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Price volatility and demand of vegetables in three Brazilian Southeast supply centers between 2017 and 2021

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INFO

Keywords
Lactuca sativa
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Daucus carota

ABSTRACT

Vegetable consumption has increased in recent years due to the predisposition of people to have a healthy diet, which includes the ingestion of fibers, vitamins, and minerals present in fruits and vegetables. In Brazil, lettuce, tomato, carrot, onion, and potato are the five vegetables with the highest consumption. In this study, the price volatility and the price elasticity measure (price elasticity of supply, price elasticity of demand, or price inelasticity) of lettuce, tomato, carrot, onion, and potato were evaluated in three supply centers (*CEAGESSP, CEASAMINAS e CEASA/RJ*) between 2017 to 2021. The results indicated that all the evaluated products had similar price volatility behavior between 2019 to 2021 in the three supply centers. Moreover, the years with higher instabilities of prices were 2020 for potatoes and carrots, 2019 for lettuce, and 2018 for onion. The price elasticity or inelasticity had independent behavior per supply center. However, there are some periods of inelasticity where the price does not influence the quantity demanded or supplied of the evaluated products. In conclusion, there is high variability of price and volume for tomato, potato, onion, lettuce, and carrot during the year. There was a negative in the price and volume of vegetables which indicates that the reduction of volume increases the price of vegetables. The prices of commercialized vegetables are strongly influenced by the forces of supply and demand, which configures a seasonal characteristic.

RESUMO

Palavras-chaves
Lactuca sativa
Solanum lycopersicum
Solanum tuberosum
Allium cepa
Daucus carota

Volatilidade de preços e demanda de hortaliças na CEAGES/SP, CEASA/MG e CEASA/RJ durante 2017 e 2021

O consumo de hortaliças tem aumentado nos últimos anos devido à predisposição das pessoas para uma alimentação saudável, que inclui a ingestão de fibras, vitaminas e minerais presentes nas frutas e hortaliças. No Brasil, as cinco hortaliças com maior consumo são alface, tomate, cenoura, cebola e batata. Neste estudo calculou a volatilidade de preços e as medidas de elasticidades de preços (elasticidade preço da oferta, elasticidade preço da demanda ou inelasticidade preço) de cinco hortaliças em três centros de oferta (CEAGESSP, CEASAMINAS e CEASA/RJ) entre 2017 e 2021. Os resultados indicam que todos os produtos avaliados tiveram comportamento ou padrão semelhante de volatilidade de preços de 2019 a 2021 nos três centros de abastecimento. Além disso, os anos com maiores instabilidades de preços foram 2020 para batata e cenoura, 2019 para alface e 2018 para cebola. Além disso, o resultado mostra que a elasticidade ou inelasticidade de preço teve comportamento independente por centro de oferta, porém nesta pesquisa identificou alguns períodos de inelasticidade onde o preço não influencia na quantidade demandada ou ofertada do produto avaliado. Conclue que existe uma grande variabilidade de preço e volume de tomate, batata, cebola, alface e cenoura durante o ano. Existe uma correlação negativa do preço e volume das hortaliças o que indica que a redução do volume aumenta o preço das hortaliças no centro de abastecimento. Os preços das hortaliças comercializadas são fortemente influenciados pelas forças de oferta e demanda, o que configura uma característica sazonal.

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INTRODUCTION

Brazil is the greater producer of vegetables in the world with high production of garlic (*Allium sativum*), tomato (*Solanum lycopersicum*) potato (*Solanum tuberosum*), onion (*Allium cepa*), and carrot (*Daucus carota*) (EMBRAPA, 2023). The ingestion of fruits and vegetables is part of healthy eating patterns which is why in the last decade, one of the priorities around the world is to promote their consumption (Moreno and Ferraz-Almeida, 2023; Oliveira et al., 2022). The food demand depends on preferences or lack of access for socioeconomic or logistical reasons, being the last two the most recurrent in developing countries (FAO, 2021).

The price volatility is the variation of price changes around their mean value. At present, it is an ongoing concern because it may have a negative impact at the economic level on growth and poverty as reported by some economists. Thus, it is important to know the evolution of price volatility to develop different instruments and design appropriate policies to transfer risk or at least to lessen the extent of world market price volatility (Brander et al. 2023).

Additionally, it is important to understand the demand and supply of vegetables to help in the decisions regarding market performance and market activities. The elasticity is one of those analyses, and is an economic instrument that measures the rate at which quantities of a product respond to price changes; the percentage at which a one percent change in prices will cause a certain percentage change in quantities (Rosales and Mercado, 2020).

