The pear market in Brazil: analysis of price transmission between the markets of São Paulo-SP, Porto Alegre-RS and Recife-PE

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Summary
Aims to analyze the price transmissions between the pear market in Brazil. Specifically, the chosen markets were Porto Alegre-RS, São Paulo-SP and Recife-PE, with monthly series from June 2009 to December 2015. The Granger causality test showed that the São Paulo market causes the others, but the reverse is not true. Johansen's cointegration test showed that the matrix of interest has complete rank (r=n), which indicates that the columns of the matrix are linearly independent and, thus, it is not necessary to estimate a VEC, but a VAR at the level. The price transmission elasticity according to the estimated VAR model shows that the price increase in São Paulo is passed on in greater magnitude to Porto Alegre than to Recife. A 10% increase in the price of pear in period t-1, ceteris paribus, will cause Porto Alegre and Recife to increase by 3.5% and 1.7%, respectively, in period t. The variance decomposition confirms what the Granger causality test showed, that is, that the São Paulo market is the central market and it is this one that determines prices, while the others are price takers.
Keywords: Price transmission. Granger causality. Johansen cointegration. Elasticity.

Mercado das peras no Brasil: análise da transmissão de preços entre os mercados de São Paulo-SP, Porto Alegre-RS e Recife-PE

Resumo
O presente trabalho tinha como objectivo analisar a transmissão de preços entre o mercado da pêra no Brasil. Especificamente, os mercados escolhidos foram Porto Alegre-RS, São Paulo-SP e Recife-PE, com séries mensais entre Junho de 2009 e Dezembro de 2015. O teste de causalidade da Granger mostrou que o mercado paulista causa os outros, mas o inverso não é verdade. O teste de cointegração de Johansen mostrou que a matriz de interesse tem uma classificação completa (r=n), o que indica que as colunas da matriz são linearmente independentes, pelo que não é necessário estimar um VEC, mas sim

um VAR de nível. A elasticidade dos preços de transmissão de acordo com o modelo VAR estimado mostra que o aumento de preços em São Paulo é transmitido em maior magnitude para Porto Alegre do que para Recife. O aumento de 10% do preço da pêra no período t-1, ceteris paribus, irá aumentar Porto Alegre e Recife em 3,5% e 1,7%, respectivamente, no período t. A decomposição da variância confirma o que o teste de causalidade da Granger mostrou, ou seja, o mercado de São Paulo é o mercado central, é este mercado que determina os preços, enquanto que os outros são tomadores de preços.
Palavras-chave: Transmissão de preços. Causalidade da granjeira. Cointegração de Johansen. Elasticidade.

1 Introduction

The pear (from the genus Pyrus) is the edible fruit of the pear tree, belongs to the family Rosaceae and is one of the most important fruits of temperate regions. The pear, as well as the apple, originated in Asia, probably in China, and was introduced in Europe, where nowadays there is also an expressive production (NEVES, 2015).

The pear is cultivated in many countries, which makes it a fruit of great acceptance and importance in the international market. In Brazil, however, the pear tree does not stand out among the most expressive fruit trees. Among temperate climate fruits, it has the lowest expression in terms of production, planted area and value of production (FIORAVANÇO, 2007).

The world's largest producer of pear trees is China, followed by the United States and Argentina. China's production in 2013 was 17.44 million tons, which is equivalent to 69.2% of world production (25.2 million tons). Whereas, the production of the United States and Argentina for the same year 2013 was 795.56 thousand tons (3.16% of world production) and 722.32 thousand tons (2.87% of world production), respectively (FAO, 2016). In the period from 2005 to 2012, the annual production growth rates of China, the United States and Argentina were 5.32%, 1% and -1.18%, respectively. The rate of 1% p.a. for the United States, however, was not statistically significant, even at the 10% level of significance, thus showing that

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there was no increase in production for that country in this period (RIBEIRO REIS et al., 2015).

Brazil is a major importer of this fruit, importing from 2001 to 2012 an average of 117,973 tons, and of this import, most comes from Argentina, reaching 96,606.9 tons (81.89%). The second country from which Brazil most imports the fruit is Portugal, receiving from it 9853.9 tons, which represents 8.35% of Brazilian imports of the fruit (ALICEWEB, 2014).

According to data from IBGE (2014), in 2001, the production of pear in Brazil was 21,522 tons, increasing in 2012 to 22,078 tons, which shows a geometric growth rate of 0.196% p.a. Brazilian production is concentrated in the Southeast and South regions, specifically the latter, which accounts for more than 79% of national production, considering the period from 2001 to 2012 (IBGE, 2014).

This fruit is of great importance, given that its apparent consumption (production + import - export) in Brazil, according to Ribeiro Reis and Lima (2015), was 139,000 tons in 2001, increasing to 230,000 tons in 2012.

Thus, we sought to analyze whether there are price transmissions between some Brazilian markets and which market is responsible for price formation (central market). Specifically, the chosen markets were: Recife-PE, São Paulo-SP and Porto Alegre-RS. The study will be carried out by means of a Vector Autoregressive Model (VAR), as well as the Granger causality test and Johansen's cointegration test.

2 Literature review

The VAR (vector autoregressive) methodology spread rapidly after the study by Sims (1980), and is today one of the most widely used models in the field of macroeconomics. Unlike the simultaneous equations model, in VAR one does not have the problem of defining which variables will be endogenous. In it, all variables are endogenous, and exogenous variables can also be inserted, such as trends, dummies, etc. In VAR, one can work with identical variables in different markets

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(prices of an identical type of good or service in different markets), as well as distinct variables in the same or different markets.

Mayorga et al. (2007) estimated a VAR(2) model in the period from January 2001 to December 2005, aiming to examine the price transmission and causality relationships among the yellow melon wholesale markets in Brazil. The markets analyzed by the authors were: São Paulo-SP, Natal-RN, Fortaleza-CE, Salvador-BA, Recife-PE, Curitiba-PR, Belo Horizonte-MG and Brasilia-DF. The authors concluded that, although the Açu/Mossoró-RN and Baixo Jaguaribe-CE poles represent the largest national melon producing areas, variations in yellow melon wholesale prices from the supply centers of Natal and Fortaleza do not affect significantly the prices of the other studied markets and that variations in the São Paulo distribution centers have an impact on all the wholesale markets analyzed, even explaining by the variance decomposition analysis all the variables more than the variables themselves explained. Thus, the São Paulo distribution centers show themselves as a market that sets prices, characteristics of an oligopolistic market.

