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PRICES OF A STAPLE FOOD AFFECTING THE RATE OF INFLATION: THE CASE OF POTATO PRODUCTION IN THE BRAZILIAN ECONOMY

Marco Tulio Ospina Patino
FEAGRI/UNICAMP, Campinas/SP, Brazil, Email: mtospina@unicamp.br Tel:+55 19 98880-1503, ORCID: 0000-0002-4285-7761

Livia Nicioli Berti
FEAGRI/UNICAMP, Campinas/SP, Brazil, ORCID: 0000-0003-0951-7957

Eder Benedito Simonato
FEAGRI/UNICAMP, Campinas/SP, Brazil, ORCID: 0000-0001-9543-8299

Ricardo Soares de Arruda Pinto
FEAGRI/UNICAMP, Campinas/SP, Brazil, ORCID: 0000-0003-2448-1817

Abstract

Potatoes play an important role in the global agricultural sector with annual production of approximately 3.5 million tons. However, it is exposed to both climate variations and changes in market trends that directly influence supply and demand, determining product prices. This paper aims to analyse and characterize the potato market, to determine its relationship with the variation in inflation in Brazil. To this end, the Broad Consumer Price Index - IPCA, planted area, harvested area, yield per hectare, the gross value of production, and potato prices were used as variables. The results demonstrate a minimal correlation between the quantity produced and the area planted with potatoes and the IPCA, with these two variables participating in the formation of the potato price at the retail market.
Keywords: *Agricultural prices, food prices, agricultural production, inflation effects.*
Jel Codes: *Q11, Q1, Q00*

1. Introduction

In Brazil, potatoes are grown in several states, but the largest volume of production is concentrated in Minas Gerais, Paraná, São Paulo, Rio Grande do Sul, and Santa Catarina, with Minas Gerais being the largest producer with 1.26 million tons in the 2016 harvest, in an area of 39,431 hectares, which represents around 30% of national production. The second largest Brazilian producer is Paraná, with a production of 775,000 tons on an area of 30,249 hectares, and São Paulo in third place, with production of 665,000 tons on 21,651 hectares. These three states produce the equivalent of 70% of the total produced in Brazil, which corresponds to around 2.7 million tons (IBGE, 2019).

The vast majority of Brazilian potato production is destined for the common market (fresh), which in 2014 absorbed around 1.8 million tons (ABBA, 2016). To serve this market, the potato must be delivered from the farmer to processing companies, where the potato is washed, classified, packaged, and sent to other wholesalers and retailers, who will sell the product to

the end consumer (Ramos, 2003). Another possibility is to deliver the processed potatoes to the industry, which produces pre-fried frozen potatoes and potato chips (ABBA, 2016). In 2017, the Brazilian market consumed approximately 4.3 million tons of potatoes, giving an annual per capita consumption of 20.6 kg (IBGE, 2019).

As similar agricultural markets, the potato market in Brazil is influenced by the supply and demand of the product throughout the year, generating uncertainty about the prices that will be received by the producer (García-Salazar et al., 2014). This situation is characterized by the fact that potato producers act in a market of perfect competition, with no influence on product prices.

Thus, when analysing the production and commercialization dynamics of potato cultivation in Brazil, it becomes clear that the volume of annual production is determined mainly by the area cultivated with potatoes each year, since increasing the area also increases potato production, and vice versa. In the same context, there is an interaction between production and prices, which means that in years of greater cultivated area and greater volume produced, prices are low, which reduces the profitability of agricultural production, which is thus linked to the fluctuations in the prices received by producers.

Brazilian agriculture stands out in the economy for its participation in the primary, secondary, and tertiary sectors. Inflation indices are used to measure the country's inflationary process in these sectors. In Brazil, the most important inflation index is the Broad Consumer Price Index – IPCA. This index has been calculated and published by the Institute of Geography and Statistics (IBGE) since 1979. However, due to a decision by the National Monetary Council (COPOM), it has only been used as an official indicator of inflation in Brazil since 2000. The IPCA makes it possible to check the variation in market prices for the end consumers with one to 40 minimum wages, in 11 metropolitan regions of most populated cities including the Federal District and the city of Goiania (IBGE, 2019).

Food and commodity inflation accounts for more than 30% of the variation in the IPCA in the short term (Souza et al, 2015), a fact that highlights the importance of agricultural products as influencers of inflation indicators. Therefore, since the potato is an essential product on people's food consumption in all regions of Brazil, its participation in the food basket should be studied to identify how variations in potato prices affect inflation. In this context, the central hypothesis of this work is that variations in potato prices significantly influence food inflation and general inflation indices.

