CIÊNCIA e NATURA

ISSN 2179-460X
Acesso aberto

Ci. e Nat., Santa Maria, v. 44, e56 , 2022 • https://doi.org/10.5902/2179460X68858
Submitted: 10/12/2021 • Approved: 29/09/2022 • Published: 05/01/2023

Statistics

The establishment of soybean price and its interrelation with the prices of its derivatives: soybean meal and soybean oil

A formação do preço da soja e sua inter-relação com os preços de seus derivados: farelo de soja e óleo de soja

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ABSTRACT

The theme of this article is to analyze the influence of soy prices on its two main derivatives, soybean meal and soybean oil, and the other way around. For doing so, we used Johansen method, Granger causality tests and the impulse-response function among the three studied variables. Among the main results obtained, connections were found between the establishment of the future price and the three studied variables. It should be noted that the impacts on price fluctuation of soybean oil and meal may not be immediate on the price of soy. It might extend over a certain period, so that this change in soy price will be seen in the future, resulting from past oscillations in the two other variables.

Keywords: Soybean; Price; Johansen method; Causality; Impulse response

RESUMO

O objetivo deste artigo reside em analisar a influência dos preços dos futuros da soja em seus dois principais derivados: farelo e óleo de soja. Para tanto, utilizou-se o método de Johansen, de causalidade de Granger e a função impulso-resposta entre as três variáveis estudadas. Entre os principaisresultados obtidos, verificaram-se conexões estabelecidas na formação dos preços futurosdas trêsvariáveis estudadas. Ressalta-se que os impactos na variação de preços do óleo e farelo de soja não impactaram de maneira imediatano preço da soja. No entanto, em períodos mais longos de tempo essa mudança poderá ser perceptível no preço futuro da soja, resultante de oscilações passadas nas duas outras variáveis

Palavras-Chave: Futuros de soja; Cotação de futuros agrícolas; Método de Johansen; Causalidade; Função impulso resposta.

1 INTRODUCTION

Due to the modernization in Brazil's agriculture from the 1950s through the 1960s, soy started playing an important role in the country's economy. The oilseed became part of national statistics from the 1970s through *Rio Grande do Sul*, first Brazilian state to implement it. For the harvest of 2019/20, Brazil expects to crop 126 million tons, surpassing the US as global leader. So far, Brazil is currently world's number one exporter of the oilseed. By studying its market and the history of its evolution, we were able to identify three main price determinants, in particular: the seed price in the stock exchange of Chicago; the currency in Brazil; and the prize paid in the shipment ports of Brazil.

In regard to the Chicago Stock Exchange, there has been a historical relationship with its two by-products: soybean meal and soybean oil. And in special since the 2000s, it has been observed that not only the traditional negotiators - producers and buyers, plus speculators - are the ones to set the price (US$ / bushel). On the speculation side alone and following a trend which affects all commodities, a new type of trader was introduced in the stock market: the investment funds, the pension funds and other categories. Due to their economic dimension, studies developed by the authors have shown that there is an important correlation between their performance on the Stock Exchange and the prices behavior, especially in regard to the seed price, with directly influences on soybean prices in Brazil and in the rest of the world.[11]

In global terms, the market for soybean oil, as well as for seed and soybean meal, is based on the Chicago Cereal Exchange's dollar prices. In this case the oil is quoted in cents of dollars per pound (0.4536 kilos), while the bushel corresponds to

[1] Cf. BRUM, A.L. *et al*. Influência dos fundos de investimentos na formação do preço da soja na Bolsa de Cereais de Chicago; Influência dos fundos de investimentos na formação do preço do farelo de soja na Bolsa de Cereais

27.21 kilos and the short ton corresponds to 907.1 kilos.

This article's central theme is the identification of the real relation between seed prices in Chicago and the prices of its two by-products on a two-hand way, taking as time-reference the period between 2006 and 2019. The objective is to verify the intensity of this relationship and what are the main elements which define it, based on Johansen method and Granger causality tests and the impulse response function among the three studied variables: the future prices of soy, of soybean oil and soybean meal.

Apart from this introduction and the final considerations, the article is divided into three parts: the first one quickly analyzes the evolution of soy economy and its derivatives, emphasizing the role of Brazil in that context. Next, there is a detailed explanation of the Johansen method. The third part deals with the methodology used in the present study, while the fourth analyzes the results obtained in the research, by using the statistical methods explained in the methodology.

