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**Conference Paper**

## Analysis of Increased Participation of Agriculture in the Brazilian GDP From 1960 to 2004

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# Analysis of Increased Participation of Agriculture in the Brazilian GDP from 1994 to 2004

Paper to be presented at 46<sup>th</sup> Congress of the European Regional Science Association, hold at Volos, Greece, from August 30<sup>th</sup> to September 3<sup>rd</sup>, 2006

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**Abstract:** According to global experience, agriculture's contribution to a country's gross domestic product (GDP) has diminished over the years. This has occurred in all nations, including in Brazil from 1960 to 1993. However, from 1994 to 2004, Brazil experienced an increase in this variable, what was not followed by most of the South American countries. This paper analyzes the factors that explain the increase in agriculture's contribution to the Brazilian gross domestic product during 1994–2004 period, comparing the Brazilian experience with other South American and the world's most developed countries. The methodology used is both organization of published dataset in graphs and tables as well as econometric analysis of these data. An accounting model is used to explain the main factors affecting agriculture's contribution to GDP growth and an econometric model is adapted for estimating the accounting model. Using dataset from 1986 to 2004, our econometric findings confirm there is a structural change in the curve of agriculture participation in the GDP, and the main variables determining this, from 1993 to 2004, are (received/paid prices) ratio, agricultural and industrial productivities as well as lagged participation of agriculture in the GDP.

**Key words:** GDP, agriculture's participation, Brazil.

## 1 - Introduction

For this paper, agriculture includes all farming production such as crops, meats, and forest products. Worldwide evidence shows that agriculture's contribution to the gross domestic product (GDP) has trended downward over the years, with an increase in the importance of other sectors, such as industry and services. At the start of this century, agriculture accounted for less than 2% of the GDP of developed countries – such as Japan, the UK and the USA – showing a clear decrease over the past forty years. Underdeveloped countries such as Bolivia, Colombia and Ecuador also saw a downward trend in the agriculture's contribution to the GDP (currently between 7.5% and 15% in relation to the GDP, according to World Bank information).

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In a few countries, such as Chile and Venezuela, agriculture's contribution to GDP has oscillated around a stable average over the past 15 years. However, in the case of Brazil, agriculture's contribution to GDP declined until 1993 (following the global pattern), before a steady growth reverted this situation between 1994 to 2004, with agriculture's contribution to GDP rising from around 5.77% in 1993 to 9.65% in 2004 (according to the Brazilian Institute of Geography and Statistics, IBGE). This also occurred in Argentina, where agriculture's contribution to GDP rose from below 5% in 2001 to approximately 11% in 2002 and 2003 (World Bank).

This atypical trend of rising income from agriculture to the Brazilian GDP had already been identified and analyzed by Bacha & Rocha (1998), who attributed it to three factors: increased productivity in agriculture, increased ratio of agricultural/industrial prices, and an increase in the ratio of prices received/paid by agriculture. Nevertheless, the importance of these factors were not quantified using an econometric model, nor were other factors discussed that affect agriculture's contribution to GDP.

## **2 - Objective**

The purpose of this paper is to assess factors that can explain the increase in the importance of agriculture in Brazil's GDP from 1994 to 2004, quantifying the influence of such factors using an econometric model.

This paper is divided into seven parts, including introduction and objective. Section three discusses a literature review of agriculture's participation in GDP. Section four presents world evidence on the behavior of agriculture's contribution to GDP. Section five discusses the methodology and data used in this study, and sections six and seven address the results and final considerations, respectively.

## **3 - Literature review**

A number of papers have been written on agriculture's decreasing contribution in overall GDP, namely, for example, Schultz (1951), Ahumada (1967), Araújo (1975) and Stern (1994). However, although there is very little literature about agriculture's rising importance in Brazil's GDP, Bacha & Rocha (1998) may be mentioned, who report on this

upward trend since 1989, which was not confirmed after reviewing data from IBGE (Brazilian Institute for Geography and Statistics) in 1997, when the New System of National Accounts was adopted to measure GDP. Nevertheless, agriculture's contribution to GDP increased since 1994, as demonstrated by Bacha & Rocha (2001).

Schultz (1951) reports a downward trend in agriculture's importance in the composition of the gross domestic product for the UK and the US between 1800 and 1950. With the increase in per capita income, people now looked for goods other than food, since the quantity of food consumed was already at the desired level for the high-income population (income level that permits meeting food requirements). Thus, since the other sectors of the economy grew faster than agriculture, the latter tends to reduce its importance in GDP composition. The growth of other sectors in the economy is facilitated by releasing labor from agriculture to those sectors due to the increase in labor productivity in agriculture as a result of technological advances.

When Ahumada (1967), Araújo (1975) and Araújo & Schuh (1988) describe the characteristics of a society in development, they discuss the occurrence of structural changes in production and income, with a decrease in agriculture's contribution to the formation of income (product), while at the same time the industrial sector's participation in income composition increased. Araújo (1975) also recounts agriculture's diminishing importance as a job creator as a result of the high degree of urbanization which characterizes the economic development process.

Araújo (1975) points out that, with economic development (and a consequent rise in income), the demand for manufactured goods and specialized services increases. These sectors increase their share in the composition of income in detriment to agriculture, since the secondary and tertiary sectors grow faster than the primary sector (in which agriculture is included).

Syrquin (1988)<sup>3</sup>, quoted by Alves (2000), comments that technical changes in agriculture and/or increase in the relative labor price induce mechanization and use of inputs (fuel, fertilizers, capital goods), which cause the added value of the agriculture sector to fall.

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<sup>3</sup> SYRQUIN, M. Patterns of structural change. In: CHENERY, H.; SRINIVASAN, T.N. Handbook of development economics. Amsterdam: Elsevier Science Publishers, 1988. v.1. Chapter 7, p.203-273.

The same author points out that the decrease in agriculture's contribution in income and employment in a study of 97 countries between 1950 and 1983.

Stern (1994) points to the loss in relative prices (agricultural/industrial prices) as the main cause for agriculture's diminished contribution to total GDP of a country.

Guilhoto (2004), using cross-section and recent data, also demonstrates that agriculture tends to play a small importance in GDP in countries with a higher per capita income.

Bacha & Rocha (1998) point out that the improvement in the ratio of agricultural/industrial prices, improvement in the ratio of received/paid prices by agriculture, and increase in the physical quantity produced in agriculture as a result of the increase in productivity are responsible for the increased participation of agriculture in the composition of Brazil's GDP.

Barros (1999) says that the increase in agricultural production in recent years is due mainly to the productivity gains of productive factors (provided by technological advances) and to the increase in capital inventory (principally tractors) and use of inputs, furthered by the heavy investment in Brazilian agriculture until 1986, both in rural research and extension and in the concession of subsidized rural credit. This growth in productivity is confirmed by Gasques et al (2004), who note the sharp rise in total factor productivity (TFP) since 1994, and was calculated using the Tornqvist index.