Hence, the general objective of this paper was to analyse historical data on potato production and the potato market and its relationship with inflation indicators in Brazil. The specific objectives to achieve this goal were related to examine historical data on the area under cultivation and potato production in Brazil; to analyse the history of Brazilian inflation through the IPCA (Broad Consumer Price Index), and explain the correlation between the change in producer potato prices and the IPCA indexes.

2. Literature Review

The potato (*Solarium tuberosum* L.) is one of the most widely grown crops in the world, and the fourth largest agricultural product worldwide, with a volume of 376 million metric tonnes in 2021, behind wheat, rice, and corn. This volume of production was obtained in an area of 18.13 million hectares, which determines a world average productivity of about 21 tonnes per hectare (Potato News Today, 2023).

The potato Brazilian market needs to import seed potatoes and frozen potatoes. In 2013, Brazil imported 321,000 tons of potatoes from Belgium, the Netherlands and Argentina, 282,000 tons of which were frozen potatoes, 29,000 tons of seeds and 9,300 tons of dehydrated potatoes (FAOSTAT, 2019).

Two aspects that are related to the profitability of potato farming are the average production yield and total costs. According to Brazilian statistics from IBGE (2019), in the state of São Paulo, the average yield of potato production between 2003 and 2017 was around 26.12 tons per hectare, which is low compared to other countries. According to FAOSTAT (2019), the average yield in the United States is 47 tons per hectare, which also contributes to the reduction in gross revenue. Another aspect considered in this analysis is total production costs, which have been increasing over the same period in the state of São Paulo, 2006 it costs around R$16,000 to produce one hectare of potatoes and in 2017 this figure rose to over R$34,000, negatively impacting the profitability of potato producers in São Paulo (Deleo, 2017).

The agricultural sector in Brazil is one of the largest sources of employment, so this sector of the Brazilian economy is linked to external demand for primary products, i.e. the growth of the Brazilian agricultural sector is associated with demand decisions in foreign markets. According to Sasmal (2015), an important characteristic of agricultural prices is that they exhibit large fluctuations over time compared to non-agricultural prices because the elasticity of demand for most agricultural products is so low that a small change in demand with supply remaining unchanged generates a large change in price. According to Gilbert (2010), if supply is very elastic, the price increase will be small, but if the speed of supply response is slow, the price increase will be greater. And if supply is inelastic, even small changes in demand can have a big impact on prices.

The continuous and generalized increase in prices in an economy refers to inflation. Thus, according to Holland and Mori (2007), inflation is generally conditioned to aggregate demand, the variations in wages, and changes in productivity, in other words, to internal factors ("country-centric-model"). Imports, commodity prices, and world growth are some of the external factors that have been indicated as significant sources for explaining the performance of domestic inflation.

A country's inflationary process is measured using inflation indices. In Brazil, the most important index is the IPCA (Broad National Consumer Price Index), which measures the variation in prices of products and services consumed by Brazilian families with incomes between 1 and 40 minimum wages and is used by the Central Bank of Brazil to calculate inflation targets. Thomé (2017) points out that the Central Bank considers this index to judge whether the inflation target is in line with what has been stipulated and to determine the level of the interest rate which is used to define monetary policies and calculate the other interest rates in the national market.

According to Carrara and Barros (2019), inflation rates in Brazil have an important indexation component, but they are also affected by market expectations and the behaviour of suppliers' prices. Thus, the economy is the result of the analysis of certain behaviours, such as the fall in inflation expectations, the value of the exchange rate, and, above all, demand policies.

In economics, it is possible to use linear regression analysis to try to estimate a value that was not initially possible. Thus, this technique can determine the relationship between variables through an equation. According to Amaral et al. (2009), this technique can generally be used for various types of study, such as calculating the value of a variable from others with already known values, stipulating some values for a variable in a certain range, as well as characterizing a process or phenomenon that occurs between variables.

According to Sampaio (2015), regression develops a conditional expected value for some cases and linear regression is about estimating a value from the parameters of variables to a linear function.

3. Materials and methods

The methodology proposed for this research comprises data processed using multiple linear regression (MLR). To achieve the scope of the study, the statistical procedures were specifically least squares employing (MLR), as it is a statistical technique for investigating and modelling the relationship between variables, and is one of the most widely used in data analysis (Freedman, 2009).

We estimated regression models to investigate the relationship between potato prices and inflation indices using a traditional linear model for the expected value of the independent variable.

$$E(Yi) = xi\beta \quad (1)$$

Where *Yi* is the dependent variable that was selected one at time from the available set of dependent variables corresponding to the different inflation indices used in this research (Table 1.). The vector *xi* contains the explanatory variables (explained below) for participant *i* and the β is the vector of coefficients. The parameters of equation (1) are estimated by ordinary least squares (OLS).