Inquiring about the results that fluctuations in the price of corn and soybean have on the price of chicken meat in the state of Pernambuco, from January 2005 to December 2015, Melo et al. (2016) estimated a VAR(1) with the prices of soybean, corn, and chicken meat, all R$/Kg as the unit of measurement. They concluded that the effects on chicken meat prices due to exogenous shocks to corn and soybean prices are similar. Initially, they have a positive impact, indicating an attempt of the producers to pass on the increase in production costs to the price of their products, but probably, due to the competition of chicken produced in other regions, they have to adjust to the market conditions. The effect of the shocks stabilizes after four periods.

Seeking to analyze the relationship between natural rubber prices between domestic (Brazil) and international (Malaysia) markets, Soares et al. (2008) modeled a VEC for the period January 2000 to May 2007. The results showed that a large percentage of the long-run variation in Malaysian natural rubber prices was passed

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on to the domestic market in the period studied, and that the Law of One Price (LPU) is not verified perfectly for such a market, and thus there is no perfect integration. The authors also concluded that prices in Brazil are influenced by prices in Malaysia, but the opposite is not true.

Carneiro and Parré (2005) analyzed the price transmission between producer, wholesaler and retailer in the production chain of beans in the State of Paraná, from 1995 to 2003. The marketing margin, according to the authors, in the price to the final consumer was 49.6%, 24.0% and 26.4%, respectively, for the producer, wholesale and retail segments. The authors concluded that, by the Granger causality test, retailing is the sector that dictates the market, that is, that commands prices. Changes in this sector reflect the producer and wholesale level. The results, according to the authors, expected that the independent variable would be the wholesale, that is, it would be expected that the wholesale would be the market leader. This is because, according to Barros (1990) apud Carneiro and Parré (2005), prices in the wholesale market adjust instantaneously and at low cost, besides the fact that sales are centralized, short term, and have greater specialization with easier access to information..

3 Methodology

In this section, the procedures used in the work will be shown, as well as the data source used.

3.1 Unit root test

To work with time series, it is necessary that they are stationary in time. A time series (stochastic process) is said to be stationary if it shows constant mean and variance over time and the value of covariance between two periods depends only on the distance between the two periods and not the actual time at which the covariance is computed. This can be represented, according to Gujarati and Porter (2011, p. 734), as follows:

- Media: $E(Y_t) = \mu$ (1)

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- Variancia: $\mathrm{Var}(Y_t) = E(Y_t - \mu)^2 = \sigma^2$ (2)
- Covariance: $\mathrm{Cov}(Y_t) = E[(Y_t - \mu)(Y_{t+K} - \mu)] = \gamma_k$ (3)

where γ_k, the covariance (or autocovariance) at lag k, is the covariance between the values of Y_t and Y_(t+k), that is, between the values of Y separated by k. If k=0, we get γ_0, which is simply the variance of Y (=σ^2); k=1, γ_1 is the covariance between adjacent values of Y (GUJARATI; PORTER, 2011, p. 734).

If a series is not shown to be stationary, its behavior can only be studied for the period considered, that is, it cannot be inferred for steps ahead (OZAKI et al., 2016). If the series is not stationary, it takes d differentiations until it becomes stationary (integrated of order d). Thus, a stationary series at level is called I(0). If the first difference makes it stationary, it is said to be integrated of order 1, that is I(1), and so on (SILVA FILHO et al., 2005).

There are several tests in the literature for detecting the stationarity of a series, such as the Phillips-Perron test; Augmented Dickey-Fuller (ADF); Dickey-Fuller - GLS, developed by Elliot et al. (1996), KPSS, among others. With the exception of the KPSS test, the null hypothesis 〖(H〗_0) of the other tests is that the series has unit root (ALMEIDA et al., 2015). The KPSS test assumes that the series has no unit root, and is thus stationary (MAYORGA et al., 2007).

In this study, the unit root test used was Augmented Dickey-Fuller (ADF), around intercept and trend, which has the following form:

$$\Delta Y_t = \beta_0 + \beta_1 t + \phi Y_{t-1} + \sum_{i=1}^{m-1} \lambda \, \Delta Y_{t-1} + \epsilon_t \qquad (4)$$

where: ∆Y_t is the first difference of Y_t; t is a time series;

The variable 〖∆Y〗_t enters lagged in the model to avoid serial autocorrelation of the residuals, thus obtaining an unbiased estimate of ϕ, coefficient of Y_(t-1) (GUJARATI; PORTER, 2011, p. 751). A major problem in estimating the ADF shown in equation (4) is

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defining the number of lags (lags) of the endogenous variable (ΔY_t). If, on the one hand, the more lags improve the possibility of analyzing intertemporal characteristics, on the other hand, this implies a reduction in degrees of freedom, something that can become a serious problem conditioned on the size of the database.

As shown in the literature, the choice of the number of lags can be made according to the AIC (Akaike), SBC (Schwarz) and HIQ (Hannan-Quinn) information criteria, choosing the lag that indicate lower values for these criteria (MORETTIN, 2006). In this study, the information criterion chosen was Akaike's. In equation (4), if the value of the calculated t-statistic is greater than the tabulated critical values, then the null hypothesis that the series is nonstationary is rejected.

The first difference of a series is given by: $\Delta Y_t = Y_t - Y_{t-1}$. The second difference is $\Delta^2 Y_t = \Delta(\Delta Y_t) = \Delta(Y_t - Y_{t-1}) = \Delta Y_t - \Delta Y_{t-1}$. Thus, the d-th difference of Y is $\Delta^d Y_t = \Delta(\Delta^{d-1} Y_t)$ (FARIAS, 2008).