Bonelli (2005) tells how agriculture's increased contribution to Brazil's GDP reflects the sector's high productivity gains since the 1990s. Bonelli (2001) also points out that the poor performance of the industrial sector with regard to TFP (Total Factor Productivity) for the same period contributes to agriculture's larger share in GDP. Rossi Jr. & Ferreira (1999) calculated a drop in the industrial TFP between 1985 and 1990, and slower growth from 1990 to 1997, confirming the tendency presented by Bonelli (2001).

Regunaga (2004) says that the increased participation of agriculture in Argentina's GDP is a reflection mainly of domestic policy. The author mentions that a large share of this growth came from the introduction of genetically modified products that help cut costs, and therefore increase the profit earned by the sector.

Furtuoso & Guilhoto (2003) and Guilhoto (2004) agree that the development process based on the urban-industrial model leads to less importance being given to agriculture in the

economy. Nevertheless, the concept of agribusiness becomes more important since it boosts the economic production process, even though agriculture has a small participation in GDP.

By examining the above literature, it is found that some variables are highlighted to explain agriculture's contribution to Brazil's GDP. However, no study has prepared and estimated an econometric model to quantify the importance of the variables emphasized when determining GDP. This is the purpose of this paper.

#### **4 – Global evidence of the behavior of agriculture's contribution to GDP**

As mentioned above, there are several groups of countries where agriculture's contribution to GDP is changing. Mention may be made of the group of countries where agriculture's participation in total GDP is diminishing, which is true of most countries. The cases of Japan, the UK and the US are shown in figure 1 and Bolivia, Colombia and Ecuador in figure 2.

Countries such as Chile and Venezuela have a certain oscillation in agriculture's participation in total GDP, but with a tendency toward stability (this behavior can be seen in figure 3). Brazil and Argentina have atypical behavior, with an upward trend of this participation in recent years. This upward trend began in Brazil in 1994 and in 2001 in Argentina, as can be seen from figure 4.

Insert figures 1, 2, 3 and 4 here
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After confirming the trend of agriculture's rising contribution to Brazil's GDP from 1994 to 2004, the factors governing this growth are analyzed below.

### **5 - Methodology and Data Used**

#### **5.1 – Model for determining the participation of the agriculture in the GDP**

This section shows the accounting model of Bacha & Rocha (1998) on determining agriculture's contribution to GDP, deriving from it an econometric model and discussing the feasible data to estimate it.

Bacha & Rocha (1998) defined the following variables:

$VA_A$  = value added by the agriculture sector

$VA_I$  = value added by the non-agriculture sector

$P_A$  = general price level in the agriculture sector

$P_I$  = general price level in the non-agriculture sector

$P_A^I$  = general price level of agricultural goods used as inputs in the non-agriculture sector

$P_I^A$  = general price level of non-agricultural production used as inputs in the agriculture sector

$I_I^A$  = non-agricultural inputs used in the agriculture sector

$I_A^A$  = agricultural inputs used in the agriculture sector

$I_I^I$  = non-agricultural inputs in the non-agriculture sector

$I_A^I$  = agricultural inputs in the non-agriculture sector

$Q_A$  = physical quantity produced in the agriculture sector

$Q_I$  = physical quantity produced in the non-agriculture sector

Therefore, the overscript number is the producing sector and the subscript number indicates the user sector. **A** is the agriculture sector and **I** is the non-agriculture sector.

The Bacha & Rocha (1998) model has four basic equations, as follow:

$$P_{agr} = \frac{VA_A}{VA_I + VA_A} \quad \text{or} \quad P_{agr} = \frac{1}{1 + \frac{VA_I}{VA_A}} \quad (1)$$

where  $P_{agr}$  is the participation of agriculture in the GDP.

According to equation (1), the increase of  $\frac{VA_A}{VA_I}$  enlarges  $P_{agr}$ .

To determine the variables that influence  $\frac{VA_A}{VA_I}$  ratio, consider that:

$$VA_A = P_A \cdot Q_A - P_A \cdot I_A^A - P_I^A \cdot I_I^A \quad (2)$$

$$VA_I = P_I \cdot Q_I - P_A^I \cdot I_A^I - P_I \cdot I_I^I \quad (3)$$

Dividing (2) by (3), and proceeding with mathematical adjustments, this gives us:

$$\frac{VA_A}{VA_I} = \frac{\left(Q_A - I_A^A\right) - \frac{P_I^A}{P_A} \cdot I_I^A}{\frac{P_I}{P_A} \cdot \left(Q_I - I_I^I\right) - \frac{P_A^I}{P_A} \cdot I_A^I} \quad (4)$$

Equation (4) in its numerator reveals that an increase in the physical productivity of the agriculture sector [an increase of  $(Q_A - I_A^A)$ ], in *coeteris paribus* conditions, leads to the increase of  $\frac{VA_A}{VA_I}$ , which, through equation (1), leads to an increase in the participation of the agriculture sector in the GDP. Also, equation (4) in its numerator shows that an increase of  $\frac{P_A}{P_I^A}$  (unit value added in the agriculture sector), in *coeteris paribus* conditions, raises  $\frac{VA_A}{VA_I}$ , causing an increase in the agriculture sector's participation in the GDP.

Equation (4), in its denominator, states that the increase of  $\frac{P_A}{P_I}$  (ratio of agricultural/non-agricultural prices), in *coeteris paribus*, increases  $\frac{VA_A}{VA_I}$ , which also increases the agriculture sector's participation in the GDP.

These three aforementioned elements were emphasized by Bacha & Rocha (1998). It is also worth mentioning that the increase in industrial productivity [increase of  $(Q_I - I_I^I)$ ], in *coeteris paribus* conditions, reduces the ratio  $\frac{VA_A}{VA_I}$  thereby reducing the participation of agriculture in the GDP. These conclusions permit the estimation of the equation (4) using the following formula:

$$P_{\text{agr}} = \frac{VA_A}{VA_I + VA_A} = f\left[\left(Q_A - I_A^A\right), \frac{P_A}{P_I}, \frac{P_I^A}{P_A}, \left(Q_I - I_I^I\right)\right] \quad (5)$$

## 5.2 – Data Used

Secondary data are used to estimate equation (5). The data showing agriculture's contribution to the overall GDP is from IBGE. Price indexes are from Getulio Vargas Foundation. The Total Factor Productivity index in the agriculture sector is from Gasques et



al (2004) and the Total Factor Productivity index in industry is from Bonelli (2001), added by personal information provided by Regis Bonelli. Labor productivity data in agriculture are given by Gasques et al (2004) and labor productivity data in the industrial sector is from IBGE, consulted through the IBGE's SIDRA system.

The price indexes presented as received / paid prices ratio are for the State of São Paulo and ratio of agricultural/industrial prices for all Brazil. Both are published by the Getulio Vargas Foundation (FGV).

Data referring to employment, production, crop and livestock productivities and planted areas is published by IBGE, collected through the SIDRA System and in various editions of the Statistical Yearbook of Brazil, and they are presented to characterize agriculture's evolution in Brazil. The labor productivity data in agriculture comes from Gasques et al (2004). Labor productivity data in the industrial sector published by IBGE is also presented for comparison purposes.