Regression analysis is often used to determine how the response variable changes as a specific predictor variable changes, not necessarily for prediction. Thus, this study is not intended to predict, but rather to examine the relationships between variables, and residual diagnoses, as well as to perform lack of fit tests (Chatterjee & Simonoff, 2013). A linear regression was carried out using official information, with data for the period between 1987 and 2017. The dependent variables adopted for this work are the Broad National Consumer Price Indices as described in table 1.

To assess the normal distribution of the data, the Kolmogorov-Smirnov test is used, which analyses the maximum absolute difference between the cumulative distribution function of the data and the empirical distribution function. A value is then generated to determine whether it is a normal assumption when compared to the statistical value corresponding to the number of years used and the significance level.

3.1 National Broad Consumer Price Index

In the first stage of calculating the Broad National Consumer Price Index (IPCA) data, prices are collected for different categories (such as food and beverages and clothing) charged to consumers in cash payments. Each product surveyed has a different weight in the calculation, after generating a price estimate through a simple arithmetic average and then comparing it with the previous two months, resulting in a relative average between the months for each region. Next, the price variation for each sub-item is added, using a geometric mean. Then, the Laspeyres formula is applied, which consists of the weighted arithmetic average of the relative prices of certain goods, using the monetary values of each good sold at the basic time in a period as weighting factors (IBGE, 2019).

Reaching all levels of aggregation of item structure up to the overall index for each region. The national index is obtained using the weighted arithmetic average of the regional indices. Table 1 contains the dependent variables used in the linear regression, which are the The Broad National Consumer Price Index (IPCA), Food and Beverages IPCA, Tubers, Roots and Vegetables IPCA and Potato IPCA.

Table 1. Description of the Dependent Variables

Dependent variables	Description	Source
The Broad National Consumer Price Index General IPCA (%)	Published by the IBGE analysing the prices in all the sectors of the economy	IBGE
Food and Beverages IPCA (%)	Calculated based in the value of IPCA and the weight of food and beverages sector	IBGE
Tubers, Roots and Legumes IPCA (%)	Calculated based in the value of IPCA and the weight of tubers, roots and legumes sector	IBGE
Potato IPCA (%)	Calculated based in the value of IPCA and the weight of potato sector	IBGE

Notes: IPCA: Consumer Prices Ample Index; IBGE: Brazilian Institute of Geography and Statistics

To use the values of the dependent variable (Y) referring to the inflation indices measured by the IPCA, a correction factor was included, calculated as the share (weight) of the food basket (including potatoes) used to calculate this index.

Table 2 - Description of the independent Variables used in the Linear Regression.

Variable name	Description	Source
Planted Area (ha)	Total area planted with potatoes in Brazil	IBGE
Harvested Area (ha)	Total area harvested for potatoes in Brazil	IBGE
Total Production (tonnes)	The total quantity of potatoes produced	IBGE
Production yield (tonnes per ha)	Calculated using the ratio between total production and harvested area	Calculation
Value of production (US$)	Calculated using the ratio between the value of production and the exchange rate	IBGE B.C.B.
Potato prices (US$/ton)	Calculated as the ratio of converted production value to total production	Calculation

Notes: IBGE: Brazilian Institute of Geography and Statistics. B.C.B.: Central Bank of Brazil

In order to validate the normal distribution of the data, the Kolmogorov-Smirnov test was used, which is a method that assesses the greatest absolute difference between the cumulative distribution function of the data and the empirical distribution function. It provides a value which, when compared with the value of the statistic (Dn), is equivalent to the number of years used and the level of significance, whether or not the hypothesis is valid (Artuzo et al., 2018).