There are four different elasticity measurements: price elasticity of demand, income elasticity of demand, price elasticity of supply, and cross-price elasticity (Mankiw, 2001). The size of the price elasticities is important from a policy perspective because if the price elasticity is greater than one, any increase in the price will lead to a reduction in the quantity exported, so the governments have to stabilize the income of farmers with subsidies.

This study has two hypotheses: (i) due to the price volatilities in the fruits sector during the year, there is a pattern for each product, and (ii) the price elasticities are highly variable depending on the product within the vegetable sector. The aim is to analyze the price volatility, demand, and elasticity of vegetables in Brazil during 2017 and 2021.Sweet oranges also contain natural pigments known as carotenoids, displaying colors ranging from yellow to red. Classified as tetraterpenes (C40), these pigments are composed of isoprene units (C5). Although generally insoluble in water, carotenoids can dissolve in organic solvents like ethanol (Kultys and Kurck, 2022; Honda et al., 2019; Tiwari et al., 2019). Carotenoids fall into two categories: (a) carotenes, identified by a linear hydrocarbon chain with one or two cyclic structures at the ends, and (b) xanthophylls, oxygenated compounds derived from carotenes. Among the most prevalent in citrus peels are α-carotene, β-carotene, lutein, zeaxanthin, and β-cryptoxanthin (Figure 2) (Maoka, 2020; Meléndez-Martínez et al., 2019)

MATERIAL AND METHODS

Study characterization

The study was developed between 2017 and 2021. Lettuce, tomato, potato, onion, and carrot were the vegetables selected for the study due to the high demand and production in Brazil. The distribution centers are (i) *Companhia de Entrepostos e Armazéns Gerais de São Paulo (CEAGES/SP*; DC 1), located in Vila Leopoldina – São Paulo – São Paulo; (ii) *Companhia de Entrepostos e Armazéns Gerais de Minas Gerais (CEASA*/MG), located Rodovia BR-040 km 688, Kennedy, Contagem, Minas Gerais; (iii) *Centro de Abastecimento do Rio de Janeiro, (CEASA*/RJ), located in Irajá, Rio de Janeiro, Rio de Janeiro.

Data collecting and analysis

A data set was created using data from the *Boletim Hortigranjeiro*, available by the National Supply Company (CONAB, 2022) with information on vegetable prices from years 2017, 2018, 2019, 2020, and 2021. For all the calculus, the units for these prices were reais per kilograms (R$/Kg) to Brazilian reality and the prices were corrected by the index IPCA (*Índice de Preços ao Consumidor Amplo*), which measures the inflation of a set of products sold in retail, using the online calculator, available by IBGE (2022).

To analyze the price elasticities, we utilized the previous data and complemented it with information on the quantity sold. The quantity sold over the years was estimated by the bar graphs from the *Boletim Hortigranjeiro* (CONAB, 2022). The calculus of quantities used the ton unit in all the cases.

The price volatility was defined as price variability around a central value. The tendency of individual prices to vary from their mean value. Volatility is often defined as high deviations from a global tendency. In this study, we calculated the historical volatility, based on past prices of the last five years, using the coefficient of variation (CV) (Eq. 1), which is described in the investigations of Traore and Diop (2021). This measure was calculated per year from 2017 to 2021 and for each of the ten products selected previously.

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The price elasticity of demand or the elasticity of demand measures the responsiveness of consumers to a change in price. Sometimes price elasticities of demand are reported as negative numbers. This is because the percentage change in quantity will always have the opposite sign as the percentage change in price.

In the present study, we used the absolute value for dropping the minus sign and reported the results as positive numbers when we were comparing the price elasticities of demand of a specific product, but we maintained the negative sign to differentiate the price elasticities of demand from the price elasticities of supply. The price elasticity of demand is mathematically defined as the percentage at which a one percent change in prices will cause a certain percentage change in quantities (Mankiw, 2001). The price elasticity of demand was calculated according to Eq. 1.

Eq. 1

$$e_d = \left|\frac{\%\Delta Q_d}{\%\Delta P}\right|$$

where $\boldsymbol{e_d}$ is the price elasticity of demand or coefficient of demand, $\%\Delta Q_d$ is the percentage change in quantity demanded and $\%\Delta P$ is the percentage change in price.