2 SOYBEAN ECONOMY AND ITS DERIVATIVES

The evolution of soybean intake in the world can be divided in three phases. Between the 1950s and the 1990s the greatest consumer of oilseed was then West Europe, what is known today as European Union (France, Netherlands, Belgium, Spain and Germany, to quote a few). After that, between the late 1980s and the 2000s, former USSR, and then Russia and other new countries which emerged from the extinct USSR, entered the radar of this market. Finally, from the 2000s and especially from 2005 on, China took the lead in global purchases of soy. In the first two stages, the largest consumption was of soybean meal, a fact that led to a strong industrialization of the sector in Brazil, with a large expansion of the soy milling park. With the entrance of China and its high demand on the seed, a new reality was observed: the concentration of the Brazilian milling park, accelerated by the consequences of the Kandir Law since 1997 (this subject is not the object of this article and, therefore, will not be developed here).[2]

[2] Complementary Law No. 87/1996, known as "Kandir Law", gives exemption of tax payment on the Circulation of Goods and Services (aka ICMS in Portuguese abbreviation) on exports of primary products,

In practice, the structure of soybean market in the world can be established based on the figures of the 2018/19 harvest: the three largest producers of oilseeds in the world were the USA (123.7 million tons), Brazil (117 million) and Argentina (56 million). These three countries represented 82% out of the total world soybean production in that year. Soy imports worldwide were concentrated in China (86 million tons) and in the European Union (15.5 million). These two regions accounted for 68% of the world oilseed imports. Global production of soybean meal was concentrated in China (68.1 million tons in the referred year); USA (44.5 million); Brazil (33.1 million); and Argentina (31.8 million). These four countries produced 75% of the soybean meal in the whole world, and the largest exporter was Argentina with 28.1 million tons, or 42.3% of total sales of the by-product in the whole world. USA and Brazil consumed a large part of their soybean meal internally, due to the strong development of the countries' animal production. Finally, global soybean oil production was concentrated in China (15.4 million tons); USA (11.1 million); and Brazil and Argentina (8.2 million each). The largest individual importer of soybean oil was India, with about a third of the world total of 10.95 million tons, while the largest exporter was Argentina, with 5.1 million tons (45.5% of the total worldwide) (USDA, 2019).

It can be presumed therefore that the global market for soya and its derivatives is extremely concentrated, both in production and consumption. Soy began to be implemented commercially in Brazil from the 1950s to the '60s, when the modernization of agriculture in *Rio Grande do Sul* was consolidated according to the logic of the Green Revolution (BRUM, 1988). In 1980 Brazil reached the second position as soy global producer, after the US. In that year the country produced 14,88 million tons, way more than the 77.880 tons from 1952, the first year where statistic data could be found over oilseed production (BRUM, 1989).

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such as agricultural, semi-finished items or services. Created by the Minister of Planning at the time, Antonio Kandir, under the government of Fernando Henrique Cardoso, the tax exemption measure aims to make Brazilian products more competitive in the international market. Due to the exemption from this state-imposed tax, the law has always provoked controversy among governors and exporters, who claim loss of revenue on these products.
By exempting natural product from tax, the law favored seed exports to the detriment of soybean meal and oil.

Brazilian soy production reached 32.89 million tons two decades later, in the year 2000, growing 121% in 20 years. Eventually, Brazilian production reached its record in 2018/19 with 119.4 million tons, and the estimate is for 126 million tons in 2019/20 (CONAB, 2019).

The main reason for the tremendous growth in the soybean production in Brazil was the increasing worldwide (and domestic) demand for the product. Such growth happened because soy is a product rich in protein, being still to date one of the cheapest sources in the world of this chain of amino acids. When a single soy seed is milled, the outcome from it is in average 78% meal, 18.5% oil and 3.5% leftovers. Depending on the way soybean meal is extracted, it can contain between 38% to 50% of protein, being essentially used as animal food worldwide, especially swine, poultry and dairy cattle (BRUM, 2002). With the so-called westernization of human food, the consumption of meat, eggs and milk, as well as their derivatives, has grown exponentially in the world in the last 50 years, reaching today Far East countries such as China. To meet this growing demand, soybean meal associated with corn has become an essential element in animal food. Meanwhile, soybean oil has been particularly directed to human consumption through cooking oil. It is also used in the paint and varnish industries and more recently in biodiesel production (fuel which is compound of 90% of diesel oil and 10% of soybean oil). Leftovers are generally used to produce soap and some related products of such industry.

Regarding soybean meal, its projected global production for 2019/2020 amounts to 240 million tons. From this total, the largest producer shall be the United States (45 million), followed by Brazil and Argentina (34 million each), and the European Union (12.5 million). China, the world's largest importer of soy (85 million tons in the 2019/20 estimate) produces 67.3 million tons locally. The difference between the Asian country and the other three American countries is that China consumes practically all soybean meal in its own territory. At the same time, it is expected the US to export 12.4 million tons and to consume around 32.5 million tons internally. Brazil is expected to export

15.2 million tons and to consume a total of 15.8 million. Finally, Argentina should export 30.5 million tons while its domestic consumption will be only one or two million tons. Thus, Argentina shall be the world's largest exporter of soybean meal, reaching 45% of global exports of this soy by-product; the total estimated global trade for soybean meal in 2019/2020 is of 68.2 million tons (USDA, 2019).