## **6 - Results**

This section uses graphs to analyze the behavior of some variables that determine the value of the gross domestic product for agriculture and/or its participation in the overall Brazilian GDP. These variables were defined based on the literature consulted and on the model developed by Bacha & Rocha (1998). These variables are analyzed for the 1986-2004 period<sup>4</sup>, when there was an increase in agriculture without major government subsidies. Then the econometric model defined in item 5.1 (equation 5) is estimated in various ways to determine the importance of the variables selected for determining agriculture's contribution to GDP.

### **6.1 – Relative Prices**

- **Ratio of agricultural/industrial prices**

When analyzing figure 5, it is found that since 1994, except for some oscillations, the ratio of agricultural/industrial prices (industrial prices as proxy of non-agricultural prices) is rising (except in 2004), that is, favorable to the increased participation of agriculture in the GDP.

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<sup>4</sup> Some variables are assessed from 1986 to 2002/2003 due to availability of data.

Insert figure 5 here

- **Ratio of received/paid prices**

Figure 6 shows that there was a major increase in the received/paid price ratio in agriculture in São Paulo (São Paulo as proxy for Brazilian agriculture) in 1993 and 1994, with a drop in 1995, and followed by relative stability since 1996. However, the average value of this ratio since 1996 is higher than that between 1988 and 1992.

Insert figure 6 here

## 6.2 – Quantity Produced and Agricultural Productivity Indices

- **Crop Farming Production**

Brazilian crop farming production, assessed for 38 main crops<sup>5</sup>, showed a rise between 1986 and 2004, from 343 million to 601 million tones, respectively (figure 7). It is found that the sharpest rise was between 1993 and 2004, when the geometric growth rate was 3.7% per year, considerably higher than the growth for the years 1986-1993, when the geometric rate of growth was 0.7% per year (growth assessed for the 38 main crops in Brazil). Soybean production rose at a geometric growth rate of 7.9% per year between 1993 and 2004, reaching almost 50 million tones at the end of the period. This increase in production contributed to the agriculture's higher contribution to GDP.

Insert figure 7 here

There was an increase in crop farming's productivity in Brazil between 1986 and 1993, coupled with a reduction in area. The harvested area dropped from 52.5 million hectares in 1986 to 45.7 million hectares in 1993. Productivity rose from approximately 6,500 kg/ha in 1986 to around 8,000 kg/ha in 1993 (comprising data for the 38 main Brazilian crops). These figures show a 1.9% per year reduction in the harvested area for the 38 main Brazilian crops and a 2.63% rise in productivity. Between 1993 and 2004,

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<sup>5</sup> Apples, annual cotton, avocado, barley, beans, black pepper, cacao, castor oil, coconut, coffee, corn, garlic, grapes, guarana, guava, jute, limes, mallow, mangos, manioc, nuts, oats, onion, oranges, passion fruit, peanuts, perennial cotton, potatoes, rice, rye, sisal, soybean, sorghum, sugarcane, tangerines, tobacco, tomato and wheat.

production increased due to the increase in the amount of land dedicated to farming (a geometric growth rate of 1.84% per year) and increase in productivity (geometric growth rate of 1.82% per year). There was intense growth in the area, with an irreversible upward trend since 1996. In 2004, the harvested area with the 38 main Brazilian crops covered 60.9 million hectares, with productivity of almost 10,000 kg/ha. This evolution can be tracked in figure 8.

Insert figure 8 here

If soybean is excluded from the study, in other words, assessing Brazilian agriculture for the 37 main crops, the total farmed area only rose after 1998, as shown in figure 9. Between 1993 and 2004 the increase in area of the 37 main national crops was only 0.3% per year while the harvested soybean area grew 5.9% per year over the same period. Soybean was cultivated in another 8.6 million hectares between 1999 and 2004 (rising from 13 million to 21.6 million hectares, respectively).

Insert figure 9 here

- **Meat Production**

An analysis of Brazil's meat production<sup>6</sup> shows a steady increase between 1986 and 2002 (figure 10) from 3.76 million tons in 1986 to 12.65 million tons in 2002, contributing to agriculture's greater contribution to Brazil's GDP. Meat production showed a geometric growth of 6.8% per year between 1986 and 1993 and 7.8% per year from 1993 to 2002, with emphasis on poultry meat production, which increased 8.4% per year and 12.7% per year for the 1986-1993 and 1993-2002 periods, respectively. This increase shows that meat production performed better than crop farming over the same period, as Furtuoso & Guilhoto (2003) already mentioned.

Insert figure 10 here

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<sup>6</sup> Beef, swine and poultry meat.

This sharp rise in meat production is partly due to the increase in the yield of carcass per animal and also to a larger number of animals slaughtered between 1986 and 2002.

Figure 11 shows the increase in the yield of a kilo of carcass per animal slaughtered for the three animal groups (beef, swine and poultry). For the 1986-1993 period, beef production per animal slaughtered dropped 0.22% per year, while pork and poultry production per animal slaughtered had geometric growth rates of 0.13% per year and 1.15% per year in yield of carcass, respectively. Between 1993 and 2002, all meat showed a positive geometric growth rate for yield of carcass (1.33% per year, 0.93% per year and 0.86% per year for beef, swine and poultry, respectively).

Insert figure 11 here

Concerning the number of slaughtered animals (figure 12) between 1986 and 1993, beef, swine and poultry had geometric growth rates of 6.6% per year, 4.9% per year and 7.1% per year, respectively. From 1993 to 2004 these rates were 3.8% per year, 4.4% per year and 9.7% per year, respectively, showing a sharp growth in the number of slaughtered poultries. To have an idea, in 1993 1.23 billion poultries were slaughtered, rising to 3.55 billion in 2004.

Insert figure 12 here

This sharp rise in the slaughter of animals is due to further domestic demand and, principally, attracting new foreign markets for Brazilian meat this century.

- **Total Factor Productivity of Labor and Participation of Agriculture in Employment**

The study in the preceding sections gave some productivity indicators for crop farming and cattle breeding separately. This section gives the Total Factor Productivity (TFP – land, labor and capital) and for labor for the entire Brazilian agriculture.

Gasques et al (2004) show that the Total Factor Productivity calculated using the Tornqvist index increased throughout the 1986-2002 period, as can be confirmed in figure

13. In the 1986-1993 period, this growth was 1.78% per year, while in the 1993-2002 period it was 5.31% per year (geometric growth rate).

Insert figure 13 here

Although agriculture's participation in Brazil's GDP increased, agriculture's contribution to total Brazilian employment showed a decline. Its contribution to employment is still higher than its contribution to GDP, though. In 2003, agriculture accounted for almost 19% of employment and approximately 9.4% of the GDP. Agriculture's importance in employment can be seen in figure 14.

Insert figure 14 here

If in recent years agriculture's contribution to GDP is moving upward and downward in employment, presumably this indicates an increase in labor productivity. Gasques et al (2004) confirm this trend, which can be ascertained in figure 15.

Insert figure 15 here

Labor productivity in Brazilian agriculture increased at a geometric rate of 2.8% per year between 1986 and 1993 and 4.4% per year between 1993 and 2002. This growth is possibly the result of greater use of machinery and inputs, plus more efficient production techniques.

