better capture the dependence structure, and the market risk of the portfolio stems from market diversifications (Hammoudeh et al., 2014), which in this research are the agricultural commodities.

In the scenario analyzed, copulas allow the analytical construction of multivariate distributions, contributing to modeling, creating a flexible pattern of dependence between the series and conditions to retrieve the conditional distribution information. Financial dependencies generate changes over time, and copula modeling must have an appropriate model for each situation, enabling to estimate parameters and analyze the diagnosis for an efficient result (Abbara, 2009). On the other hand, one of the main disadvantages of bivariate analysis lies in the fact that it does not comprise relationships between more than two commodities (He et al., 2019).

The present study used the copulas that best fit in the search for dependence between assets. These copulas ranged from Vines copulas - which demonstrate a more flexible model for describing multivariate copulas, in which each copula can be chosen independently of the others - to hierarchical Archimedean copulas, which identify dependence structures; in addition to different copula families (Müller et al., 2018). Regarding the copula structure, the bivariate case is presented, which occurs when one commodity is analyzed in conjunction with another. The function is given by C: $[0,1]^2 \rightarrow [0,1]^2$. It is a copula for the cases: $0 \leq x \leq 1$, and this function fulfills the properties:

$$C(x,1) = C(1,x) = x,\ C(x,0) = C(0,x) = 0, \qquad (1)$$

$$C(x_2,y_2) - C(x_2,y_1) - C(x_1,y_2) + C(x_1y_1) \geq 0 \qquad (2)$$

The first property refers to the uniformity of the margins; the second property, an *n*-increasing property, represents the fact that $P(x_1 \leq X \leq x_2,\ y_1 \leq Y \leq y_2) \geq 0$ for (X,Y) with *C* distribution. Sklar (1959) identifies that a *C* copula is connected to a distribution function and its marginal distributions. From a *C* copula and univariate distribution functions F_1 and F_2, and a *F* distribution with marginal distributions F_1 and F_2, it highlights:

$$F(x,y) = C\big(F_1(x), F_2(y)\big), for\ (x,y) \in R^2 \qquad (3)$$

C is the copula that satisfies (3) for a two-dimensional distribution function, *F* with marginal distributions F_1 and F_2, *C* is unique if F_1 and F_2 are continuous for each $(x, y) \in [0,1]^2$:

$$C(x,y) = F\left(F_1^{-1}(x), F_2^{-1}(y)\right), \qquad (4)$$

$F_1^{-1}(x)$ and $F_2^{-1}(y)$ represent the inverse of the marginal distribution functions of F_1 and F_2, respectively. The C-Vines copula formula of Brechmann and Schepsmeier (2013) was used for a flexible analysis to define the risk and use bivariate copulas for each pair. The C-Vines copula with root-nodes $1, \ldots, d$ is represented by:

$$f(x) = \prod_{k=1}^{d} f_k(x_k) \qquad (5)$$

$$* \prod_{i=1}^{d-1} \prod_{j=1}^{d-1} C_{i,i+j|1:(i-1)} \left(F(x_1, \ldots, x_{1-1}), F(x_1, \ldots, x_{i-1}) \middle| \theta_{i,i+j} \middle| 1:(i-1)\right),$$

f_k, k = 1, …, *d* represents the marginal densities, and c_i, $i{+}j|1{:}(i{-}1)$ is the bivariate copula parameter density (s) $\boldsymbol{\theta}_i$, $i{+}j|1{:}(i{-}1)$ 1).

To identify the copula families used and those that best fit the identification of dependence on each commodity, we used the method by Frees and Valdez (1998), Normal, t-student, Gumbel, Frank, Clayton, Joe, BB1, BB7, and BB8. Rotated copulas were as follows: Clayton (180 degrees), Gumbel (180 degrees), Joe (180 degrees), BB1 (180 degrees), BB6 (180 degrees), BB7 (180 degrees), BB8 (180 degrees), Clayton (90 degrees), Gumbel (90 degrees), Joe (90 degrees), BB1 (90 degrees), BB6 (90 degrees), BB7 (90 degrees), BB8 (90 degrees), Clayton (270 degrees), Gumbel (270 degrees), Joe (270 degrees), BB1 (270 degrees), BB6 (270 degrees), BB7 (270 degrees), BB8 (270 degrees).

4 Results and Discussion

Table 1 present the descriptive statistics for the four agricultural commodities. Soybean has the lowest standard deviation, while Arabica coffee has the highest standard deviation. Soybean and Robusta coffee have greater variance than other commodities, being farther from the average. Wheat and Arabica coffee are priced closer to the average. Soybean and Robusta coffee have negative asymmetries, that is, a greater number of values to the left of the distribution curve around the mean. Robusta coffee presents a different price variance in relation to Arabica coffee, even though both were produced with related competitive criteria (Jarvis, 2005).