To facilitate the calculation of the price elasticity of demand we used the midpoint method, described in Eq. 2, and based on studies of Mankiw (2001).

Eq. 2

$$e_d = \left|\frac{\frac{Q2-Q1}{\left(\frac{Q1+Q2}{2}\right)}}{\frac{P2-P1}{\left(\frac{P1+P2}{2}\right)}}\right|$$

where $\boldsymbol{e_d}$ is the price elasticity of demand, Q_1 is the quantity demanded at time 1, Q_2 is the quantity demanded at time 2, P_1 is the price at time1, and P_2 is the price at time 2.

We can interpret the $\boldsymbol{e_d}$ as follows: if the $\boldsymbol{e_d}$ is greater than one the demand is elastic, so the quantity demanded changes by a larger percentage than does price; if $\boldsymbol{e_d}$ is equal to 1, the demand is unitary elastic, so the percentage increase in quantity demanded is equal to percentage decrease in price; and if the $\boldsymbol{e_d}$ is less than 1, the demand is inelastic which means that quantity demanded is relatively insensitive to price (Mankiw, 2001).

The price elasticity of supply measures how much the quantity supplied responds to changes in the price. It is because sometimes producers of a good offer to sell more of it when the price of the good rises (Mankiw, 2001). Thus, economists compute the price elasticity of supply as the percentage change in the quantity supplied divided by the percentage change in the price (Eq. 3). In addition, the price elasticity of supply is never negative since price and quantity supplied are directly related.

Eq. 3

$$e_S = \left|\frac{\%\Delta Q_s}{\%\Delta P}\right|$$

where $\boldsymbol{e_s}$ is the price elasticity of supply or coefficient of supply, $\%\Delta Q_s$ is the percentage change in quantity supplied and $\%\Delta P$ is the percentage change in price. In the same way that the price elasticity of demand, the price elasticity of supply can be calculated by the midpoint method (Eq. 4) (Mankiw, 2001).

Eq. 4

$$e_S = \left|\frac{\frac{Q2-Q1}{\left(\frac{Q1+Q2}{2}\right)}}{\frac{P2-P1}{\left(\frac{P1+P2}{2}\right)}}\right|$$

where $\boldsymbol{e_s}$ is the price elasticity of supply, Q_1 is the quantity supplied at time 1, Q_2 is the quantity supplied at time 2, P_1 is the price at time 1, and P_2 is the price at time 2. The degree of price elasticity or inelasticity of supply is measured by the $\boldsymbol{e_s}$. If the $\boldsymbol{e_s}$ is greater than one the supply is elastic, which means that producers are relatively responsive to price changes. If the $\boldsymbol{e_s}$ is equal to 1 the supply is unit elastic, which indicates that the quantity produced changes in the same percentage as the price. On the other hand, if the $\boldsymbol{e_s}$ is less than 1, the supply is inelastic, so the producers are relatively insensitive to price changes (Mankiw, 2001).

The results of price volatilities and price elasticities are analyzed per vegetable. We showed the results in tables containing four statistical measures: standard deviation (SD), mean, maximum value, and minimum value to have a context in the data set (price volatilities and price elasticities calculated), per supply center (CEAGESSP, CEASAMINAS or CEASA/RJ) and from 2017 to 2021. Correlations between price and volumes in the supply center (CEAGESSP, CEASAMINAS, or CEASA/RJ) were tested by the Pearson correlation using a p of 0.05.

RESULTS AND DISCUSSION

Prices and volumes of vegetables in CEASA/GEAGES

There was a variation in price between the CEASA and GEAGES of lettuce, tomato, potato, onion, and carrot during 2017 and 2021 (Figure 1). The prices of vegetables are higher in DC 1 and DC 2, while DC 3 presented the lower price exception to the price of lettuce that was higher in DC 3 (Fig-

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ure 1). This result was expected because DC 1 attends all the demands of the great city in Brazil, as São Paulo capital and great-São Paulo.

In addition, DC 1 is considered the greater vegetable and fruit markets and the largest intermediary, playing the role of distribution center for other wholesale markets (Mayorga et al., 2017). The fruits and vegetables traded in DC 1 are produced in different regions of Brazil, mainly the vegetables produced in the nearby region. In the region of São Paulo, the area of incidence of the Cinturão + Verde in the Cabeceiras sub-basin, in the Alto Tietê, which comprises 10 municipalities, mainly Salesópolis, Biritiba-Mirim, Mogi das Cruzes, Suzano, Poá, Itaquaquecetuba, Ferraz de Vasconcelos, Arujá, Guarulhos, and São Paulo (FGV, 2022).