3.2 Granger Causality Test

The Granger causality test, for two data series, aims to show whether one data series X_t has an effect on the forecast determination of another series Y_t (MELO et al., 2016; CAVALCANTI, 2010).

According to Farias (2008), consider two stationary time series (X_t and Y_t):

- $X_t \to Y_t$: X_t causes Y_t in the Granger sense, if Y_t can be best predicted with all availab
  X_t. In this case, there is unidirectional causality from X_t to Y_t, or from Y_t to X_t,
- There is feedback when $X_t \leftrightarrow Y_t$, that is, X_t Granger causes Y_t and Y_t, Granger causes X_t.

The Granger causality test for two data series is done by estimating both variables in the dependent variable position, as shown below (FARIAS, 2008; SILVA FILHO et al., 2005; BUENO, 2011; SOUZA et al., 2013):

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$$Y_t = \varphi + \sum_{i=1}^{n} \delta_i X_{t-i} + \sum_{i=1}^{n} \rho_i Y_{t-i} + \varepsilon_{yt} \tag{5}$$

$$X_t = \emptyset + \sum_{i=1}^{n} \alpha_i X_{t-i} + \sum_{i=1}^{n} \beta_i Y_{t-i} + \varepsilon_{xt} \tag{6}$$

The null hypothesis is that there is no causality, neither X causes Y nor Y causes X. That is, the null hypothesis is that the coefficients δ_i in (5) and β_i in (6) are equal to zero, being described as follows: {"(H_0:δ_i=0@H_0:β_i=0)┤ .

If δ_i and β_i are null, the null hypotheses are not rejected, so the consequence is that X_t does not Granger cause Y_t, and that Y_t Granger does not Granger cause X_t, i.e., X_t in (5) and Y_t in (6) do not influence the model. Obviously, if the null hypotheses are rejected, you have a causality relationship and can observe how the markets' prices adjust (SILVA FILHO et al., 2005).

According to Farias (2008), the next step is to perform a restricted regression for (5) and (6), i.e., we remove X_(t-i) from (5) and Y_(t-i) in (6), as follows:

$$Y_t = \varphi + \sum_{i=1}^{n} \rho_i Y_{t-i} + \varepsilon_{yt} \tag{7}$$

$$X_t = \emptyset + \sum_{i=1}^{n} \alpha_i X_{t-i} + \varepsilon_{xt} \tag{8}$$

After the restricted regressions (7) and (8) have been estimated, the F,

$$F = \frac{(SQR_R - SQR_{IR})/q}{SQR_{IR}/(N-K)} \tag{9}$$

where: 〖SQR〗_R is the sum of squares of the residuals from the restricted regression given by (7) and (8); 〖SQR〗_IR is the sum of squares of the residuals from the unrestricted regression given by (5) and (6); q is the number of parameter

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constraints in (7) and (8); and K is the number of parameters in (5) and (6). This statistic follows an F(q,N-K) distribution.

If the value of the F-statistic is greater than the tabulated critical value of F(q,N-K) at the chosen significance level, the null hypothesis is rejected, and thus X causes Y and/or Y causes X (BUENO, 2011; FARIAS, 2008).

3.3 VAR model, VEC and Johansen's cointegration test

The VAR is a model in which all data series of the system are considered endogenous. Thus, there is not that problem that simultaneous equations express, which is to define which variable will be exogenous (CARNEIRO; PARRÉ, 2005; MUSSOLINI; TELES, 2010). Consider a stationary bivariate VAR (1) in its structural form (BUENO, 2011, p. 196).

$$Y_t = b_{10} + a_{12}X_t + b_{11}Y_{t-1} + b_{12}X_{t-1} + \varepsilon_{yt} \quad (10)$$

$$X_t = b_{20} + a_{21}Y_t + b_{21}Y_{t-1} + b_{22}X_{t-1} + \varepsilon_{xt} \quad (11)$$

With a little matrix algebra, one can write the system of equations (10) and (11) in matrix form (SILVA FILHO et al., 2005; CAVALCANTI, 2010).

$$\begin{bmatrix} 1 & -a_{12} \\ -a_{21} & 1 \end{bmatrix} \begin{bmatrix} Y_t \\ X_t \end{bmatrix} = \begin{bmatrix} b_{10} \\ b_{20} \end{bmatrix} + \begin{bmatrix} b_{11} & b_{12} \\ b_{21} & b_{22} \end{bmatrix} \begin{bmatrix} Y_{t-1} \\ X_{t-1} \end{bmatrix} + \begin{bmatrix} \varepsilon_{yt} \\ \varepsilon_{xt} \end{bmatrix} \quad (12)$$

In a more compact form, we have:

$$\mathrm{B}Z_t = \mathrm{A}_0 + \mathrm{A}_1 Z_{t-1} + \varepsilon_t \quad (13)$$

whereby:

$$\mathrm{B} = \begin{bmatrix} 1 & -a_{12} \\ -a_{21} & 1 \end{bmatrix};\ \mathrm{A}_0 = \begin{bmatrix} b_{10} \\ b_{20} \end{bmatrix};\ \mathrm{A}_1 = \begin{bmatrix} b_{11} & b_{12} \\ b_{21} & b_{22} \end{bmatrix};\ Z_t = \begin{bmatrix} Y_t \\ X_t \end{bmatrix};\ \varepsilon_t = \begin{bmatrix} \varepsilon_{yt} \\ \varepsilon_{xt} \end{bmatrix}$$

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B B is known as the contemporaneous relations matrix. If one multiplies (13) by B^(-1) (the inverse of B), one arrives at the standard VAR in the reduced form given in (14).