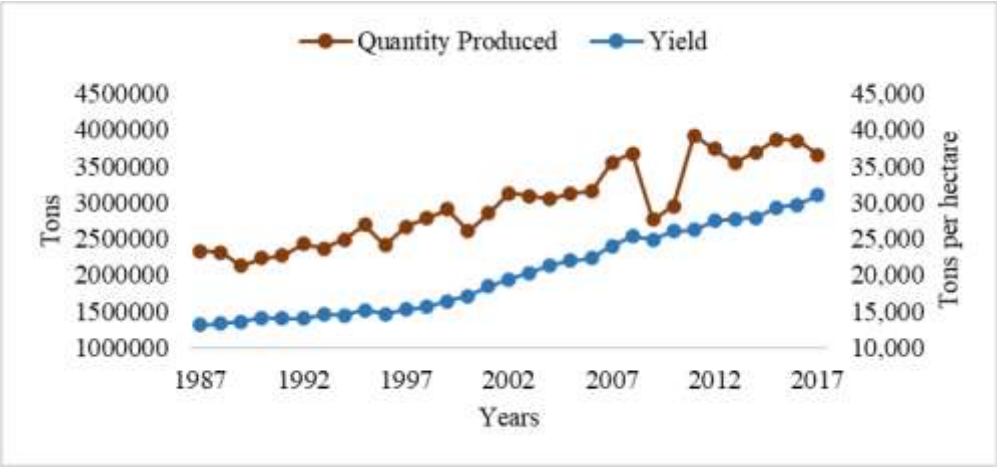
4. Results

An analysis of the characteristics and performance of the potato sector in Brazil using data from the Brazilian Institute of Geography and Statistics (IBGE, 2019) shows that Brazil has more than 180,000 hectares of land under potato cultivation, with a high yield index. Historical

data shows that 1998 and 1995 were the years with the largest planted are a, but they represent the years with the greatest loss in production, around 0.83% in 1998 and 1.12% in 1995.

In the 2000s there was a decrease in losses during the harvesting process, an indication of the increased use of cultivation technologies. In this decade, 2005 had the highest loss rate with 0.28%, and continued with few losses until 2017. There was also a decrease in the area planted and the area harvested, with the largest area planted in 2002 and the smallest in 2009 over the 30 years analysed. In addition, in 2011, there was an increase in production, which did not persist in the following years characterized by a decrease in the area planted with potatoes (IBGE, 2019).

According to data from the IBGE (2019), Brazilian production of potatoes in 2017 was 3.7 million tons, with the highest yield recorded in the 30 years studied at 30.9 tons per hectare, due to yields that have continued to grow due to the use of better agricultural techniques. Graph 1 shows a comparison of the quantity produced with the yield from 1987 to 2017.

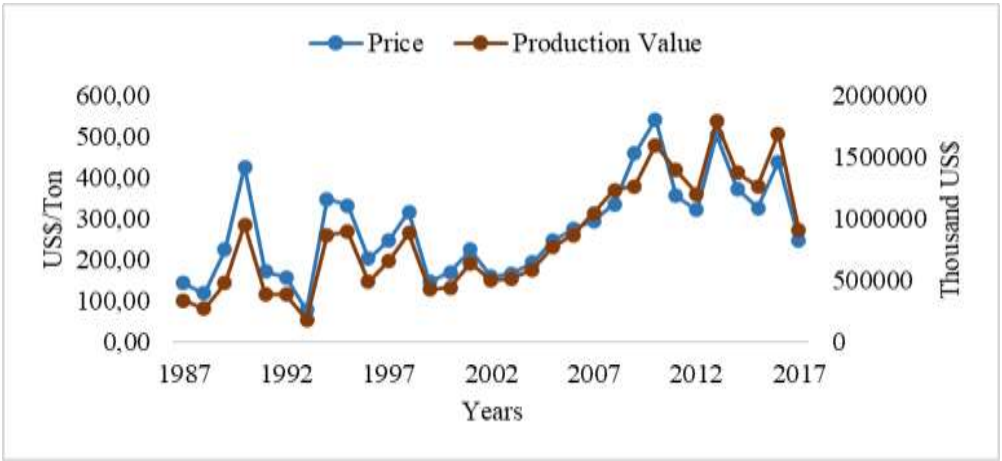


Source: IBGE, 2019.

Graph 1. Quantity Produced and Yield of Potatoes in Brazil.

The yield and quantity produced of potatoes in Brazil, showed an increase over the three decades from 1987 to 2017 and at the end of the 1980s, they remained stable, with the lowest amount produced in 1989 being 2.1 million tons, with almost the same harvested area of the previous year. With the start of the 1990s, it continued to grow until 1995, with the lowest figure in this decade approaching in 1996, with 2.4 million tons produced. After this drop, the amount produced grew again until the 2000s (IBGE, 2019). Giving the data from the IBGE (2019), the 2000s saw the biggest increase in production, but in 2009, it recorded the lowest figure with 2.7 million tons, followed by increases in production to record production of 3.9 million tons in 2011, the highest in the 30 years being analysed (1987-2017).