The evolution of soybean meal production in Brazil can be divided in two phases over the past 50 years. In the first one, which lasted more precisely from the late 1960s through 1996/97, exports were the central element. During this period soybean milling evolved practically in proportion to the increase in its production. As a result, the production and the export of soybean meal were very close related (BRUM, 2002) to such an extent, that in 1991/92 the Brazilian production of soybean meal reached 11.6 million tons. Out of this total, 8.3 million (71.6%) were exported. In 1996/97, when the Kandir Law was implemented in the country, soybean meal production reached 14.6 million tons, whilst exports reached 10 million (68.5% of the total produced).

The second phase (from 1997/98 to 2019/20) highlighted a stagnation of exports and an increase in domestic consumption. The country also started to prioritize the export of seeds rather than milling it from 1996/97 on, largely due to the Kandir Law and the consolidation of China as a strong importer of soybeans from the years 2000/01. Thus, soybean meal production reached 22.4 million tons in 2003/04, while its exports attained 14.5 million tons (64.7% out of the total). In 2007, soybean milling still represented 54% of the total produced (31.5 out of 58.7 million tons), however, soybean meal exports dropped to 53% of its production in the country (12.7 million tons against 24.1 million produced). In that same year, domestic consumption of soybean meal reached 11.2 million tons. Eventually, soybean milling dropped to 37% of total production, reaching 43.2 million tons in 2019. Such volume resulted in the production of 32.6 million tons of soybean meal, in which 15.8 million tons (48%) out of the total produced were exported, while the internal consumption of seed came to 16.3 million tons. Thus, between 2007 and 2019, while Brazilian soybean production doubled its number from 58.7 to 117.6 million tons, internal oilseed milling grew only 37%; soybean meal production increased by 35%; exports registered a 24% increase, while internal soybean meal consumption increased by 45%, consolidating an important change in both soybean milling and in the final destination of soybean meal (ABIOVE, 2019).

As for soybean oil, the projected global production of this soy by-product is of 56.7 million tons in 2019/2020. The largest producer shall be China (15.1 million tons), followed by the USA (11.1 million), Argentina (8.6 million tons), Brazil (8.4 million) and the European Union (3 million). For the international trade of soybean oil, the projection for 2019/20 is of 11.6 million tons. China consumes practically all of its production, not interfering in the world export market of the product. In turn, European Union exports around one million tons of the commodity each year, whilst the USA also consumes almost all its production internally (its export projection in 2019/20 is of only 800,000 tons). After biodiesel, Brazil, which in the past was an important exporter of this by-product of soy, considerably reduced its participation in the world market. The country projects exports of 1.2 million tons for the referred business year. Thus, the major exporter of soybean oil ought to be Argentina, with a projection of 6 million tons for the cited year. The neighboring country shows this behavior, since its domestic consumption of edible oils is particularly concentrated in sunflower and olive oils, respectively. The largest importers of soy oil are India (3.5 million tons), North Africa (1.6 million tons) and China (1.2 million tons) (USDA, 2019).

In Brazil, the evolution of soybean oil production can also be described in two phases through the past 50 years. In the first one the product's internal consumption, especially for human intake, and exports happening only for the surplus which was not consumed. This phase extends especially from 1960 to 2006. The second phase, from 2006 to the present day (2019/20) has witnessed an increase in internal consumption of soybean oil, despite it has to do with the production of biodiesel. Thus, exports have an important reduction in volume, a fact also stimulated by the consumption of sunflower oil, canola and olive oils by the population. In 2006/07, out of 6 million tons produced, Brazil consumed 3.6 million of it and exported 2.4 million. The projected production is to be of 8.8 million tons in 2019/20; domestic consumption is expected to reach 8.7 million tons; and exports to be around only 300,000 tons (the difference between the sum of these two items and the production lies in the existing initial storage each year). Through this period, the use of soybean oil for biodiesel went from almost zero to about 4 million tons, while human consumption reached 4 million, in comparison to 3 million tons in 2006. In fact, biodiesel production in Brazil increased from 69,000 tons in 2006 to around 6 million tons in 2019, a great deal of this raw material being soybean oil. (ABIOVE, 2019).