We estimate the VAR in the reduced form, because in the structural form, it is impossible to estimate it directly, because the variables in the structural form are influenced contemporaneously. And thus, Y_t and X_t are individually correlated to the errors ε_yt or ε_xt, respectively (BUENO, 2011).

$$Z_t = C_0 + \Phi_1 Z_{t-1} + e_t \tag{14}$$

whereby:

$$C_0 = B^{-1}A_0;\ \Phi_1 = B^{-1}A_1;\ e_t = B^{-1}\varepsilon_t$$

This can be generalized to a VAR(p),

$$Z_t = C_0 + \sum_{i=1}^{p} \Phi_i Z_{t-i} + e_t \tag{15}$$

The VAR is only reliable if it is stable. The stability condition is to have all eigenvalues (roots of the characteristic polynomial) of

$$|I - \Phi_i L| \tag{16}$$

outside the unit circle (BUENO, 2011; MORETTIN, 2011).

As the solutions of (16) are inverses of the roots of Φ_i, a condition for the stationarity of the VAR is to have all eigenvalues of Φ_i smaller than one, in modulus (MORETTIN, 2011). According to Souza et al., (2013), the number of eigenvalues is given by: p×n, where p is the order of the VAR and n is the number of endogenous variables in the system. Thus, a bivariate VAR(2) has 4 characteristic roots.

The vector model with error corrections (VEC) is a parameterized form of the VAR given in (15), being estimated according to equation (17) (SOARES et al., 2008; SOUZA;

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CAMPOS, 2008). The VEC analyzes whether there is any long-run relationship among the variables (CHAGAS et al., 2008).

$$\Delta Z_t = C_0 + \sum_{i=1}^{p-1} \Phi_i \Delta Z_{t-i} + \Pi Z_{t-1} + e_t \qquad (17)$$

Johansen's cointegration test allows analyzing the rank of Π, which may have the following situations (MAYORGA et al., 2007; OZAKI et al., 2016):

If the matrix Π presents all eigenvalues different from zero, this will have complete rank (r=n), which suggests that all variables Z_t are stationary and its representation may be the VAR at the level given in (15) fitting no cointegration analysis;

If all eigenvalues of Π are null (r=0) this matrix is therefore indistinguishable from the null matrix. There are therefore no linear combinations concluding that the series are not cointegrated. If this occurs, it suggests modeling the VAR in first difference, without the variables in lagged levels, that is, estimating equation (17) without the Z_(t-1) term.

If the rank of Π is reduced (0<r<n), there exist in that case r non-zero cointegration vectors.

In the case where assumption (iii) occurs, it is said that there is at least one cointegration vector, and thus the matrix Π can be represented (CHAGAS et al., 2008; MAYORGA et al., 2007; SOUZA; CAMPOS, 2008) by Π=αβ^', where α are the long-run adjustment coefficients and β is the matrix whose columns are the cointegration vectors. The parameters α and β are matrices of dimension n x r, where n is the number of variables included in the model and r is the number of cointegration vectors of the matrix Π (MAYORGA et al., 2007).

Enders (1995) apud Souza and Campos (2008) describes that the rank of a matrix is equal to the number of non-zero characteristic roots of that matrix. To test the rank of Π, two tests are used, as shown in the literature, developed by Johansen

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(1988). The first is the trace test, where it tests the null hypothesis of at most r^* cointegrating vectors (H_0: r=r^*), against the alternative hypothesis that the number of vectors is greater than r^*, (H_1:r>r^*). The second test is the maximum eigenvalue test. The null hypothesis of this test is that there are r^* cointegrating vectors (H_0: r=r^*); the alternative hypothesis is that there are r+1 cointegrating vectors (H_1: r=r^*+1) (SOARES et al., 2008).

The trace and maximum eigenvalue tests are represented in equations (18) and (19), respectively, (SOARES et al., 2008; SOUZA; CAMPOS, 2008; BUENO, 2011; MORETTIN, 2011).

$$\lambda_{tr}(r) = -N \sum_{i=r+1}^{n} \ln\left(1 - \hat{\lambda}_i\right) \qquad (18)$$

$$\lambda_{máx}(r, r+1) = -N \ln\left(1 - \hat{\lambda}_{r+1}\right) \qquad (19)$$

where λ ̂s are estimated values of the characteristic roots obtained from the matrix Π, and N is the number of observations.

3.4 Data Source

The data were obtained from the website of the Brazilian Program for the Modernization of the Horticultural Market (PROHORT, 2016) under the National Supply Company (Conab). The periodicity of the data is monthly and comprises the prices of pear, practiced in: Recife-PE (Ceasa-PE); São Paulo-SP (Ceagesp - SP); and Porto Alegre-RS (Ceasa-RS). The period studied is in the interval from June 2009 to December 2015, thus comprising 79 observations. Prices were deflated by the General Price Index - Domestic Availability (IGP-DI) of the Getúlio Vargas Foundation, available at Ipeadata (IPEA, 2016), being December 2015, the month used as reference for price deflation.

The estimations were done using the "R" environment (R Core Team, 2018). "vars" (PFAFF, 2015) was used as an additional package. To facilitate interpretations, the series

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were logarithmized by Euler's natural logarithm (Neperian logarithm), so that the estimated coefficients can be interpreted as elasticities (MARGARIDO, 2004). The series for Recife, São Paulo and Porto Alegre were denominated LRECIFE, LSP and LPALEGRE, respectively.

4 Results and Discussion

4. 1 Descriptive analyses of prices

As shown in Table 1, the market that denoted the lowest price was Porto Alegre, an average price of 4.42 R$/Kg. In this market, prices (R$/kg) ranged from 3.32 to 6.19, a difference of R$ 2.87. Meanwhile, in Recife and São Paulo the difference between the highest and lowest price, in R$/kg, was 4.92 and 3.68, respectively. Recife was the market that showed the highest maximum price, since in February 2010, it reached 9.00 reais per kilogram of pear, as shown in Table 1.

The market that showed the highest price variability was São Paulo, with a coefficient of variation of 16.58%, higher than the other markets, i.e., pear prices in the São Paulo market are more heterogeneous.

Table 1: Pear price series statistics (Jun/2009 - Dec/2015)

	RECIFE-PE	SÃO PAULO-SP	PORTO ALEGRE-RS
Mean	5,38	4,93	4,42
Median	5,36	4,73	4,51
Maximum	9,00	7,18	6,19
Minimum	4,08	3,50	3,32
Standard Deviation	0,86	0,82	0,68
Coefficient of Variation (%)	15,99	16,58	15,28

Fonte: Elaboração própria, com base nos dados da Conab.
Nota: *p-values* entre parênteses.