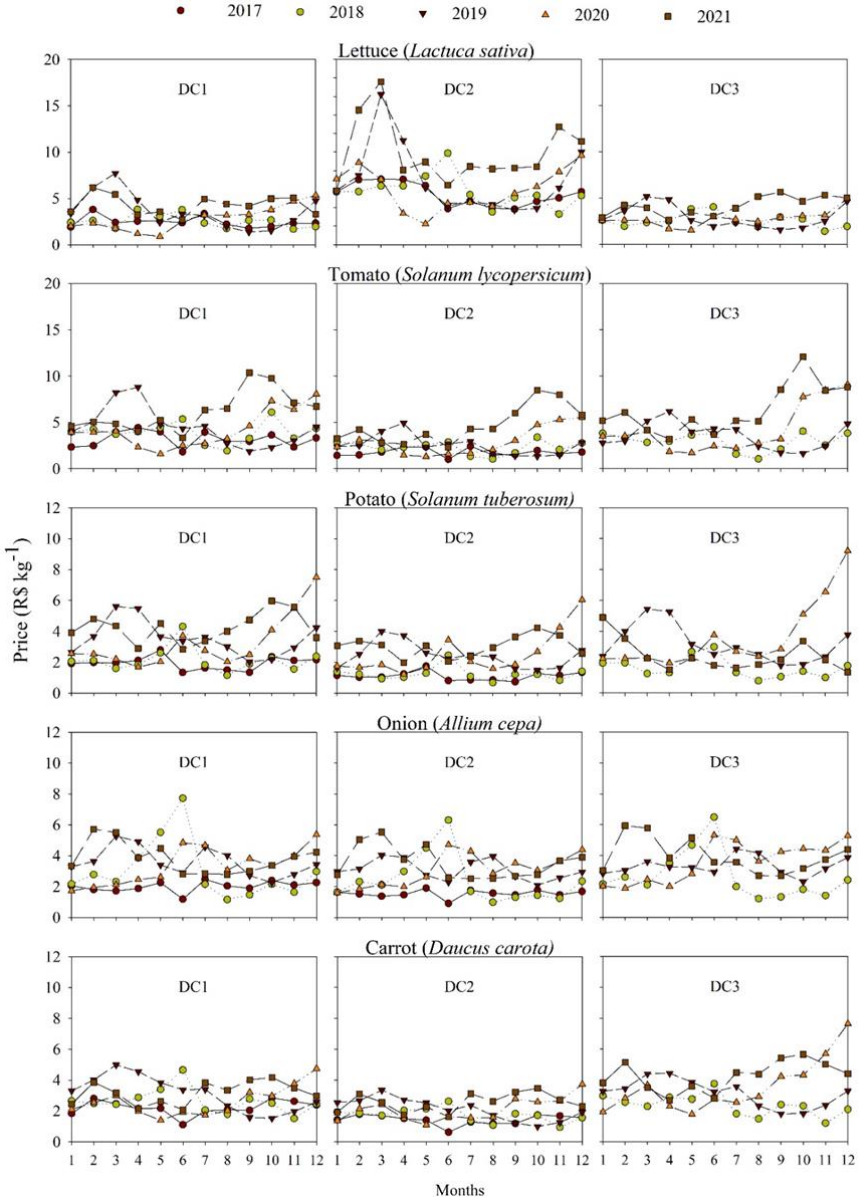

Figure 1 - Monthly price of lettuce, tomato, potato, onion and carrot in the CEAGES/SP (DC1), CEASA/MG (DC 2) and CEASA/RJ (DC3) between 2017 and 2021

Between supply centers, the lettuce presented a higher price in DC 2 (R$ 6.79 kg^{-1}), followed by DC 1 (R$ 3.14 kg^{-1}) and DC 3 (R$ 3.12 kg^{-1}). Tomato presented a higher price in DC 1 (R$ 4.40 kg^{-1}), DC 3 (R$ 4.24 kg^{-1}), and DC 2 (R$ 2.83 kg^{-1}), as well there was a higher price of potato in DC 1 (R$ 3.01 kg^{-1}), DC 3 (R$ 2.69 kg^{-1}) and DC 1 (R$ 2.04 kg^{-1}), Figure 1.