### **6.3 – Productivity in the Industrial Sector**

Productivity data from the industrial sector is used as proxy of productivity of the non-agriculture sector.

Figure 16 presents the Total Factor Productivity in the industrial sector from 1986 to 2004. The industrial TFP fell annually by 0.79% between 1986 and 1993, however, grew annually by a geometric growth rate of 0.38% between 1993 and 2004 (calculated from Bonelli (2001) data and personal information provided by Regis Bonelli). Although the industrial TFP grew between 1993 and 2004, it increased at a lower rate than the TFP in

agriculture for the same period, contributing toward the increased participation of agriculture in the GDP.

Insert figure 16 here

Labor productivity in the industrial sector showed a geometric growth rate of 1.7% per year for the years 1986-1993 and 3.1% per year for the 1993-2002 period (according to the IBGE industrial labor productivity data showed in figure 17).

Insert figure 17 here

#### 6.4 – Econometric Analysis

To statistically check the presence of a “break” in the upward trend of the agriculture participation in the Brazilian GDP a binary model was used based on Hoffmann & Vieira (1987) and Greene (2003). In accordance with this model, there is a “break” in the trend if the coefficient associated to the binary variable is statistically different from zero. The econometric model is:

$$P_{agr,j} = \alpha + \beta_1 \cdot (Year_j - K) + Z \cdot \beta_2 \cdot (Year_j - K) + u_j \quad (6)$$

where,  $\alpha$  = constant;

$K$  = year of break (1993);

$u_j$  = regression residue;

$Z$  = binary.

$$Z = \begin{cases} 0 & \text{for year} < K \text{ (1986-1992)} \\ 1 & \text{for year} \geq K \text{ (1993-2004)} \end{cases}$$

The data used for the regressions<sup>7</sup> is found in table 1.

Insert Table 1 here

<sup>7</sup> Other regressions were estimated using the TFP for agriculture and industry and the Prec/Ppag ratio for the entire Brazilian agriculture, but did not give as clear results as those presented here.

The econometric adjustment was made using the Ordinary Least Square (OLS) method. The value in brackets below the coefficient is the statistic “t” (“a” indicates a level of significance below 1% and “b” a level of significance below 5%).

$$\text{Part } \text{agr}_j = 6.7169 - 0.3765 \cdot (\text{Year}_j - K) + Z \cdot 0.6291 \cdot (\text{Year}_j - K) + u_j \quad (7)$$

(14.23)<sup>a</sup>    (-3.42)<sup>a</sup>                      (3.59)<sup>a</sup>

$$R^2 = 0.669 \quad n = 19 \quad F = 6.481^a$$

As can be seen, the value of the “t” test for coefficient  $\beta_2$  is 3.59, while the critical “t” value at 1% is approximately 2.86. Therefore, the hypothesis  $H_0: \beta_2 = 0$  is rejected in favor of the alternative hypothesis in which there is a “break” in the trend.

Having statistically checked the “break” in the trend, ten econometric models were adjusted using the Ordinary Least Square (OLS) method for the years 1993-2004 to estimate equation (5) in item 5.1. The models are: (1) normal data (observed data); (2) normal data and absence of PTind; (3) normal data, absence of PTind and inclusion of the time variable; (4) variables in neperian logarithm (LN) and time variable at an observed value; (5) variables in LN and time variable at observed value and exclusion of PTind variable; (6) all data in LN and inclusion of the dependent variable lagging for one period as an explanatory variable; and (7) all variables in LN, inclusion of the dependent variable lagging for one period as an explanatory variable and exclusion of the PTind variable; (8) explanatory variables and the lagging of the variable in LN (dependent variable at observed value); (9) explanatory variables and the lagged dependent variable in LN (but dependent variable on observed value) and exclusion of the P<sub>agr</sub>/P<sub>ind</sub> variable; and (10) explanatory variables and the lagged dependent variable in LN (variable dependent on observed value) and exclusion of the P<sub>rec</sub>/P<sub>pag</sub> variable. The results of these models are given in chart 1.

Insert Chart 1 here
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It is found that the adjusted models have satisfactory determination coefficients and F significance, which reveal the significance of the models. Some models show signals of the coefficients of the variables that represent the agricultural versus industrial price indexes

contrary to what is expected by the theoretical model. A possible explanation for this outcome is the occurrence of a high correlation rate between the two variables used in the models (Prec/Ppag and Pagr/Pind), creating a problem of multi-collinearity, since this problem is solved when a variable of relative prices is excluded (moving from model 8 to 9 and 10). It is also found that excluding the Pagr/Pind variable (model 9) gives better results if compared with the model that excludes the Prec/Ppag variable (model 10).

The best estimated equation, from an econometric viewpoint, is number 9, what is reproduced below. The value in brackets below the coefficient is the statistic “t” (“a” indicates a level of significance below 1%, “b” a level of significance below 5% and “c” a level of significance below or equal to 10%). Below statistic “t” appears the elasticity of Pagr in relation to independent variable.

$$\text{Pagr} = - 12.9096 + 9.1633 \cdot \text{LN}(\text{Prec/Ppag}) + 4.9761 \cdot \text{LN}(\text{PTagr}) - 11.14132 \cdot \text{LN}(\text{PTind}) + 4.3565 \cdot \text{LN}(\text{Pagr}_{t-1})$$

	(-1.189)	(2.833) <sup>b</sup>	(1.891) <sup>c</sup>	(-2.054) <sup>c</sup>	(2.196) <sup>c</sup>
elasticity		1.0082	0.5475	-1.2258	0.4793

$$R^2 = 0,7577 \quad n=12 \quad F = 5,473615^b \quad h\text{-Durbin} = \text{indeterminable}$$

The above equation has all coefficients with the expected signals. By considering the elasticity, the main variables determining Pagr are (counting down order): PTind, Prec/Ppag, PTagr and Pagr<sub>t-1</sub>.

## 7 - Final Comments

Contrary to global behavior and to what the literature predicts on the subject, Brazilian agriculture’s contribution to the country’s GDP from 1994 to 2004 has increased.

Brazilian meat production grew due to the increase in yield of carcass per animal and, principally, to the greater number of animals slaughtered, with emphasis on the 245% increase of slaughtered poultries from 1994 to 2004. Crop farming productions have also increased since 1994, due mainly to the increase in planted area and productivity gains.

There was also an increase in the Total Factor Productivity and labor productivity in agriculture, as well as a drop in the participation of this sector in employment generation. The regressions for the period 1993-2004 confirm that the increase in labor productivity in the agriculture sector contributed toward agriculture’s greater contribution to Brazil’s GDP.



The industrial Total Factor Productivity was found to have dropped between 1986 and 1990, and shown a growth since 1990, albeit at a lower rate than in agriculture.

The adopted econometric model statistically confirmed the “break” in the upward trend of the agriculture participation in the Brazilian GDP in 1993, which had already been found in graphs.