3 JOHANSEN METHOD

The current method aims to verify causality and cointegration among the variables. For this purpose, Granger causality tests and the impulse-response function shall be carried out. Johansen method is based on an unrestricted VAR model, represented in terms of the variables levels which are relevant to the analysis. To illustrate the process, we shall consider the following vector equation:

$$\mathbf{y}_t = \mathbf{A}_1\mathbf{y}_{t-1} + \cdots + \mathbf{A}_p\mathbf{y}_{t-p} + \boldsymbol{\mu} + \mathbf{u}_t \tag{1}$$

In this case, y_t represents a vector of k non-stationary endogenous variables, Ai represents matrices k × k of parameters and u_t represents a vector of residues i.i.d, with zero mean and matrix of contemporaneous variances and covariances Ω. The matrix Ω is positive definite, so that the residues are not correlated in series, but may be contemporaneously correlated. Formula number 1 is in reduced form, where each variable in y depends on its out of date values, the out of phase values of the other system variables and the constant μ.

According to Sims (1980), this type of model has the particularity of allowing the modelling of dynamic relations among endogenous joint variables without imposing strong restrictions to the system, such as particular structural relations or the exogeneity of some of the variables. The VAR model also permits the historical decomposition of prediction variance errors, k periods ahead, into percentages to be attributed to each system component variable, analyzing the importance of every shock in each variable of the model occurred in the past (in the explanation of the deviations from observed values of variables in relation to their forecast at the beginning of the period studied).

The concept of cointegration was first introduced by Granger (1980) and Granger (1988). The economic interpretation of integration is that if two (or more) variables have a long-run equilibrium relationship, even if the series may contain stochastic trends, they will move together over time and their ratio will be stable, stationary. In short, the concept of cointegration indicates the existence of long-run equilibrium, for which the economic system converges into time (HARRIS, 1995).

Cointegration tests are vital for those who work with time series in economics, since they make it possible to study and analyze structural relations among economic variables. More precisely, these tests allow us to determine if variables have a long-term equilibrium relationship between them (MARGARIDO, 2004). Johansen and Juselius (1990) methodology considers a VAR model of order p, where it is necessary to know the number of lags used in the VAR model in an earlier step. For the determination of the number of integration vectors, the methodology determines two tests denominated trace statistic ($\lambda_{traço}$) and maximum eigenvalue (λ_{max}). In the trace statistic ($\lambda_{traço}$) the null hypothesis (H0) is that there are at least r cointegration vectors. The maximum eigenvalue test (λmax) has the following premises: (H0) the number of cointegration vectors is equal to r vectors and (H1) the number of cointegration vectors is equal to r + 1 vectors. If the calculated values are higher than the critical values, we reject the null hypothesis of non-cointegration, the critical values of the trace test and the maximum eigenvalue test.

In a nutshell, Johansen's cointegration methodology generally involves the following steps: (1) testing the order of integration of the model variables using ADF and KPSS tests; (2) choose the number of lags of the VAR model to be included in the cointegrating space, so that the residuals shall be white noise. The identification of cointegration among the studied variables and the fact that a VAR model with error correction can be written, identify which are the causal relations existing amid the series under study.

Causality tests are used to identify causality relationships. According to Granger (1969), causality is when a variable X causes another variable Y; if the observation of X in the present or in the past helps to predict the future values of Y for some time horizon. Causality can exist in one of the directions, either X causes Y or Y causes X, or even bi-causal. This causality means that oscillations in X can be perceived in Y or vice versa. Hall, Anderson and Granger (1992) note that cointegration between two variables is enough condition (but not necessary) for the presence of causality in at least one direction.

Finally, the effect of a shock from one variable to the other is verified, in order to measure the extension of shocks without distinction, that is the reason why impulse response function is used. When a "shock" is applied (an innovation of a standard deviation), in the error term on one of the variables of the equations system, and if that shock does not produce an effect on the variance predictions of other variables errors, it can be said that this variable is exogenous, that is, independent from others. If we consider the variables X_t and Y_t to verify the existence of cointegration and causality between them, we observe that the effect of a shock on Y_t not only changes immediately the values of the variable X_t, but also the future values of X_t and Y_t, once the lagged values appear in both equations.

The impulse-response function represents, basically, the behavior of a variable when another variable of the system, or the own variable itself gets a shock (impulse) at that given instant t and is transferred to the future period at t + 1, t + 2, and so on. It can be stated that the results presented in impulse-response function allow us to proper evaluate the results of the shocks in any of the variables system variables.