In DC 3, there was a higher price of onion with an average of R$ 3.38 kg^{-1} followed by DC 1 (R$ 3.15 kg^{-1}) and DC 1 (R$ 2.71 kg^{-1}), as well there was a higher price of carrot in DC 3 (R$ 3.32 kg^{-1}), DC 1 (R$ 2.75 kg^{-1}) and DC 2 (R$ 1.97 kg^{-1}), Figure

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1. In DC 1, there was a higher traded volume of lettuce (3,974 tons month^{-1}), tomato (21,159 tons month^{-1}), potato (21,298 tons month^{-1}), onion (8,930 tons month^{-1}), and carrot (814 tons month^{-1}), Figure 2.

During the months, there was a constant demand for tomatoes, potatoes, onions, and carrots (Figure 2). The second demand for vegetables was in DC 3, where there was a demand for lettuce (272 tons month^{-1}), tomato (7836 tons month^{-1}), potato (18,555 tons month^{-1}), and onion (7574 tons month^{-1}). While DC 2 presented the second higher volume of carrots with an average of 814 tons month^{-1} (Figure 2).

We can observe an alteration in lettuce demand with lower demand in the winter and higher demand in the summer. The years with higher instabilities of prices were 2020 for tomato, potato, and carrot, 2019 for lettuce, and 2018 for onion. Camargo Filho and Mazzei (2000) described that the quantity demanded of salad vegetables is higher in spring and summer, while vegetables, roots, and tubers have an increase in demand in autumn and winter. In our study, there was no alteration in demand for tomatoes, potatoes, onions, and carrots which are vegetables presented in diary food preparation. A similar result was presented by Furquim et al. (2023) with tomatoes in Goiás in constant demand during the year.