Analyzing Table 1, one can see that prices in Porto Alegre are the lowest, staying during almost the entire period analyzed below the prices in Recife and, in most months, below the prices in São Paulo. This may be due to the fact that the South region is the largest producer of pears in the country, accounting alone for

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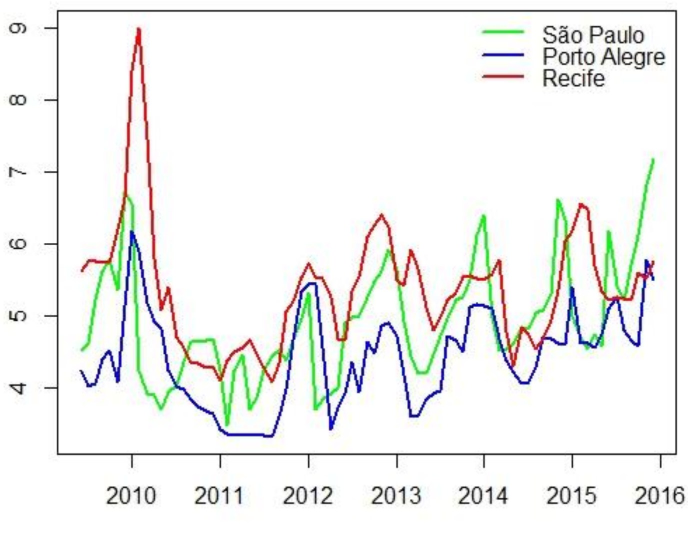
more than 79% (average from 2001 to 2002) of production, according to data from IBGE-PAM (2014). Considering the year 2012, 94% of Brazilian production is represented by the South region.

Also according to IBGE-PAM (2014), about 81% of the area of pear harvested in Brazil is in the South Region. As the fruit is produced more in the South, the transaction costs of getting them from the farms to Ceasa are lower than the others. As there is still no pear production in the Northeast, consumption comes from imports either from abroad or from the South and Southeast. This explains why prices in Recife are higher than in other markets.

From 2001 to 2015, the harvested area and production of pear in the Southeast region decreased by about 11.93% p.a. and 13.69% p.a. While the South region, for the same period, the annual increase in production was 2.45% (IBGE-PAM, 2016). This explains why prices in the city of São Paulo are higher than those in Porto Alegre.

Figure 1: Pear deflated price behavior (jun/2009 - dec /2015)



Fonte: Elaboração própria com base nos dados da Conab.

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ISSN: 2675-519X

4.2 Teste de Raiz Unitária

The ADF unit root test was performed considering intercept and trend, because as seen in Figure 1, the series express a trend behavior and thus ignoring it in the test will bring misinterpretations. As shown in Table 2, the unit root test, for the variables at the level, rejected the null hypothesis of unit root, the calculated t-statistic was higher than the critical value of up to 1%, evidencing that the series are all stationary at the level.

Table 2: ADF unit root test

Série	t_{calc}	Valor crítico		
		1%	5%	10%
LRECIFE	-5,70	-4,04	-3,45	-3,15
LPALEGRE	-4,07	-4,04	-3,45	-3,15
LSP	-4,67	-4,04	-3,45	-3,15

Fonte: Resultados da pesquisa.

4.3 Granger Causality Test

As shown in Table 3, the Granger causality test shows that prices in São Paulo cause prices in Recife, given that the calculated F-statistic value of 10.70 has a p-value less than even 1%. Thus, price fluctuations in São Paulo have an effect on prices in Recife. The reverse does not occur, that is, prices in Recife have no effect on prices in São Paulo even at the 10% significance level (p-value greater than 0.10).

The null hypothesis that prices in the city of Porto Alegre do not cause in the Granger sense the prices in Recife was rejected at the 1% level. Thus, the prices in Porto Alegre (as well as the prices in São Paulo) do cause the prices in Recife. On the other hand, the prices in Recife, considering a significance level of 10%, do not cause the prices in Porto Alegre.

Analyzing the Granger causality test between Porto Alegre and São Paulo markets, the null hypothesis that prices in São Paulo do not cause prices in Porto Alegre was rejected. The reciprocity, however, was not rejected, i.e., prices in Porto Alegre do not

Rev. Pemo, Fortaleza, v. 3, n. 3, e337173, 2021
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https://revistas.uece.br/index.php/revpemo
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cause Granger prices in São Paulo. Thus, the results showed that Recife is the price taker city (it has no market power). Meanwhile São Paulo is the central market (the one which determines prices). Changes in this market influence both Porto Alegre's prices and Recife's prices.

Table 3Granger Causality Test

Hipótese nula	Estatística F	Prob.
LSP does not cause in Granger sense LRECIFE	10,7073	(0,0000)
LRECIFE no cause in Granger sense LSP	0,2855	(0,7524)
LPALEGRE no cause shown in Granger sense LRECIFE	7,6215	(0,0007)
LRECIFE does not cause within the meaning of Granger LPALEGRE	2,6976	(0,0701)
LPALEGRE no cause within the meaning of Granger LSP	0,4380	(0,6462)
LSP no cause in Granger sense LPALEGRE	8,1922	(0,0004)

Fonte: Resultados da pesquisa.

4.4 Johansen's Cointegration Test

Before performing the Johansen cointegration test, it is necessary to define the number of lags to be used in the VAR model (SOARES et al., 2008). This number of lags is defined by the information criterion. In this study, the information criterion chosen was Akaike's (AIC) and it showed that the best model is the one with two lags, because 2 lags was the one that expressed the lowest value of this information criterion. In other words, the lag that presents the lowest value for the information criterion should be chosen (CASTRO; SILVA NETO, 2016; ALMEIDA et al., 2015). As the VAR has two lags, for estimating the VEC, a lag must be placed, i.e., if a VAR has k lags, the VEC will have k-1.