Cholesky decomposition will be used to identify the vector et. A shock in the variable does not only directly affect the ith of the model but is also transmitted to the other endogenous variables through VAR's dynamic structure. An impulse-response function traces either the effect of a shock or an innovation on current and future values of the endogenous variables of the model. The construction of the impulse-response function starts from the representation of the VAR model, expressed in current and past values of the e_{ti} shocks. Brooks (2003) points out that the impulse-response function makes it possible to say whether changes in a given variable have positive or negative effects on the other system variables, as well as to ascertain the time required for such an effect to be gathered. Thus, for each variable in the equation, a unit shock is submitted to the disturbance and the effects on the system are represented graphically. If there are g variables in the system, a total of g2 shocks can be generated.

Bliska (1990) states that one of the main advantages of orthogonalized innovations over the others is that they are not correlated. However, there is a different decomposition for each ordering of the variables, and the direction of the captured effect results from the arbitrary selection of variables order in the analyzed vector. Therefore, the smaller the contemporary covariance (lesser correlation between the residues), the smaller the importance of the selected order. Therefore, even though there is no sense of causality between two variables, there may still be a shock effect of one of them on the other due to the presence of covariance between their respective errors.

4 METHODOLOGY

To fulfill the objectives proposed in this study, data were collected in the Chicago Cereal Exchange (CBOT) database from 03/01/2006 to 07/30/2019, regarding the following categories: estimates on future price of soy; estimates on the future prices of soybean oil and soybean meal. The daily closing price of the three variables studied was used.

The analysis of data happened in two moments. Initially, the stationarity of the three series was tested and the Johansen method was applied to test cointegration, causality and impulse function in the series and utilized the ADF and KPSS tests. From such tests it was possible to perceive the influence one variable exerts on another, by impacting it positively or negatively, and how this happens and lingers over time. Therefore, the study presents the following hypothesis:

Chart 1 - Study hypothesis

H1	Future prices of soybean oil do not influence future prices of soybean meal
H2	Future prices of soybean meal do not influence future prices of soybean oil
H3	Prices of soy do not influence future prices of soybean meal
H4	Future prices of soybean meal have no influence on future prices of soy
H5	Future prices of soy have no influence on future prices of soybean oil
H6	Future prices of soybean oil have no influence on future prices of soy

Source: Elaborated by the authors

To analyze the influence of the variables, it will be used the Granger causality test. From the impulse-response test we seek to perceive to what extent one variable impacts the other.

5 RESULTS

Initially, the series stationarity was analyzed as a preparatory analysis for the time series modeling, based on Lutkepohl and Kratzig (2004). Such characteristics must be considered in the modeling of the data generating process, which builds a system of potentially related variables in time.

The stationarity verification was performed through the ADF hypothesis test. In order to validate this very test, we used another test – KPSS -, where the hypotheses presented are contrary to the ADF tests, that is, H0 presupposes that the series is I(0) against the alternative that the series is I(1), according to Souza and Souza (2010).

Table 1 - ADF and KPSS unit root level tests and first differences

	ADF	Δ (ADF)	KPSS	Δ (KPSS)
Soybean meal	-2.312	-14.332*	1.159	0.037*
Soybean oil	-2.857	-15.531*	1.251	0.024*
Soy	-2.108	-20.885*	1.336	0.066**

Notes: *Significant at 5% level. **Significant at 10% level. ADF: Critical values of MacKinnon (1996): - 3.50 (1%) and -2.892 (5%). KPSS Values: MacKinnon's critical values (1992, table 1): 0.739 (1%) and 0.463 (5%)
Source: Survey results

When the level series were analyzed by the ADF hypothesis test, as shown in table 1, it can be said that the series are stationary, and those results are corroborated by the KPSS test with p-values below 5%. After learning this, it was possible to apply the next tests.

The results from cointegration tests between price and production are reported in table 2. The number of lags order inserted in the models was performed based on the lag order selection criteria test. The lowest value of the SBC criterion was considered in order to adjust the model with a lag for each variable.

Table 2 - Results from the lag order selection criteria test among soybean meal, oil and soy

Lag	AIC	SC	HQ
0	16.726	16.761	16.740
1	9.827	9.967	9.883
2	9.559*	9.804*	9.657*
3	9.586	9.937	9.726
4	9.578	10.034	9.760
5	9.614	10.176	9.839
6	9.590	10.257	9.857
7	9.565	10.336	9.873
8	9.588	10.466	9.939

Notes: * indicates the lag order selected by criterion
AIC: Akaike information criterion
SC: Schwarz information criterion
HQ: Hannan-Quinn information criterion

Source: Survey results

Once the number of lags has been defined, it can be evaluated the presence of cointegration vectors by using the Johansen method, in which the cointegration relations of the variables were defined for the two lags model.

From this moment on, Granger's causality test was performed among the variables under study. The results shown on Table 3 are all significant for 5%, except for the price of soybean meal and soybean oil, which is not significant, and the price of soy and soybean oil, which is significant at about 75%.