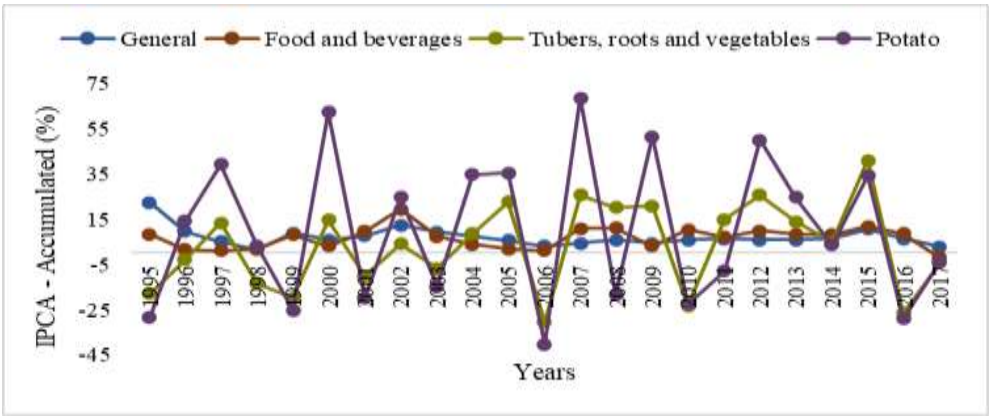
The potato market changes according to variations in production and prices. Graph 2 shows the value of production in US dollars with the potato price calculated by dividing the value of production by the quantity produced. In this context the Graph 2 shows a gradual increase between 2000 and 2010 of prices and value of production, with the highest price of potatoes in 2010. From 2011 onwards, the price fell by 34.3% along with the fall in the value of production.



Source: Adapted from the Central Bank of Brazil, IBGE, 2019.

Graph 2. Price and Value of Potato Production between 1987 and 2017.

The Broad National Consumer Price Index (IPCA) was established as the official inflation index in Brazil and created to display the variation in commercial prices to the consumer. This index is a division of the average daily price collection from the 1st to the 30th day of each month by the average price collection from the 1st to the 30th of the previous month. Graph 3 therefore shows the General index, the Food and Beverages group, the Tubers, Roots and Vegetables sub-group and the Potato item, showing the accumulated price variation from the market to the final public, as they are the average of all the CPIs calculated for each month of a year. According to data from IBGE (2019), the indices from 1989 to 1994, due to changes in the country's monetary unit, behaved differently from the following years, which remained, from 1995 with the real being the country's official currency, the indices stabilized.



Source: IBGE, 2019.

Graph 3. National Broad Consumer Price Index from 1995 to 2017.

The accumulated annual values of the General IPCA at the end of the 1980s are the highest recorded during the 30 years analyzed, with the highest value in 1989, when the index reached 1972.91%. In 90's, the Collor Plan was implemented, returning the cruzeiro as the monetary

unit to replace the cruzado novo. This led to a small drop in 1990 and 1991. With Brazil facing a major economic crisis in 1992, inflation rates rose. In 1993, the highest inflation rate was recorded, and as a measure to contain this increase, the Itamar Franco government instituted the Cruzeiro real as the new currency (IBGE, 2019).

As a result of the implementation of a new currency (Real Plan) in 1994, an strategy to stabilize the Brazilian economy the general IPCA registering a decrease of 894.05% between 1994 and 1995. In the following years, this general index remained more stable, with its lowest accumulated value (1.65%) and highest accumulated value (12.53%) in 1998 and 2002, respectively. Regarding the accumulated IPCA for the Food and Beverages category, the highest value was in 1993 (2468.2%), followed by a significant decrease until 1995, after which there was no major variation until 2017. (IBGE, 2019).

Regarding the behaviour of the IPCA for the Tubers, Roots and Vegetables subgroup, the index performed similarly to the Food and Beverages subgroup from 1989 to 1994, with its highest value in 1993, at 1938.77%, and its lowest in 2016, at -26.55%. From 1995 to 2017, this index showed large variations each year. Concerning the IPCA for potatoes, it maintained the pattern of its subgroup, with the highest values in 1990 and 1993. However, it showed the highest accumulated IPCA in 1990, when it registered an index of 3160.9%. In 1991, there was a drop of 2978.76% compared to the previous year. There were variations between 1995 and 2017, with the lowest index being -40.2% in 2006.

4.1 Contribution of the Food and Beverages group to the IPCA

The IPCA aims to measure the average variation in products and services, measuring the impact on the value of money. The Food and Beverages group has an average weight of 30% in the calculation of the overall IPCA and this contribution indicates the importance of this group in the final value of the overall IPCA. The IPCA and the Food and Beverages group had their highest values in 2002, with 19.47% and 4.36 percentage points (p.p.), followed by a drop until 2006. The behaviour of these two indices was relatively similar, except in 2009 when the IPCA fell and the contribution of food and beverages increased slightly. From 2016 to 2017, there was a 22.12% drop in the impact, which was also reflected in the General IPCA. The IPCA and the contribution behaved similarly, with small exceptions in 2006 and 2009, when the IPCA fell by 38.7% and 71.8%, respectively, and the contribution rose by 151.1% and 31.4%, respectively, and in 2010 when the IPCA rose by 226.7% but the contribution fell by 26.4%. In some years the IBGE has published the contribution of potato prices, especially in years when the IPCA for potatoes was high. In 2017, the General IPCA registered -1.87 and the potato's contribution was -0.01 percentage points. Most of the contributions follow the growth or decline of the general index, as in 2015, 2013 and 2012, which had contributions of 0.08, 0.05 and 0.07, respectively.