The Johansen cointegration test in Table 5 shows that the null hypothesis of no cointegration vector was rejected. By the trace test, the null hypothesis of no cointegration vector is rejected, since the calculated statistic of 51.18 is greater than the 5% critical value (31.52). The maximum eigenvalue test also proved significant at 5%. The calculated statistic of 23.16 is greater than its critical value of 21.07.

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ISSN: 2675-519X

These results show that there is at least one cointegrating vector and the test should continue until the null hypothesis is not rejected.

It is concluded that there are three cointegrating vectors, since the null hypothesis of up to 2 cointegrating vectors was rejected. The calculated values were greater than the critical values at 5% in both the trace test and the maximum eigenvalue test. Thus, Johansen's test suggests that a level VAR should be modeled because the number of cointegration vectors is equal to the number of variables, i.e., the matrix Π of equation (17) has full rank (full rank). Johansen's test therefore assumes that by placing all variables at the level in the VAR, the combination among them will produce a stable relationship.

Table 4: Johansen's cointegration test

Trace test				
H_0	H_1	*Eigenvalue*	Calculated statistic	Critical value at 5%
$r = 0$	$r > 0$	0,2597	51,18	31,52
$r \leq 1$	$r > 1$	0,2143	28,02	17,95
$r \leq 2$	$r > 2$	0,1154	9,45	8,18
Maximum eigenvalue test				
H_0	H_1	*Eigenvalue*	Calculated statistic	Critical value at 5%
$r = 0$	$r = 1$	0,2597	23,16	21,07
$r = 1$	$r = 2$	0,2143	18,58	14,90
$r = 2$	$r = 3$	0,1154	9,45	8,18

Fonte: Resultados da pesquisa.

The level VAR was performed considering two lags, because the chosen information criterion, Akaike, showed lower value for two lags. The results of the trivariate VAR(2) are shown in Table 5. As can be seen, the coefficients of LRECIFE and LPALEGRE were not significant. Thus, variations of LRECIFE and LPALEGRE have no effects for São Paulo markets. At least one lagged coefficient of LSP was significant in all regressions, indicating that they have an effect on all markets, corroborating the Granger causality test in Table 3. LRECIFE has no influence on any of the other two markets, as its coefficients were not significant in the regressions for São Paulo and Porto Alegre. On the other hand, these markets had

Rev. Pemo, Fortaleza, v. 3, n. 3, e337173, 2021
DOI: https://doi.org/10.47149/pemo.v3i3.7173
https://revistas.uece.br/index.php/revpemo
ISSN: 2675-519X

significant coefficients in the LRECIFE model, pointing out that the pear market in Recife behaves as a price taker. LSP is only influenced by itself in period t-1. The coefficient 0.8835 shows that a 10% increase in price in period t-1 causes the price in period t to increase by 8.835%.

Analyzing the LPALEGRE regression, it can be seen that if the price in LSP increases by 1% in period t-1, LPALEGRE will increase by 0.356% in period t. That is, the price pass-through is not full, in the totality of the LSP increase. In the LRECIFE regression, if prices in São Paulo or Porto Alegre increase by 10% in the previous period, this will lead to an increase of, respectively, 1.715% and 1.846%, in LRECIFE. The same increase for LRECIFE in period t-1 will cause LRECIFE to rise by 10.116% in period t.

Table 5: VAR (2) estimation for variables at the level

	LSP_t	$LPALEGRE_t$	$LRECIFE_t$
LSP_{t-1}	0,8835***	0,3560***	0,1715**
$LPALEGRE_{t-1}$	0,1147	0,7317***	0,1846*
$LRECIFE_{t-1}$	-0,1196	0,2301	1,0116***
LSP_{t-2}	-0,1500	-0,1592	0,0389
$LPALEGRE_{t-2}$	-0,1366	-0,1657	0,2114**
$LRECIFE_{t-2}$	0,0667	-0,0196	-0,2527**
Constante	0,5455***	-0,0209	0,1096
R^2	0,5757	0,7758	0,8559
R^2 ajustado	0,5393	0,7565	0,8436
Estatística F	15,83***	40,36***	69,31***

Fonte: Resultados da pesquisa.
Nota: ***, ** e * correspondem, respectivamente, a 1, 5, e 10% de significância.

A análise do VAR estimado só será fiável se a condição de estabilidade for satisfeita, ou seja, se todos os valores próprios da matriz de coeficientes de A, em módulo, forem inferiores a 1, permanecendo assim dentro do círculo. Como neste estudo temos 3 variáveis (n=3) e a ordem do VAR(p) era 2 (p=2), temos, portanto, 6 autovalores (n×p).

Figure 2: Characteristic roots of the estimated VAR

Rev. Pemo, Fortaleza, v. 3, n. 3, e337173, 2021
DOI: https://doi.org/10.47149/pemo.v3i3.7173
https://revistas.uece.br/index.php/revpemo
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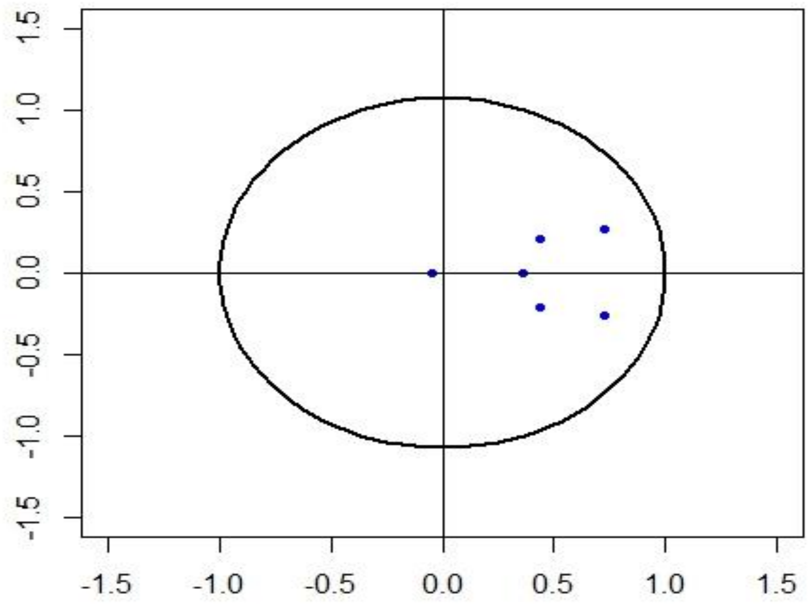

Fonte: Resultados da pesquisa.