The results point to a two-way causality, meaning prices can influence one another. The exception goes for soybean oil and meal prices which have a unidirectional causality; for instance, future prices of soybean oil influence imminent prices of soybean meal, but soybean meal future figures do not influence soybean oil upcoming prices, at a statistical level of 5%. The shocks or fluctuations in prices are transmitted amid the products analyzed.

Therefore, the results prove there is a relationship between the future price of soy and its by-products, and it is even more conspicuous in the case of soybean oil, focusing on both the price of soybean meal and soy seed. This happens due to the important relation that soybean oil has developed with international oil prices, from the moment that it began to be used with greater intensity as biodiesel in different countries in the world, particularly in Brazil. [3]In addition, as the market demands more soybean oil than meal, the need for milling soybeans increases significantly once it results in only 18.5% oil and 78% of bran. Thus, an increase in oil prices have greater impact on the price of soy than on soybean meal, and vice versa.

[3] BRUM, A. L. ; BAGGIO, D. K. ; SCHNEIDER, I. N. ; SOUZA, F. M. ; KNEBEL, E. L. ; SILVA, K. L. M. . Influência dos fundos de investimentos na formação do preço da soja na Bolsa de Cereais de Chicago. DRd - Desenvolvimento Regional em debate, v. 12, p. 1-23, 2022.

Table 3 - Granger causality test for the dollar price of soybean meal, oil and soy

Null hypothesis	Direction	F-Statistic	Prob.
SOYBEAN OIL does not influence SOYBEAN MEAL	→	10.1175	0,0000*
SOYBEAN MEAL does not influence SOYBEAN OIL	-	1.23447	0,2924
SOY does not influence SOYBEAN MEAL	→	48.9218	0,0000*
SOYBEAN MEAL does not influence SOY	←	6.85048	0,0012*
SOY does not influence SOYBEAN OIL	→	2.61231	0,0749**
SOYBEAN OIL does not influence SOY	←	9.83235	0,0000*

Notes: *Significant at 1% level; **Significant at 10% level

Source: Survey results

After causality analysis, it was executed the impulse response function of Cholesky, which shows the long-term effects on time series. The analysis of the impulse-response function is particularly useful for observing the direction, duration and reaction pattern of response from the variable of interest to pulses of a standard (and future) deviation in the model's endogenous variables.

The graphical analysis of the impulse response function is a practical way to visualize the behavior of the dependent variable in response to a series of shocks. It is important to notice that the ordering of the variables has a large influence on the analysis of the impulse response function. The importance of sorting depends on the magnitude of the correlation coefficient among error terms.

Figure 1 presents the impulse response functions from prices of soybean meal, soybean oil and soy in regard to innovations of a standard deviation. The figure 1 is organized in such a way that the analysis starts with the graph entitled "Response of FARELO to FARELO", going to the second graph "Response of FARELO to OLEO", with the sequence of graphs always from left to right.

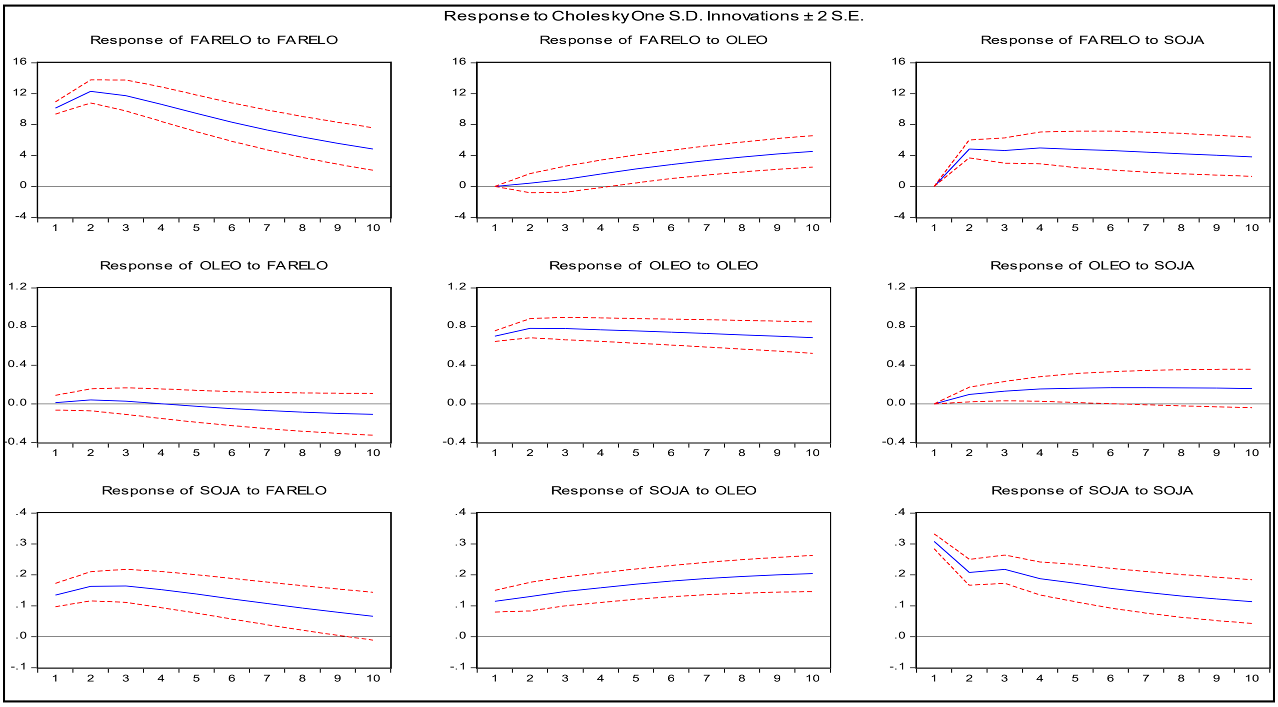
It is observed a standard deviation shock applied to the price of a single product influences in the price of the other.