Concerning the significance of the variables in the multiple linear Regression for the Broad National Consumer Price Index (Table 3), 90% reliability was considered, due to the extensive database collected. The t-statistic |1.318| was also used to confirm the significance of the variables, due to the level of significance and the degree of freedom. In general, only total production is significant, as its p-value (0.0483) is below 0.1. In addition, it has a t-statistic value higher than the 1.318 considered in the regression.

The other variables have unsatisfactory values, due to their p-values being higher than the 90% reliability level and their t-statistics being lower. The area planted, yield, percentage loss and value of production are the positive variables, in which if there is an increase the IPCA will also increase and if it decreases the IPCA will also decrease. The negative variables - planted area, total production and potato price - have the opposite effect on the dependent variable, i.e. if they increase the value of the IPCA will decrease. The Kolmogrov-Smirnov test shows a table of n (number of lines in its regression) as a function of the significance level,

in this case 30 and 0.1 respectively. The base value is 0.22, and the test result is 0.17434. Thus, as the result is below the base value, the normal distribution of the model is confirmed, guaranteeing the fit.

Table 3. Multiple Linear Regression for the National Broad Consumer Price Index

Variables	Coefficient Value	Standard Error	T-statistics	p-value
Planted Area	-2.970E+00	4.038E+00	-0.736	0.4691
Harvested Area	2.997E+00	4.038E+00	0.742	0.4651
Total Production	-2.181E-03	1.048E-03	-2.081	0.0483
Yield	1.306E+02	9.277E+01	1.408	0.1719
Production Value	2.156E-03	1.835E-03	1.175	0.2515
Potato prices	-6.094E+00	5.303E+00	-1.149	0.2618

Dependent Variable	General IPCA	Adjusted R^2	0.4134
Mean Var. Dependent	7.60	Stat-F (7,24)	4.121
Standard Deviation	652.7812	p-value	0.004187
Unadjusted R^2	0.5459	Kolmogrov-Smirnov	0.17434
Standard Error of Residuals	551.4	24 degrees of freedom	

Table 4. shows the linear regression of the dependent variable, the IPCA, with its independent variables being planted area, harvested area, total production and production value. With a p-value of 0.0157 and t-statistic of |2,579| the total production is the only significant variable. The p-values for the area planted and harvested are slightly higher than desired and the t-statistics are within the required range.

The coefficients are negative for the planted area and total production (Table 4), hence when these variables decrease, the IPCA will increase. However, since the area harvested and the value of production are positive coefficients, if they change, they generate the same behaviour in the food consumer price index.

Table 4. Multiple Linear Regression Data for the National Broad Consumer Price Index

Variables	Coefficient Value	Standard Error	T-statistics	p-value
Planted Area	-0.4455163	0.2840546	-1.568	0.1284
Harvested Area	0.4602216	0.2869979	1.604	0.1204
Total Production	-0.0006808	0.0002640	-2.579	0.0157
Production Value	0.0003335	0.0003753	0.889	0.3821

Dependent Variable	General IPCA	Adjusted R^2	0.3985
Mean Var. Dependent	7.60	Stat-F (4, 27)	6.134
Standard Deviation	652.7812	p-value	0.001204
Unadjusted R^2	0.4761	Kolmogrov-Smirnov	0.17201
Standard Error of Residuals	558.3	27 degrees of freedom	

4.2 National Broad Consumer Price Index for Food and Beverages

Multiple linear regression with the dependent variable being the National Broad Consumer Price Index for Food and beverages. The same criteria were used as for the previous regression, with a reliability level of 90% and a t-statistic of |1.318|. In this regression, all the variables show unsatisfactory values in terms of significance, since the p-values are higher than 0.1 and the t-statistic values, except for total production, are lower than modulo 1.318. The factors that contribute most are total production and production value. The Kolmogrov-Smirnov test

confirms the normal distribution of the model with a value of 0.17937, which is lower than the base value of 0.22.