The stability analysis of the VAR showed that it is stable. The 6 eigenvalues (characteristic roots) are smaller than 1, falling inside the unit circle, as shown in Figure 2.

Given the stability of the VAR, we proceed to the analysis of the variance decomposition of the forecast error and the impulse-response function. The former shows how much the forecast error of a variable is influenced by itself in the past and by the other variables. The impulse-response function shows the effect that a shock (an innovation) has on each variable in the system (MELO et al., 2016).

In Figure 3, the impulse-response functions are demonstrated. The first row shows the response of LSP given a shock to itself and to LPALEGRE and LRECIFE. In the second and third rows, the responses of prices in Porto Alegre and Recife, respectively, to shocks to the endogenous variables are represented.

As can be seen, an unanticipated shock to prices in São Paulo causes its price to denote a downward trend, stabilizing in the 15th period. This shows that

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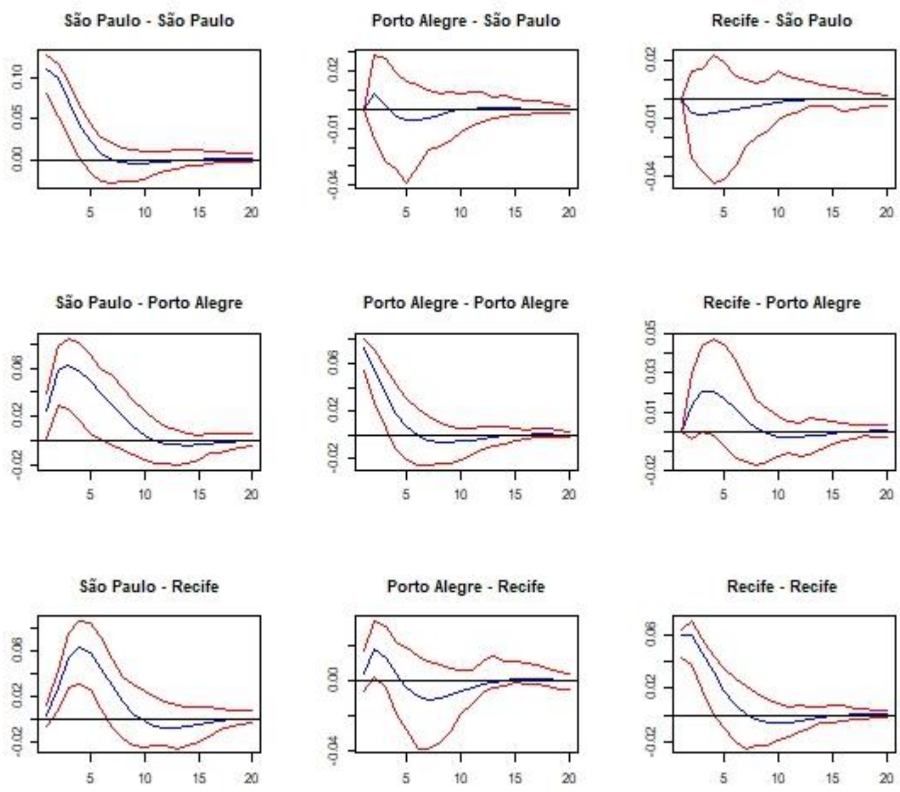
https://revistas.uece.br/index.php/revpemo
ISSN: 2675-519X

after 15 months, the shock cancels itself out. Shocks in LPALEGRE cause LSP to have a small oscillation, stabilizing in the 10th month. The LSP response to pulses in LRECIFE is a downward trend, where the effect of the shock will cancel out by the twelfth month.

The response of LPALEGRE to a shock in LSP is an increase until the 3rd month, falling from that point on, canceling itself out by the 18th month. An innovation in its own prices causes LPALEGRE to trend downward, eliminating itself at month 14. LRECIFE suffering a boost will cause LPALEGRE to have positive impacts until the 4th month, going from that point on to have negative impacts, stabilizing at the 16th month.

Figure 3: Impulse Response Functions



Fonte: Resultados da pesquisa.

Rev. Pemo, Fortaleza, v. 3, n. 3, e337173, 2021
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https://revistas.uece.br/index.php/revpemo
ISSN: 2675-519X

Finally, we have the effects of exogenous shocks on the model variables for prices in Recife. The impact that LSP has on LRECIFE is positive until the third month and, after this point, it shows a tendency to fall, with negative effects from the 12th month on, canceling itself out after 17 months. Shocks in LPALEGRE generate a small oscillation in LRECIFE, stabilizing at month 14. The effects that shocks in LRECIFE have on LRECIFE itself is a tendency to fall starting in the second month. The price increase causes demand to fall, and thus the price has to reduce also to levels that make the consumer feel attracted to buy. The effect of the shock lasts until the 16th month. In the analysis, it can also be seen that São Paulo is the market that has longer lasting positive effects on the Porto Alegre and Recife markets, which characterizes the São Paulo region as the central market.

The decomposition of the forecast error for LSP shows that after 20 months, 98.54% of its behavior is attributed to it, leaving 1.46% to the other variables, and of these 1.46%, 0.9% correspond to LRECIFE, as shown in Table 6. The series that least impacts the LSP forecast error is therefore LPALEGRE with only about 0.56%.