The first graph presents the response regarding a change in price of soybean meal after a shock. It is observed that the shock produces relatively high intensity response, with relatively long negative duration, ceasing the impact only at the tenth month after the innovation. Thus, in the first months, the price has a slight increase and from the second and third month it gradually decreases. The second graph shows the response of soybean meal prices to a shock in soybean oil prices variation. The shock produces a response of medium intensity and positive duration, ceasing the effect only at the tenth month after the innovation.

The third graph shows the response of soybean meal prices to a shock in soy prices variation. The shock results in medium intensity response and positive duration, which tends to be uniform over the duration of the innovation, ceasing the effect only at the tenth month after the innovation.

The fourth graph presents the response of soybean oil prices change to a shock in soybean meal prices. It is observed that the shock produces low intensity response, with relatively long negative duration, ceasing the impact only at the tenth month after the innovation. The other graphs follow the same logic of interpretation.

Figure 1 - Analysis of impulse response function



Note: Future prices of variables. Legend: FARELO = MEAL; OLEO = OIL; SOJA = SOY

Source: Survey results

On the seventh graph we learned that a standard deviation shock, if applied to soy prices, influences soybean meal prices, so that they slightly increase in the first months and then they fall.

The analysis of the impulse response function showed that shocks have significant impacts among prices, in terms of both duration and intensity. Shocks used to last around ten months. The 10-month forecast error variance was used. The future prices of soybean meal, soybean oil and soy were the decomposed variables in table 4. It was analyzed how much of the same variable is self-explained and explained by other variables as well.

In the first month, 100% of variance in soybean prices are self-explained. In the second period, 92.30% of soybean meal prices variance is explained by the variable itself; 0.078% is elucidated by the price of soybean oil, and 7.62% by the price of soy. Therefore, the influence of the two variables is perceived for the composition of the future price of soybean meal over time.

By analyzing the decomposition of variance according to the following tables, we verified that variables influence the price formation of the product in evidence. The relationship between these variables is short-term. The analysis of variance decomposition resulted in the percentage by which each variable participates in the formation of other indexes, in a 10 months' horizon.

Table 4 A - Decomposition of soybean meal variance

P	soybean meal			
	S.E.*	**MEAL**	**OIL**	**SOY**
1	1.018.459	100.000	0.000000	0.000000
2	1.672.440	9.229.866	0.078026	7.623.317
3	2.104.819	9.102.536	0.284231	8.690.410
4	2.425.734	8.929.089	0.756454	9.952.655
5	2.666.502	8.780.600	1.509.337	1.068.466
6	2.857.197	8.619.678	2.557.086	1.124.613
7	3.013.178	8.449.578	3.886.168	1.161.805
8	3.145.492	8.267.399	5.476.283	1.184.973
9	3.261.182	8.074.509	7.298.708	1.195.621
10	3.365.232	7.872.233	9.320.340	1.195.733