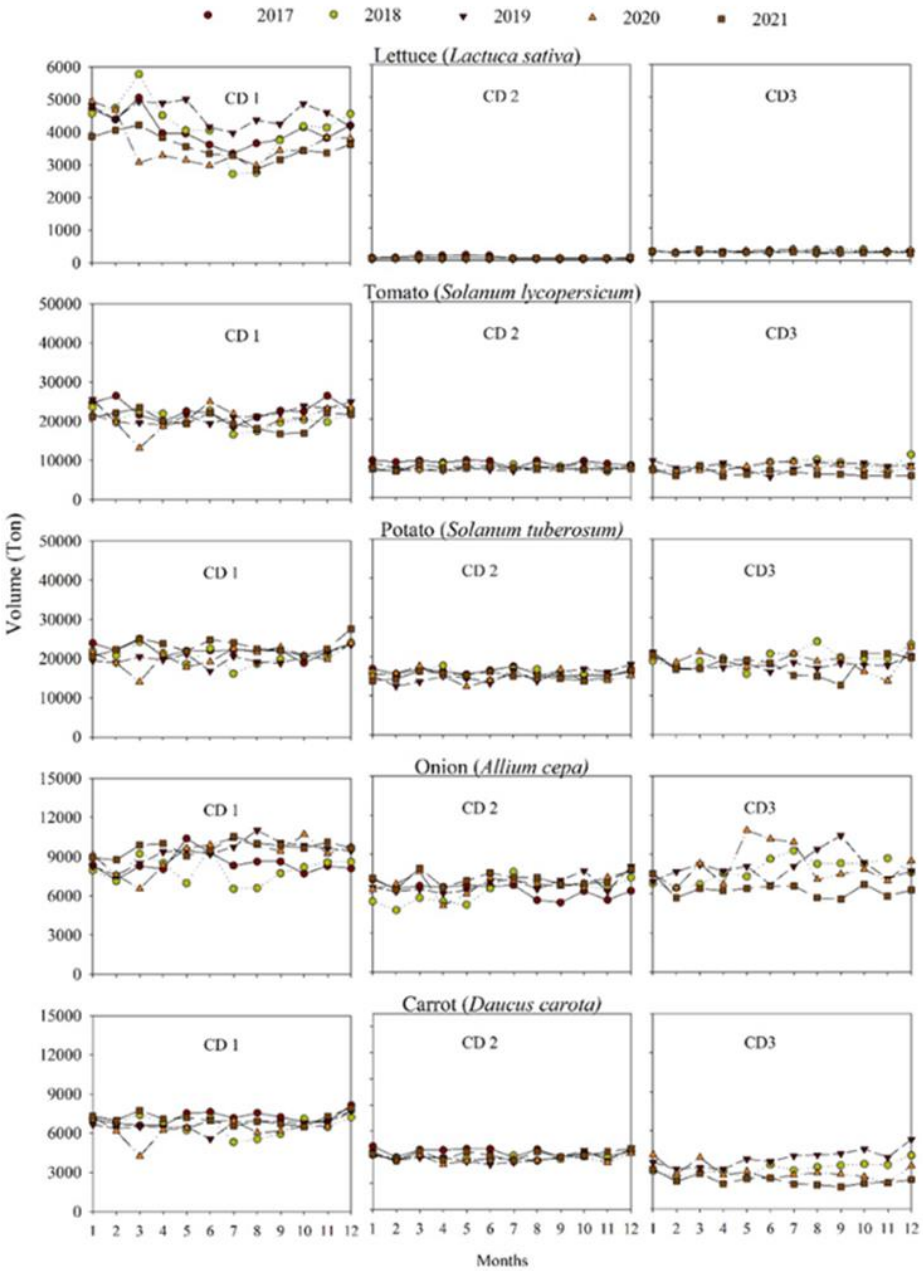

Figure 2 - Monthly volume of lettuce, tomato, potato, onion and carrot in the CEAGES/SP (DC1), CEASA/MG (DC 2) and CEASA/RJ (DC3) between 2017 and 2021

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In all supply centers, there was a significant interaction between the volume and price of vegetables with a negative r of -0.13 ($p<0.05$). This result indicates that the reduction of volume increases the price of vegetables in the all-supply center (Figure 3). The prices of commercialized vegetables are strongly influenced by the forces of supply and demand, which configures a seasonal characteristic (Pantoja et al. 2023).

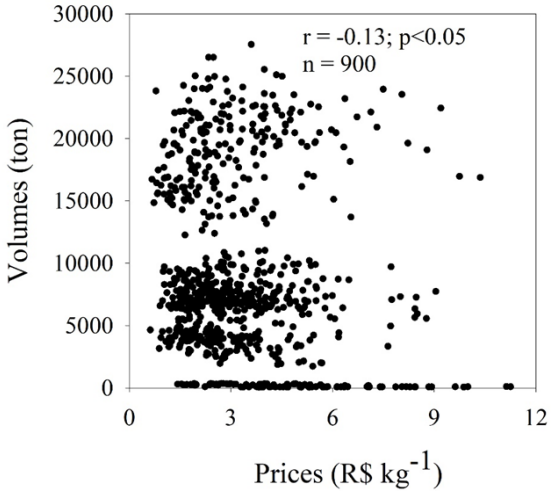

Figure 3 - Correlation between price and in the CEAGES/SP (DC1), CEASA/MG (DC 2) and CEASA/RJ (DC3) between 2017 and 2021. n: is the number of observations

There were significant influences between the supply center with significant correlations higher than 0.45 ($p<0.05$), Figure 4. For the prices, the higher influence was between CD 1 and CD 3 ($r = 0.82$; $p < 0.05$) with the price of vegetables concentrated and similar between them. While there CD 3 and CD 2 ($r = 0.45$; $p < 0.05$) presented a lower correlation (Figure 4).