Table 6: LSP variance decomposition

Period	LSP	LPALEGRE	LRECIFE
1	100,00	0,00	0,00
2	99,50	0,27	0,23
3	99,37	0,22	0,41
4	99,19	0,26	0,55
5	98,96	0,37	0,67
6	98,77	0,47	0,76
7	98,65	0,53	0,82
8	98,59	0,55	0,86
9	98,56	0,55	0,89
10	98,55	0,55	0,89
11	98,55	0,55	0,90
12	98,55	0,55	0,90
13	98,55	0,56	0,90
14	98,54	0,56	0,90
15	98,54	0,56	0,90
16	98,54	0,56	0,90
17	98,54	0,56	0,90

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ISSN: 2675-519X

18	98,54	0,56	0,90
19	98,54	0,56	0,90
20	98,54	0,56	0,90

Fonte: Resultados da pesquisa.

Regarding the variance decomposition of LPALEGRE, as shown in Table 7, the value of its own forecast error is decreasing over the months. In the first month, 89.89% of its forecast error is explained by itself, leaving 10.11% from LSP and 0% from LRECIFE. Starting in the fourth month, LSP's assigned forecast error (51.18%) is already greater than its own (44.23%). After 20 months, only 35.30% is attributed to self, 59.38% to LSP and 5.32% to LRECIFE.

Table 7: LPALEGRE variance decomposition

Período	LSP	LPALEGRE	LRECIFE
1	10,11	89,89	0,00
2	32,11	66,38	1,51
3	44,18	52,51	3,31
4	51,18	44,23	4,59
5	55,32	39,48	5,20
6	57,67	36,97	5,36
7	58,87	35,82	5,31
8	59,35	35,41	5,24
9	59,45	35,33	5,22
10	59,41	35,36	5,23
11	59,35	35,38	5,26
12	59,33	35,38	5,29
13	59,33	35,36	5,31
14	59,35	35,33	5,32
15	59,36	35,32	5,32
16	59,37	35,31	5,32
17	59,38	35,30	5,32
18	59,38	35,30	5,32
19	59,38	35,30	5,32
20	59,38	35,30	5,32

Fonte: Resultados da pesquisa.

Rev. Pemo, Fortaleza, v. 3, n. 3, e337173, 2021
DOI: https://doi.org/10.47149/pemo.v3i3.7173
https://revistas.uece.br/index.php/revpemo
ISSN: 2675-519X

Analyzing Table 8, one can see that the variance decomposition of LRECIFE, the value of its prediction error attributed from itself, goes plummeting in time. This is similar to the behavior of LPALEGRE's forecast error assigned from LPALEGRE itself, shown in Table 7.

About, 99% of LRECIFE's forecast error in the first month stems from itself, 0.6% from LPALEGRE and 0.4% from LSP. In the 5th month, this is already inverted, that is, the largest percentage of LRECIFE's forecast error comes from LSP (49.42%), against 48.09% from LRECIFE and 2.48% from LPALEGRE.

Table 8: Decomposition of Variance of LRECIFE

Período	LSP	LPALEGRE	LRECIFE
1	0,40	0,60	98,99
2	9,23	4,23	86,54
3	26,99	3,85	69,16
4	41,18	2,91	55,91
5	49,42	2,48	48,09
6	53,34	2,56	44,10
7	54,74	2,89	42,37
8	54,96	3,23	41,81
9	54,80	3,48	41,72
10	54,66	3,61	41,73
11	54,63	3,66	41,72
12	54,67	3,66	41,67
13	54,74	3,65	41,61
14	54,79	3,65	41,56
15	54,82	3,65	41,53
16	54,83	3,65	41,52
17	54,83	3,66	41,52
18	54,83	3,66	41,52
19	54,82	3,66	41,52
20	54,82	3,66	41,52

Fonte: Resultados da pesquisa.

Reaching the twentieth month, LSP and LRECIFE represent 54.82% and 41.52% of the LRECIFE forecast error respectively, leaving only 3.66% of LPALEGRE. This shows that the prices in Porto Alegre do not have much influence in explaining the prices in Recife.

Rev. Pemo, Fortaleza, v. 3, n. 3, e337173, 2021
DOI: https://doi.org/10.47149/pemo.v3i3.7173
https://revistas.uece.br/index.php/revpemo
ISSN: 2675-519X

Similarly, Table 7 showed that the prices in Recife do not influence significantly (great explanation) the prices in Porto Alegre.

5 Final considerations

The study of the behavior of pear prices from June 2009 to December 2015 showed that the market where prices are higher is Recife, reaching R$ 5.38 per kilogram. One of the hypotheses for the price of this market to be higher than the others (São Paulo and Porto Alegre), is due to the fact that in the Northeast there is still no production of this fruit to meet the local market (IBGE, 2016). And thus, it is dependent on direct or indirect imports for consumption. On the other hand, the fruit market in Porto Alegre is the one that expresses the lowest price, which may stem from the fact that the South region is the largest producing state in Brazil.

The price transmission elasticity from São Paulo to the other markets is higher for Porto Alegre than for Recife. A 10% increase in the price of pear in period t-1 causes Porto Alegre and Recife to increase by 3.5% and 1.7%, respectively, in period t.

The impulse response function given a shock in LPALEGRE shows that prices in LSP and LRECIFE rise until the 5th and 3rd month, respectively, falling from that point on. Shock to LRECIFE has a falling trend on itself and increases LSP until the 5th month. The response of LPALEGRE given an impulse (innovation) in LSP LRECIFE is almost zero.

From the variance decomposition of the forecast error, one can see that most of the percentage of the errors for all variables is attributed to LSP. Twenty months ahead, LSP's forecast error for itself represents 98.54%. For LPALEGRE, this value is about 59.38%, and for LRECIFE, 54.82%. Thus, one can see the great influence that the São Paulo market has over the others, which has the monopoly power to determine prices, leaving the competition vulnerable, that is, for this market, competition is not perfect.

Rev. Pemo, Fortaleza, v. 3, n. 3, e337173, 2021
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https://revistas.uece.br/index.php/revpemo
ISSN: 2675-519X

The study showed that the pear marketed in Recife and Porto Alegre is influenced by the prices of São Paulo pears. Thus, the production of this fruit in the Vale do Submédio São Francisco (which should soon be in the market) will have to be programmed, so that producers are not at the mercy of the imported pear, i.e., that these producers can offer the fruit at considerable prices and not have losses..

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