The adjusted econometric model with the values of explanatory variables and the lagged dependent variable in LN (but dependent variable on observed value, i.e., semi-LN regression) and exclusion of the relative agricultural versus industrial price ratio gave the best statistical results, with good levels of significance and signals of coefficients as expected by the accounting model. The other estimated models point to the fact that gains in terms of exchange result in a sharp rise in the agriculture participation in the GDP. Increased productivity in the industrial sector is also quite important to explain the agriculture’s participation in the GDP, but contributes to its reduction. According to our findings, the lower performance of industrial productivity during 1994-2004 period help to increase agriculture’s contribution to Brazil’s GDP.

As suggestions for future work, it is important to test equation (5) for other countries, comparing the results with those of Brazil.

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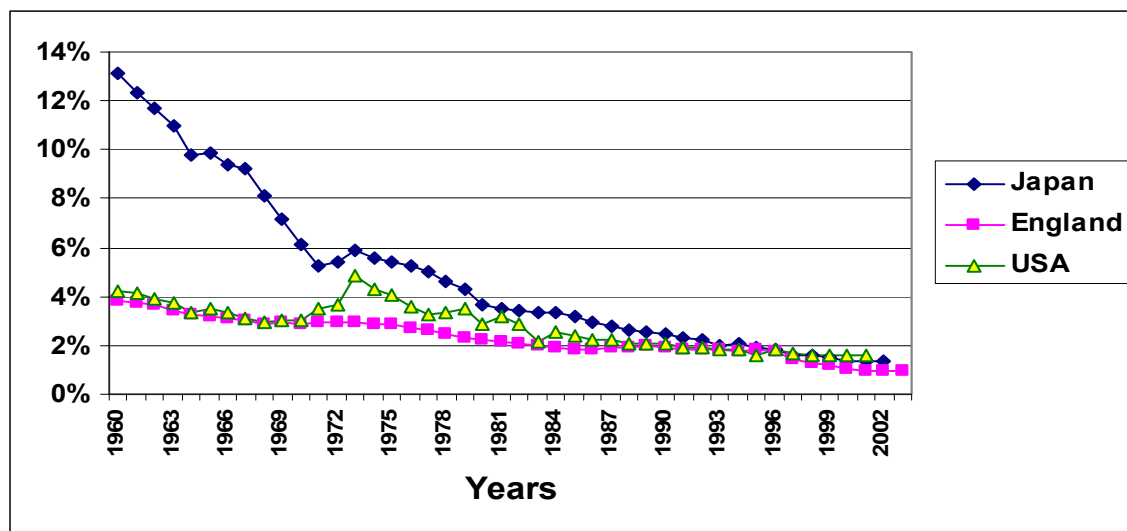
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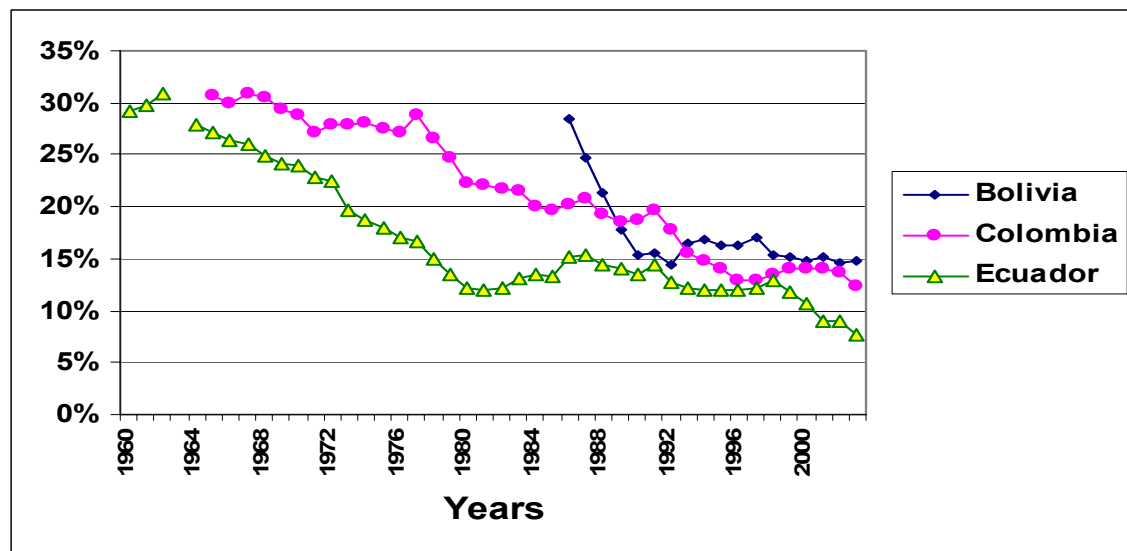
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**Figure 1.** Agriculture's participation in Japan, England and the USA's GDP – from 1960 to 2003.



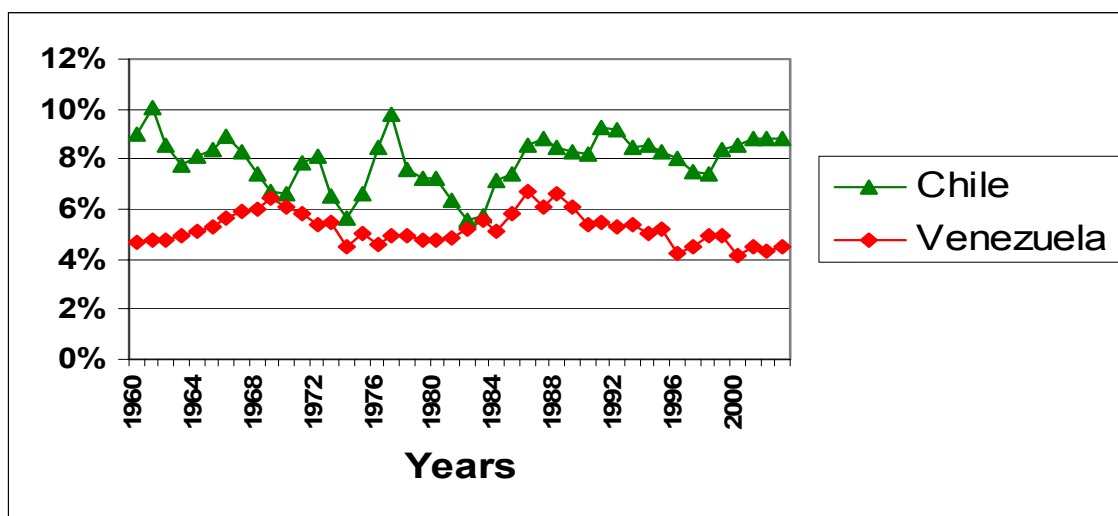
Source: World Bank (WDI 2005)