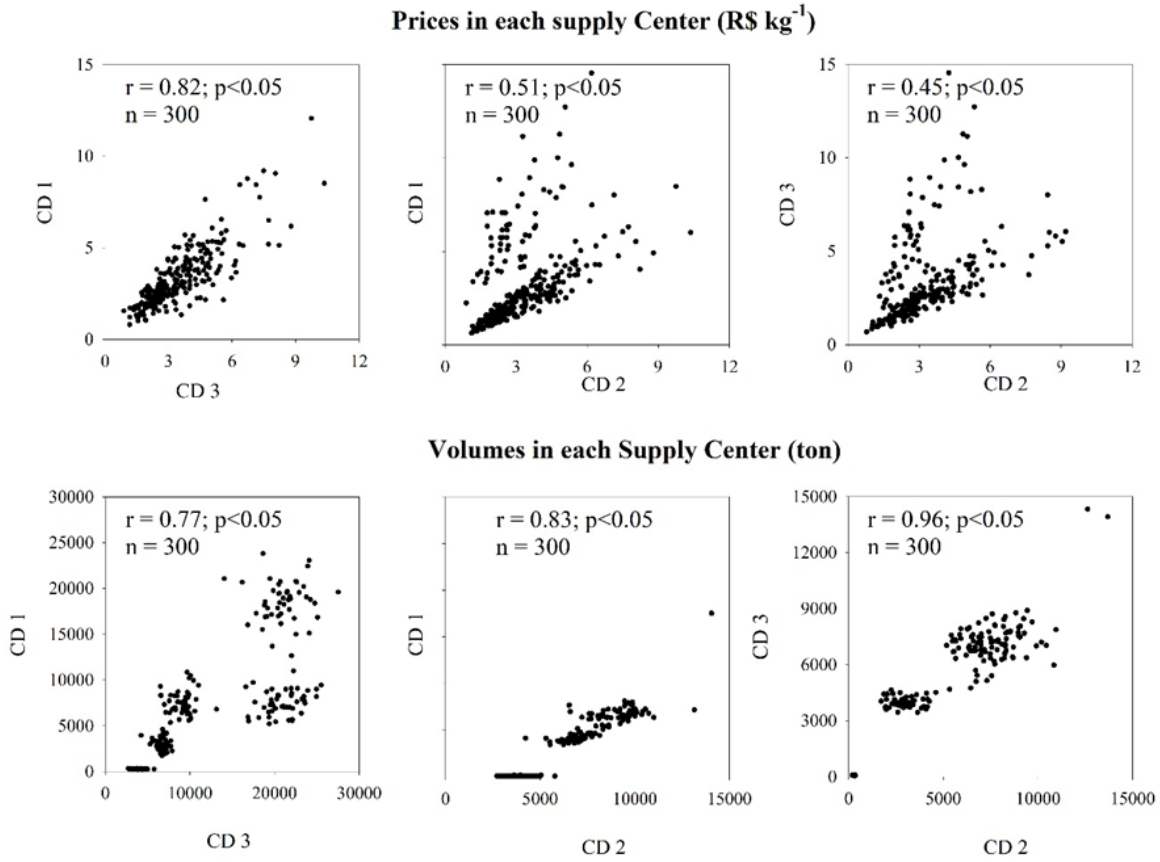

Figure 4 - Correlation between price and volumes in the CEAGES/SP (DC1), CEASA/MG (DC 2) and CEASA/RJ (DC3) between 2017 and 2021. n: is the number of observations

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Interest, for volume the higher correlation was noticed between CD 3 and CD 2 ($r = 0.96$; $p < 0.05$) followed by CD 1 and CD 2 ($r = 0.83$; $p < 0.05$), Figure 4. The influence on volumes and prices between the the supply center is associated with the demand and influence of each market (Pantoja et al. 2023). Mayorga et al. (2017) demonstrated that the price variation of melon in CD 1 influenced also the price variation in Açu/Mossoró/RN and Baixo Jaguaribe/CE represent the national biggest melon production areas impacting the Centers of Natal and Fortaleza

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Elasticity measurements

There was variation between the elasticity price of vegetables during the years. The lettuce presents the alteration in the second semester and the initial of the first semester. While, there is a predominance of variation of price in the initial of the first semester for tomato, potato, onion, and carrot (Figure 5).