Table 1

Descriptive statistics on agricultural commodity prices (from July/2009 to July/2019)

Statistical	Soybean	Wheat	Arabica coffee	Robusta coffee
Return Hope	0,0002	0,0003	0,0003	0,0002
Standard deviation	0,0087	0,0114	0,0150	0,0093
Sharpe ratio	0,023	0,026	0,022	0,023
Variance	7,6041E-05	0,000129959	0,000224565	8,62088E-05
Kurtosis	1,371	4,128	4,140	3,594
Asymmetry	-0,071053927	0,131541125	0,143142111	-0,448675626

Source: Research data.

Wheat and Arabica coffee have positive asymmetry, with more values to the right of the curve; most of the series have excess kurtosis. A result with excess kurtosis and negative asymmetry are characteristics of 'fat' and normal tails in economic/financial series. The analysis of asymmetries in market prices in certain periods is used to understand volatility and formulate predictions about commodities (Chkili et al., 2014). The Sharpe ratio shows that wheat has the best risk-return ratio and Arabica coffee the lowest among the commodities under study. Wheat prices correlate mostly with the variation of oil and energy (Mensi et al., 2017), which may indicate the need to deepen this analysis.

Table 2
Best pair-copula fits for each commodity in the copula family (from July/2009 to July/2019).

Commodity	Soybean	Wheat	Arabica coffee	Robusta coffee
Soybean	Independent	Clayton	Frank	Clayton
Wheat	13	Independent	Gumbel	Clayton
Arabica coffee	5	24	Independent	Joe
Robusta coffee	13	33	6	Independent

Source: Research data.

In Table 2, we list the copulas of greater occurrence in the pair analysis, according to the bivariate copulas. The most repeated copula was Clayton copula. The lowest dependence table was not presented, because when estimating the copulas, we identified dependence in extreme moments of loss.

Table 3.
Higher dependence between commodities prices (from July/2009 to July/2019).

Commodity	Soybean	Wheat	Arabica coffee	Robusta coffee
Soybean	0.000000e+00	0,1298919e-07	0.00000000	4,365047e-21
Wheat	1.298919e-07	0.000000e+00	0.00000000	0.000000e+00
Arabica coffee	0.000000e+00	0.000000e+00	0.00000000	3.665818e-02
Robusta coffee	4.365047e-21	0.000000e+00	0.03665818	0.000000e+00

Source: Research data.

In Table 3, we present the higher dependence, the dependence in extreme moments of gains. When the economy grows and markets are booming, there is a risk transmission effect between the series under study, involving higher risks in distribution. Commodities were analyzed in pairs and their dependencies determined using the Kendall correlation, thus, we could observe the behavior of commodities in extreme moments.

Dependencies between wheat and Arabica coffee (-0.02129446), and between wheat and Robusta coffee (-0.007973438) are negative. Dependencies between soybean and wheat (0.021389290), and between Arabica and Robusta coffees (0.015613905) are positive. It indicates the directional strength of these dependencies in extreme moments.

The result corroborates other findings in the literature, which point to the global context with impacts on local markets and developing countries such as Brazil (Araújo et al., 2020). The analysis of agricultural commodity prices must also consider the world economic situation and the oil price, factors that can be decisive for results that are more satisfactory (Sun et al., 2021).

Analyzing the case of Arabica coffee, in which Brazil stands out in world exports, the price increase that took place between 2010 and 2012 accounted for changes that occurred not only in B3, but also in the Intercontinental Exchange in New York (Bohl et al., 2019). The positive dependence between Arabica and Robusta coffees can be explained by the historical interest in coffee production in the country. In this scenario, Brazil had market policies oriented to coffee production during its colonization and the results achieved in terms of efficiency and competitiveness are because of this fact (Jarvis, 2005).

On the other hand, in terms of soybean production, it involves regulatory issues for the activity in the country, conservation areas, and environmental pacts, such as the Soy Moratorium (Harding et al., 2021). Despite having presented prices with greater variance than wheat and Arabica coffee, soybean tends to respond positively to the volatility of oil prices (Ezeaku et al., 2021).

The findings on wheat advance studies on this commodity. International studies have confirmed its dependence on products such as maize, soybean, and soybean oil (Hamadi et al., 2017). Commonly related to maize, wheat shows a tail dependence on this commodity in short periods, while its dependence on oil has been low (Mensi et al., 2017).

5 Final Considerations

Agricultural commodities are influenced by climatic factors, political decisions, macroeconomic variations, and other variables in their supply chains. The study of dependence between commodities aims to include decision-making elements to portfolio managers and market operators, generating new information about this dependence, seeking to facilitate investment management processes.

The research findings show dependence among the commodities: Arabica and Robusta coffees with wheat as negative dependence; and wheat, Arabica coffee, and Robusta coffee with soybean as positive dependence. The findings evidence that the relationship directly affects the dependence between commodities. Furthermore, when there are extreme moments of a positive nature in the economy, the existence of a dependence process between commodities can indicate transmission of volatility.

Our research sought to promote new discussions on commodities in a local market, such as the Brazilian, whose variation is impacted by moments of volatility. We suggest that further studies be carried out in comparison with other countries, using different macroeconomic variables and at different times to identify new changes and dependencies.

Acknowledgment

The authors acknowledge the Federal University of Grande Dourados, for the financial support.

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