**Figure 2.** Agriculture's participation in Bolivia, Colombia and Ecuador's GDP – from 1960 to 2003.



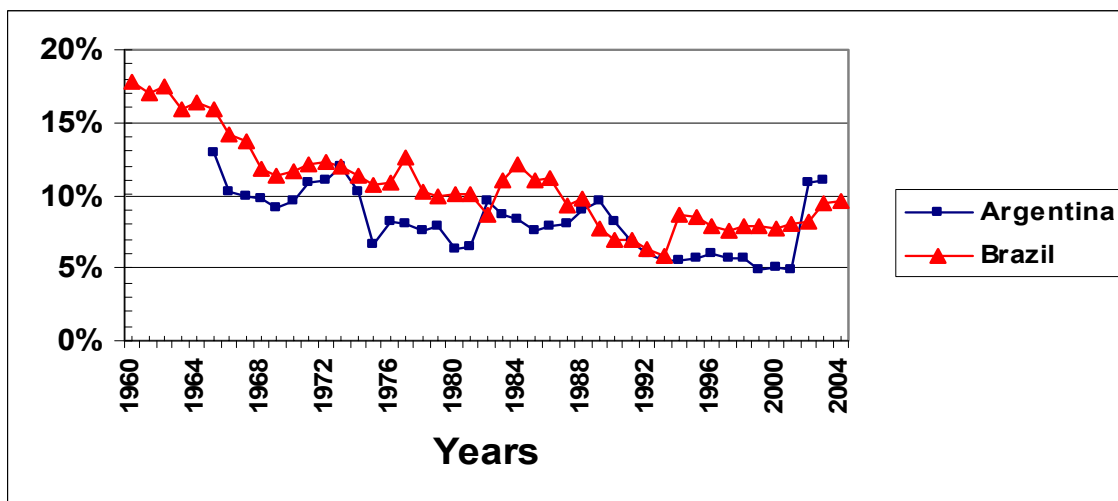
Source: World Bank (WDI 2005)

**Figure 3.** Agriculture's participation in Chile and Venezuela's GDP – from 1960 to 2003.



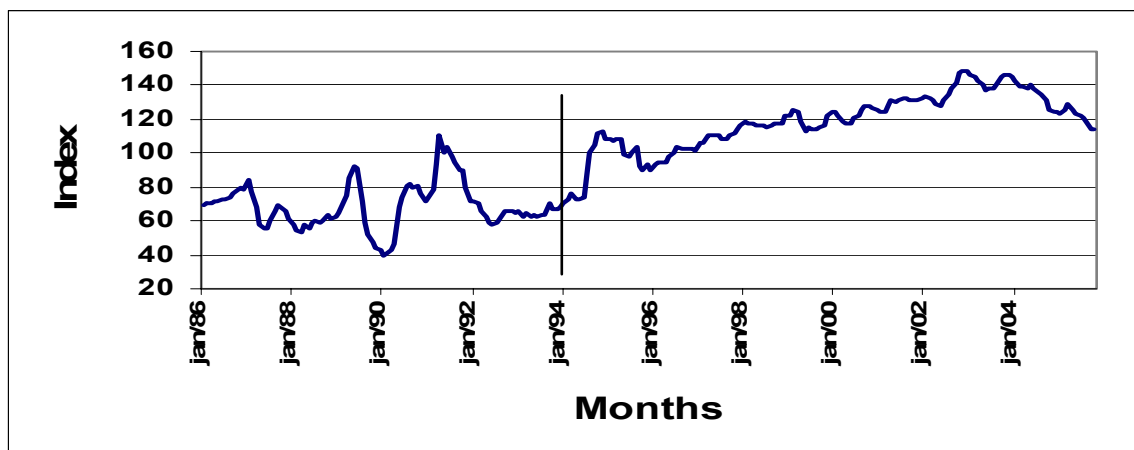
Source: World Bank (WDI 2005)

**Figure 4.** Agriculture's participation in Brazil and Argentina's GDP – from 1960 to 2004.



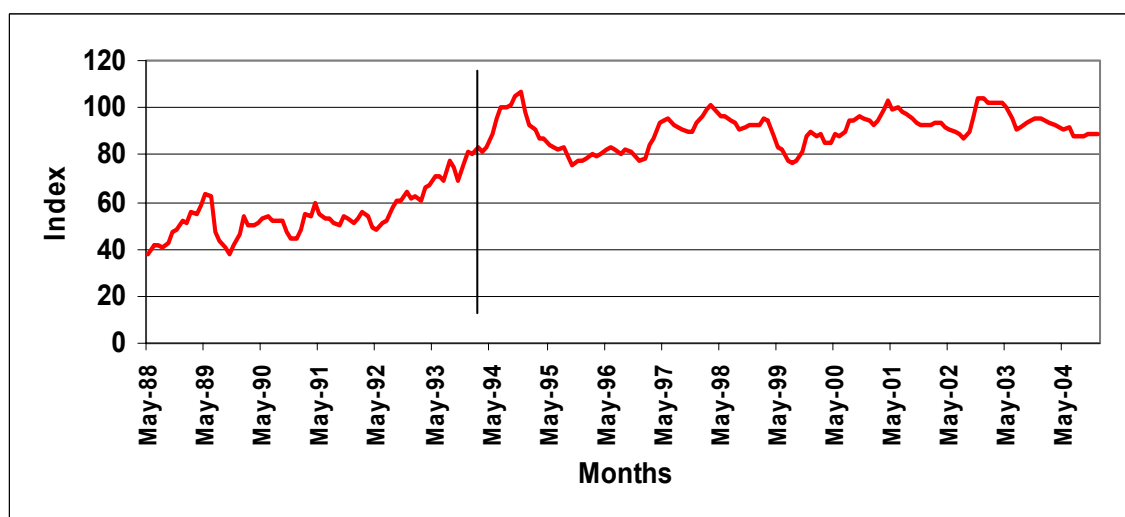
Source: IBGE (Brazil) and World Bank (WDI 2005 - Argentina)

**Figure 5.** Evolution of the ratio of agricultural / industrial prices – Brazil (index 100 = August 1994).



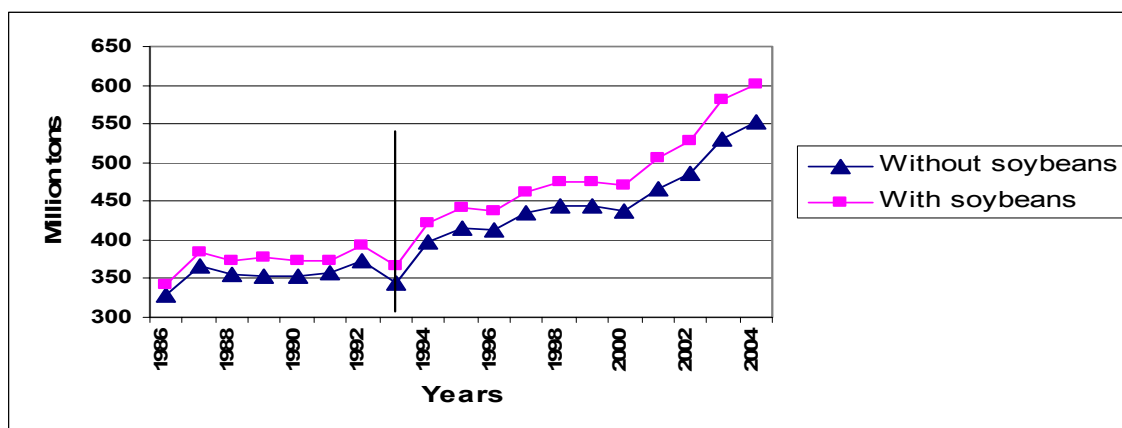
Source: Getulio Vargas Foundation (FGV)