Table 5. Multiple Linear Regression Data for the Broad National Consumer Price Index for Food and Beverages

Variables	Coefficient Value	Standard Error	T-statistics	p-value
Planted Area	-0.3735864	0.2542086	-1.470	0.1532
Harvested Area	0.3846388	0.2568427	1.498	0.1458
Total Production	-0.0005085	0.0002362	-2.153	0.0404
Production Value	0.0002550	0.0003359	0.759	0.4542

Dependent Variable	IPCA Food	Adjusted R^2	0.2905
Mean Var. Dependent	8.62	Stat-F (4, 27)	4.173
Standard Deviation	551.0524	p-value	0.009278
Unadjusted R^2	0.382	Kolmogrov-Smirnov	0.20132
Standard Error of Residuals	499.7	27 degrees of freedom	

Table 5 shows the result of linear regression for the food and beverages IPCA with the dependent variable being the IPCA for food and beverages with the independent variables being the area planted, the area harvested, total production and the value of production. The total production is the only significant variable in this model, with a p-value of 0.0404 and a t-statistic of |2.153|, shows that. The area planted and harvested have p-values slightly higher than desired and the t-statistics are higher than expected. The planted area and total production indicate equal behaviour as the assigned coefficients are negative, so when these variables increase, the food and beverages IPCA will decrease. However, as the harvested area and the value of production have positive coefficients, if they are altered they will generate the same behaviour in the food and beverages IPCA. Furthermore, the model has a normal distribution, as proven by the Kolmogorov-Smirnov test, with a value of 0.20132, which is lower than the base value of 0.22.

4.3 National Broad Consumer Price Index for Tubers, roots and vegetables

The National Broad Consumer Price Index for Tubers, Roots and Legumes was the dependent variable in the multiple linear regression showed in table 6, and the independent variables were planted area, harvested area, total production, yield, percentage loss, production value and potato price.

Table 6. Multiple Linear Regression data for the National Broad Consumer Price Index Tubers, roots and legumes

Variables	**Coefficient Value**	**Standard Error**	**T-statistics**	**p-value**
Planted Area	-0.3679978	0.2161491	-1.703	0.1001
Harvested Area	0.3785886	0.2183888	1.734	0.0944
Total Production	-0.0005169	0.0002009	-2.573	0.0159
Production Value	0.0003326	0.0002856	-1.165	0.2543

Dependent Variable	IPCA Tubers	Adjusted R^2	0.3258
Mean Var. Dependent	14.720	Stat-F (4, 27)	4.745
Standard Deviation	479.4775	p-value	0.004973
Unadjusted R^2	0.4128	Kolmogrov-Smirnov	0.18166
Standard Error of Residuals	424.9	27 degrees of freedom	

However, in the multiple linear regression applied with the independent variables planted area, harvested area, total production and production value, as shown in Table 5, it can be seen that total production, planted area and harvested area are significant as they have a p-value below or equal to 0.1 and have a t-statistic value greater than the modulus of 1.318. In addition, the values of the coefficients in this regression indicate that the area harvested, and the value of production have a positive value, i.e. that their behaviour also affects the value of the IPCA for Tubers, roots and vegetables.

The plant area and total production have a negative coefficient, so their behaviour has the opposite effect on the dependent variable. According to the Kolmogorov-Smirnov test, the model shows a normal distribution with a value of 0.18166.

4.4 National Broad Consumer Price Index for Potatoes

The independent variables refer to the multiple linear regression with the National Broad Consumer Price Index for Potatoes. Concerning the significance of the variables, all of them have unsatisfactory values, as the p-value is above 0.1 and the t-statistic values are lower than |1.318|. The Kolmogrov-Smirnov test shows a value of 0.15507, which is below the base value, confirming the normal distribution of the model.

In Table 6, the results of the coefficients show that the area harvested and the value of production are positive and indicate that if they increase or decrease they generate the same effect on the IPCA. The planted area and total production are negative, indicating that if they change they have the opposite effect. About the significance of the variables, all have satisfactory values, as the p-value is below or very close to 0.1 and the t-statistic values are greater than |1.314|. The factors that contribute most are total production and the value of production, respectively. The Kolmogrov-Smirnov test shows a result (0.21146) below the base value (0.22), ensuring that the model fits and confirming the normal distribution.

Table 7. Multiple Linear Regression Data for the National Broad Consumer Price Index for Potatoes

Variables	Coefficient Value	Standard Error	T-statistics	p-value
Planted Area	-0.5425247	0.3399092	-1.596	0.12211
Harvested Area	0.5607562	0.3434313	1.633	0.11412
Total Production	-0.0009692	0.0003159	-3.069	0.00485
Production Value	0.0007948	0.0004491	1.770	0.08804