Cholesky Ordering: MEAL OIL SO

Source: Survey result

Table 4 B - Decomposition of soybean meal variance

P	soybean oil			
	S.E.*	**MEAL**	**OIL**	**SOY**
1	0.711904	0.135297	99.86470	0.000000
2	1.087364	0.549597	99.13055	0.319857
3	1.372504	0.804810	98.90188	0.293314
4	1.610925	0.937599	98.80804	0.254358
5	1.819946	0.997568	98.79594	0.206491
6	2.008746	1.018476	98.81198	0.169547
7	2.182443	1.018355	98.83481	0.146838
8	2.344289	1.006974	98.85488	0.138144
9	2.496473	0.989629	98.86839	0.141978
10	2.640555	0.969307	98.87439	0.156304

Cholesky Ordering: MEAL OIL SOY

Source: Survey results

Table 4 C - Decomposition of soybean meal variance

P	soy			
	S.E.*	**MEAL**	**OIL**	**SOY**
1	0.356362	13.29229	8.587039	78.12067
2	0.462823	19.24187	11.50474	69.25339
3	0.559073	20.83119	13.63646	65.53235
4	0.629115	21.59282	16.23698	62.17020
5	0.687708	21.63007	19.04040	59.32953
6	0.737033	21.36318	22.04958	56.58724
7	0.780506	20.89428	25.17107	53.93465
8	0.819726	20.31207	28.35007	51.33786
9	0.855967	19.66090	31.53091	48.80819
10	0.890045	18.97270	34.67025	46.35705

Cholesky Ordering: MEAL OIL SOY

Source: Survey results

By inspecting table 4, it is noticeable that variables influence one another, mainly in in the long-run prices formation. Three variables become more influenced over the periods, mainly on future prices of soybean meal and soy. Nevertheless, soybean oil has greater autonomy in its formation, with little explanatory power due to the two other variables. It should be noted that the same results had been obtained from Granger causality test, as shown in table 3.

The importance of the price variables "soybean oil future" and "soybean meal" are also important for the formation of soybean future prices. With the pass of time, this role in the formation of soybean prices increases.

To this end, six hypotheses were proposed to be studied; five of them were rejected and only one continued to be accepted, as seen in the table below:

Chart 2 - Study hypothesis

H1	Future prices of soybean oil do not influence future prices of soybean meal	Rejected*
H2	Future prices of soybean meal do not influence future prices of soybean oil	Accepted
H3	Prices of soy do not influence future prices of soybean meal	Rejected *
H4	Future prices of soybean meal have no influence on future prices of soy	Rejected *
H5	Future prices of soy have no influence on future prices of soybean oil	Rejected **
H6	Future prices of soybean oil have no influence on future prices of soy	Rejected *

Notes: * Significant at 1% level. ** Significant at 5% level

Source: Elaborated by the authors

The results showed there is a relation on the future price formation among the three variables studied. It should be noted that soybean oil and soy influence soybean meal, just as soybean meal and soybean oil impact on soy. Soybean oil represents a more isolated variable, since it has not been statistically proven that soybean meal impacts the future price of the soybean oil; while on the other hand soy price does impact, with higher significance of 10%. Even so, soybean oil impacts on the other two variables.

6 FINAL CONSIDERATIONS

The present study aimed to identify the real relationship between soy prices in Chicago and the prices of its two by-products (soybean oil and soybean meal) and vice versa, taking as a reference the time span between 2006 and 2019.

The analysis of the impulse response function proved that shocks have significant impact among prices, both in terms of duration and intensity. In general, the shocks had durations of ten months. These findings are important, since oscillations in prices at the current time may influence other series for a long period of time.

Therefore, the findings here are important for the theory, once they attest the influence of future prices of the commodities studied. As for the practical implications of this study, it serves as a subsidy for those interested in the future price of soy, emphasizing that they should not only look at its price alone, but rather on soybean oil and soybean meal future prices, which directly impact on the formation of soy prices. It should be noted that the impacts on price fluctuation of soybean oil and meal may not immediately affect soy prices. It might extend over a certain period, so that this change in soy price will be seen in the future, resulting from past oscillations in the two variables.

As for future studies, new variables may be incorporated into the analyses, such as: future oil prices, future corn prices, stock market indexes and other important variables for its price formation.

ACKNOWLEDGEMENTS

Agradecimento ao Guilherme Batista – In Memoriam: Os autores deste artigo, assim como o Grupo de Pesquisa sobre Finanças, do PPGDR/UNIJUI, prestam sua homenagem póstuma ao doutorando Guilherme Batista, que nos deixou inopinadamente no dia 19/12/2022. Sem sua valiosa participação este artigo dificilmente seria publicado.

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Como citar este artigo

BATISTA, G.; BRUM, A. L.; BAGGIO, D. K.; SOUZA, F. M. The establishment of soybean price and its interrelation with the prices of its derivatives: soybean meal and soybean oil. **Ciência e Natura**, Santa Maria, v. 44, e56, 2022. DOI: https://doi.org/10.5902/2179460X68858.