**Figure 6.** Evolution of the received / paid price in São Paulo's agriculture (index 100 = August 1994).



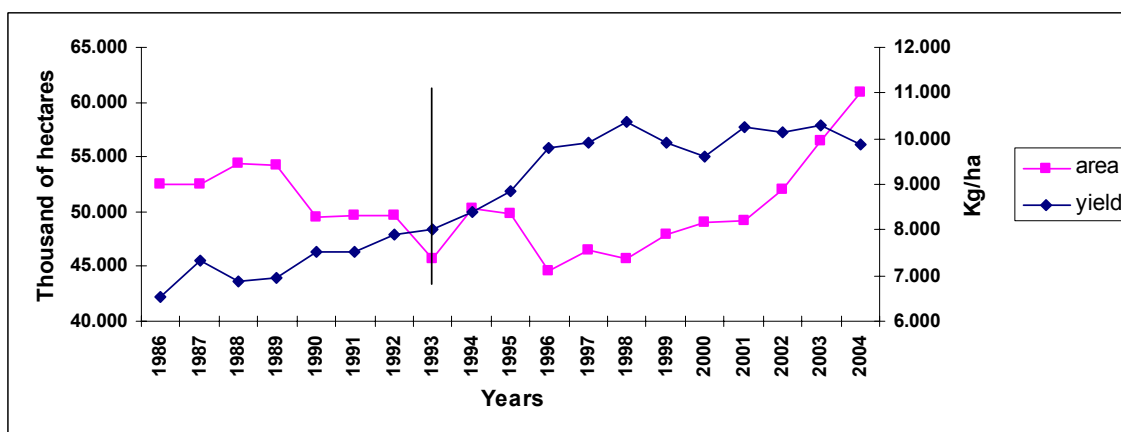
Source: Getulio Vargas Foundation (FGV)

Figure 7. Brazilian crop farming production evolution – from 1986 to 2004.



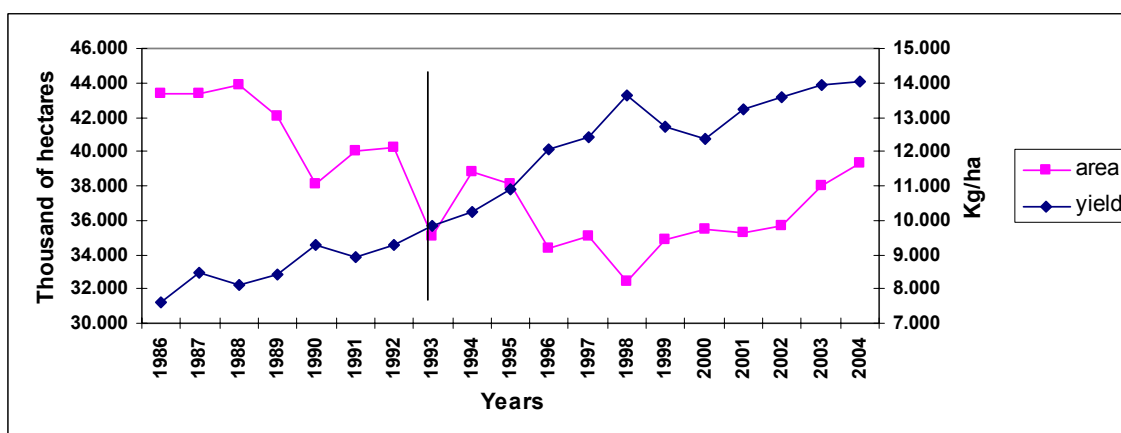
Source: IBGE

Figure 8. Evolution of area and yield for 38 main crops – Brazil - from 1986 to 2004.



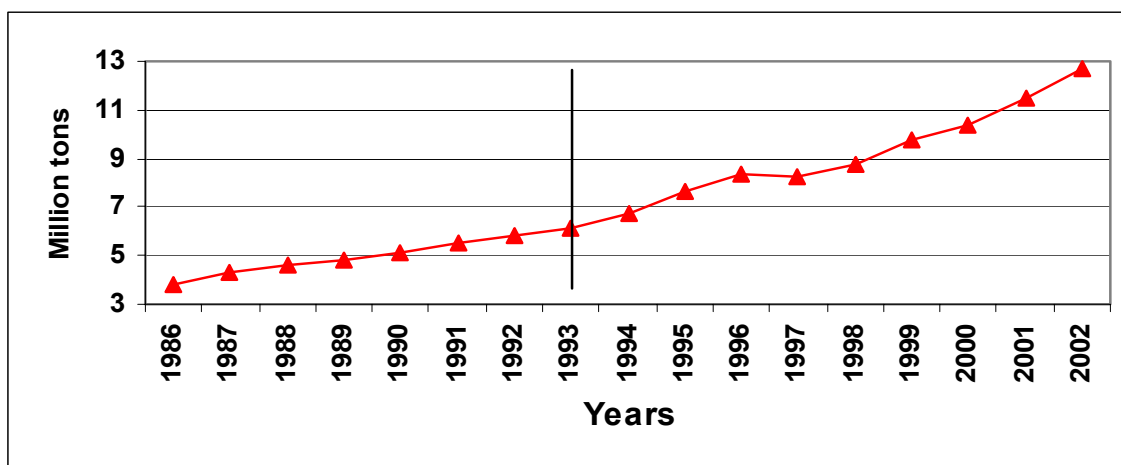
Source: IBGE

Figure 9. Evolution of area and yield for the 37 main crops – Brazil - from 1986 to 2004.