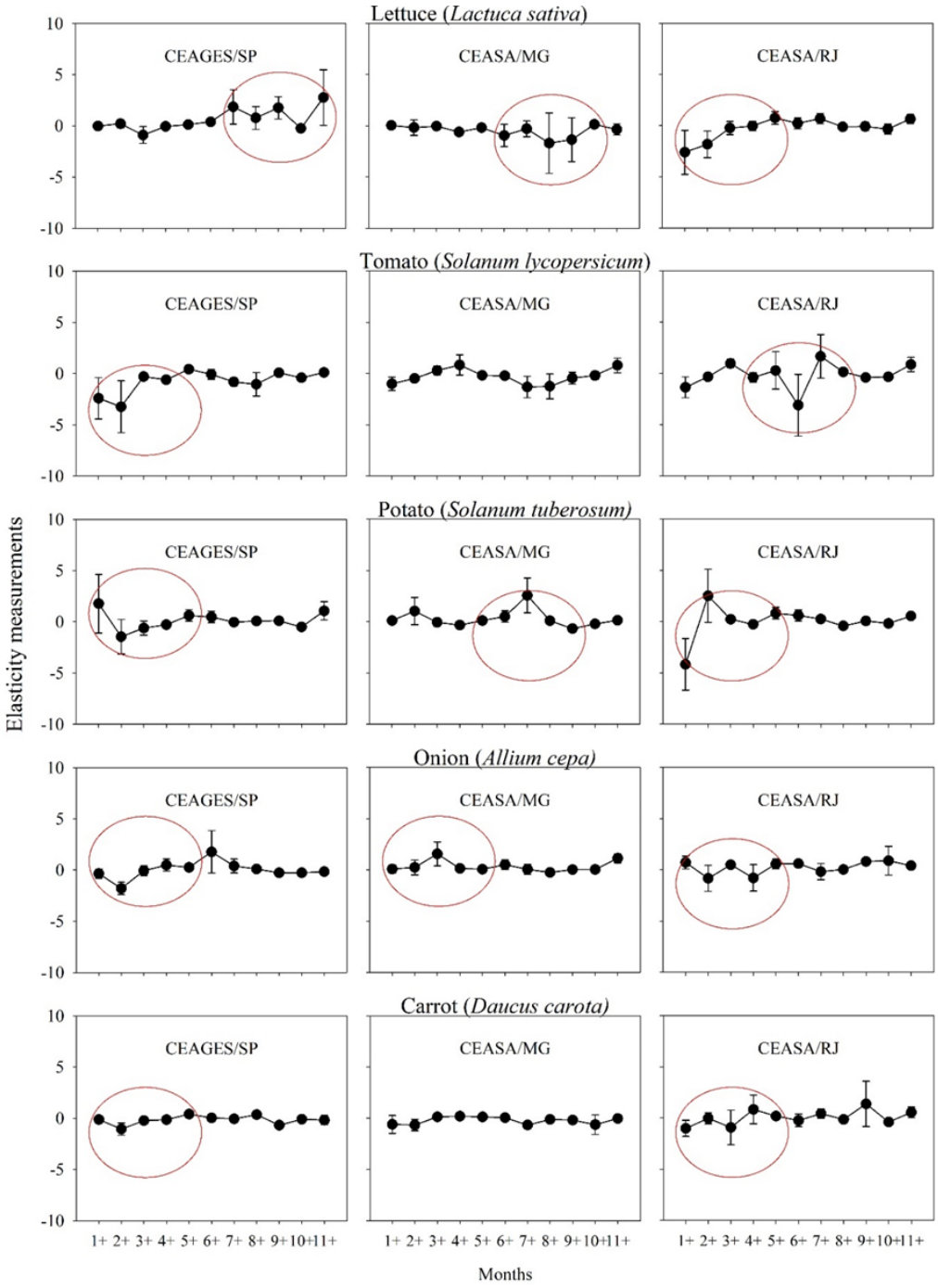

Figure 5 - Monthly elasticity price of lettuce, tomato, potato, onion and carrot in the CEAGES/SP (DC1), CEASA/MG (DC 2) and CEASA/RJ (DC3) between 2017 and 2021

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This result occurs because the price of vegetables has a direct effect on the quantity supplied in the market, which is influenced by the climate. In the field, the occurrence of greater or lesser rainfall and the temperature variation (heat or cold) determine the cost of production and yield at the station. Also, there was a larger volume of vegetables and fruits which are lost in the market impacting the price to consumers (Ferraz-Almeida and Martins, 2022)

Uçak et al. (2022) demonstrated that in Turkey there is a significant volatility spillover from the energy price index to the vegetable price index, whereas there is no statistically significant volatility spillover to the fruit price index. In Greece, Rezitis and Pachis (2020) showed that in the tomato and cucumber markets, which are regulated by the Common Market Organization of fruits and vegetables, producers are less vulnerable to volatility shocks transmitted from consumers. In contrast, in the non-regulated potato market, producers are affected by spillover effects from consumers.

CONCLUSIONS

The prices of vegetables are higher in DC 1 and DC 2, while DC 3 presented the lower price exception to the price of lettuce that was higher in DC 3. During the five evaluated years, four of the five vegetables (tomato, potato, onion, and carrot) were cheaper in DC 2. About the lettuce, the supply center where the prices were lower was DC 3. On the other hand, tomatoes and potatoes were more expensive in DC 1. Moreover, onions and carrots were more expensive in DC 3, and lettuce was more expensive in DC 2. About the price volatility, all the evaluated products had similar behavior from 2019 to 2021 in the three supply centers. The years with higher instabilities of prices were 2020 for tomato, potato, and carrot, 2019 for lettuce, and 2018 for onion. Based on the results concluded that there is high variability of price and volume for tomato, potato, onion, lettuce, and carrot during the year. There was a negative in the price and volume of vegetables which indicates that the reduction of volume increases the price of vegetables in the all-supply center. The prices of commercialized vegetables are strongly influenced by the forces of supply and demand, which configures a seasonal characteristic.

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