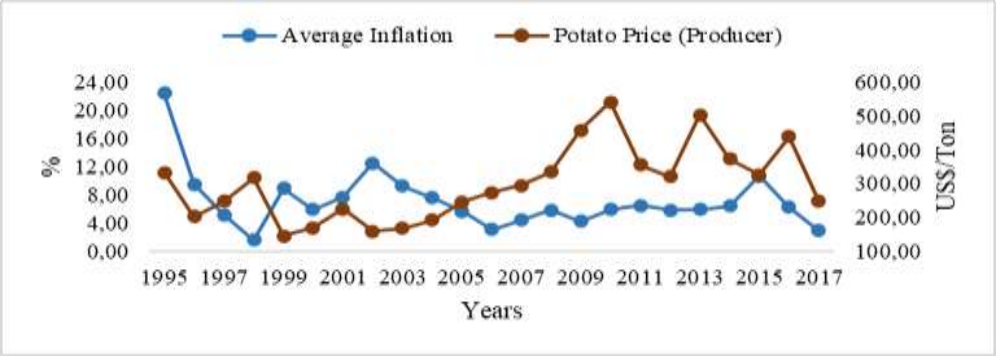
Dependent Variable	IPCA Potato	Adjusted R^2	0.3668
Mean Var. Dependent	34.18	Stat-F (4, 27)	5.49
Standard Deviation	774.4913	p-value	0.002286
Unadjusted R^2	0.4485	Kolmogrov-Smirnov	0.21146
Standard Error of Residuals	668.1	27 degrees of freedom	

Considering the linear relationship between inflation indices and potato production given the data measured using linear regression, the contributions to the proposed models are generated from the variables planted area, harvested area, production value and, above all, total production. Thus, in general, when there is an increase in Total Production, the General IPCA suffers a decrease (of 0.0006 times the value of total production) in its total value. Consequently, the same happens with the Food CPI and the Tuber CPI (0.0005 times the value of total production), and the Potato CPI decreases by 0.0009 times the value of total production. However, other variables must be considered when calculating the CPIAs, which behave differently to total production, such as the area harvested and the value of production.

Taking these aspects into account, total production is the most significant variable, but it does not show major changes in the dependent variable (IPCA) due to its small coefficient in the four linear regressions studied.

4.5 Performance of the potato market and inflation indices

According to Silveira et al. (2011), in 2008 the upper class consumed around one kilo more potatoes per person than the middle class, which consumed around two kilos more than the lower class. In this way, the potential for consumption grows as purchasing power increases. Graph 8 shows the average prices received by producers compared to inflation from 1996 to 2017.



Source: Worldwide, 2022.

Graph 8. Average Inflation in Brazil x Potato Price (Producer) in Brazil from 1996 to 2017.

The data showed in graph indicate that in the years with the highest inflation, 1996 and 2003, the prices paid were below the average for the period. However, potato prices do not reflect inflation, and other factors interfere with the behavior of the prices paid to producers.

According to Silva (2011), prices are formed from the global variables of climate, supply, demand and, above all, input suppliers and large retailers, while the producer has no direct influence on these price formation factors. As a result, the price paid to the producer does not directly influence the price paid by the consumer. In 2016, for example, the price paid to producers was higher, but the lowest prices were found in the retail sector. According to Barros (2017), it was calculated that in 2016, the production segments of agribusiness rose by around 21% compared to the previous year, but food prices for consumers registered 8.6% in the IPCA.

Olatunji et al. (2012) observed that smallholder farmers provide 85% of the total value of agricultural production, but are dependent on the agricultural labor market, the socioeconomic and production characteristics of farmers, together with government policies and poor infrastructure, interact with each other to affect the production of the agricultural sector. Leading to low production, high food prices, underdevelopment and consequent poverty in the country. However, for potato producers, some policy strategies to be used to control inflation should avoid factors responsible for the devaluation of the sector, with the definition of production compatible with market demand and increases in productivity with a reduction in the cultivated area.

5. Conclusions

With the data on the cultivated area and potato production in Brazil, it is notable that the quantity produced has increased by 56.9%, while the planted area has decreased by 33.3% between 1987 and 2017. With the advance of agricultural mechanization in the country, animals and manual labor were replaced by tractors and other machinery that increased yields and productivity.

In all cases, the potato price did not present satisfactory values to contribute to the tested models of inflation. In the cases of the IPCA, Food and Beverages IPCA and Tubers, Roots and Vegetables IPCA, their coefficients were negative, so the potato price has the opposite effect on the IPCA, i.e. if the price of potatoes decreases the IPCA will increase. This performance can be explained as one of the effects of product substitution or even by the effects of other variables like changes in income or consumer preferences. However, in the case of the Potato IPCA, its coefficient was positive, so any change in the price of potatoes has the same effect on the components of the potato IPCA.

Also, the results showed that the quantity produced and the area planted influence the definition of the price in response to increases or decreases in the supply of the product, with a shortage of potatoes generating higher prices and vice versa. Therefore, total production and yield are factors that play an important role in potato price formation, interacting with demand and determining the price paid by the final consumer in the potato market.

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