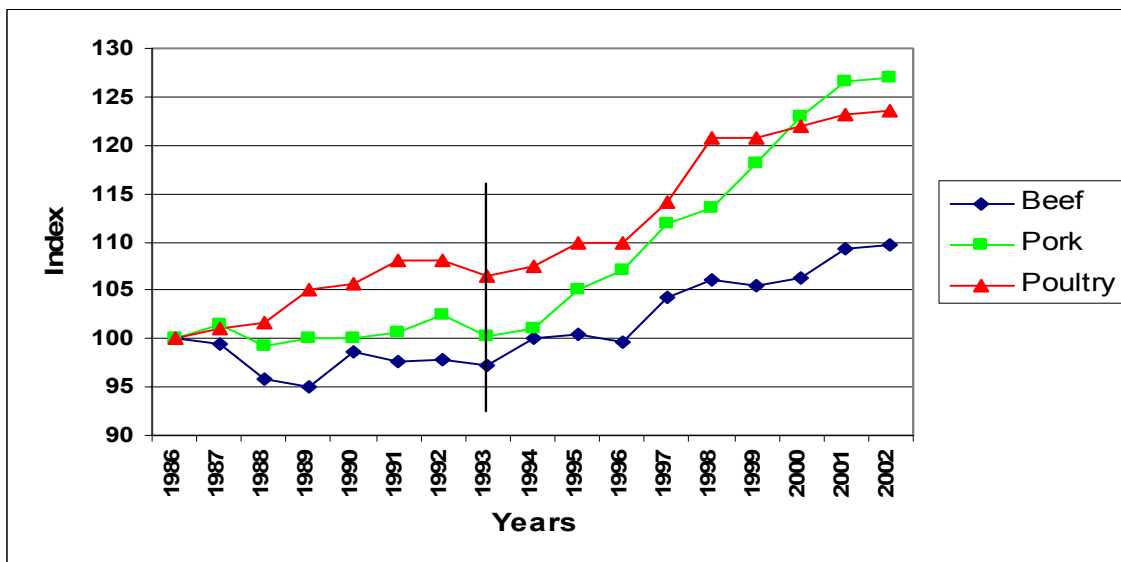
Source: IBGE

**Figure 10.** Evolution of Brazilian meat production – from 1986 to 2002.



Source: IBGE

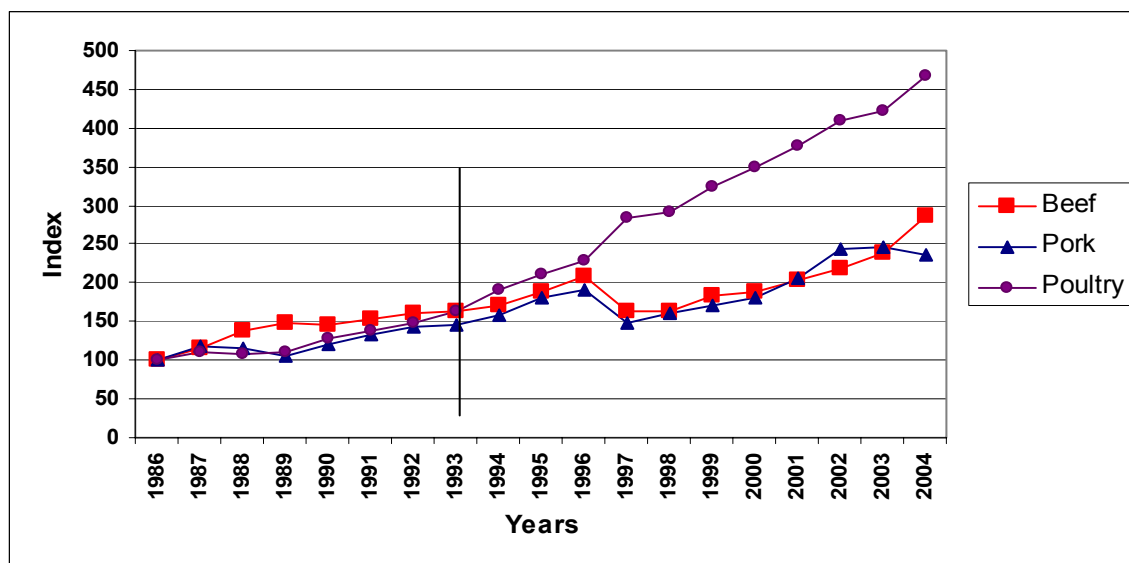
**Figure 11.** Evolution of Brazilian yield of carcass – from 1986 to 2002 (index 100 = 1986).



Source: IBGE

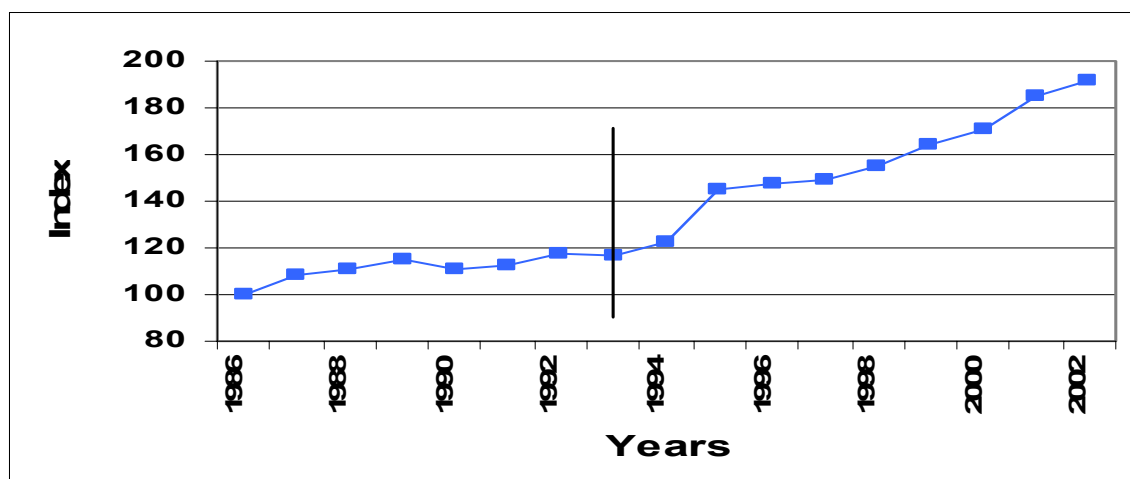


**Figure 12.** Number of slaughtered animals – from 1986 to 2004 (index 100 = 1986).



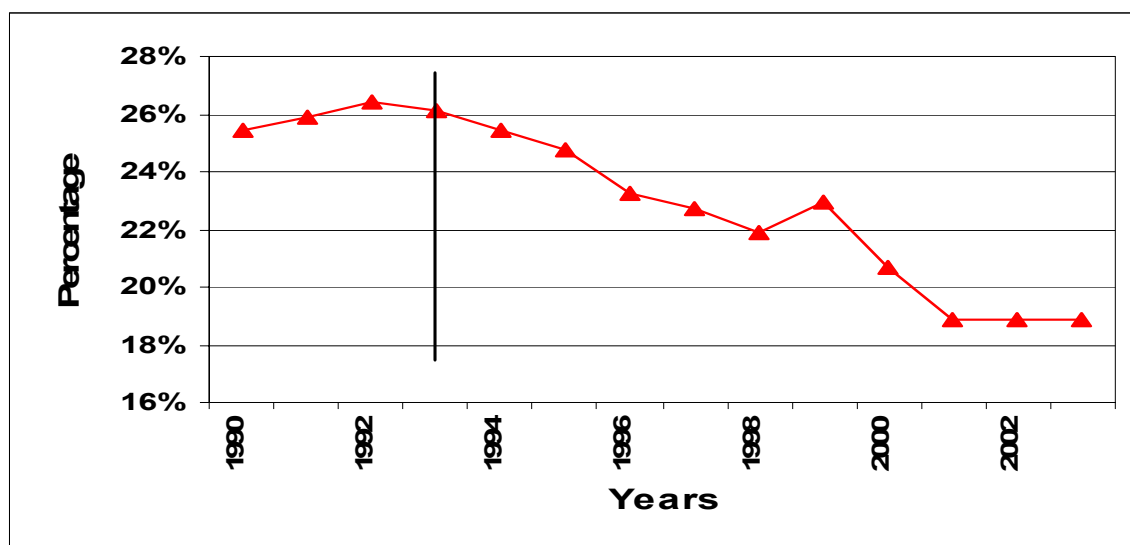
Source: IBGE

**Figure 13.** Evolution of Total Factor Productivity in Brazilian Agriculture – from 1986 to 2002 (index 100 = 1986).



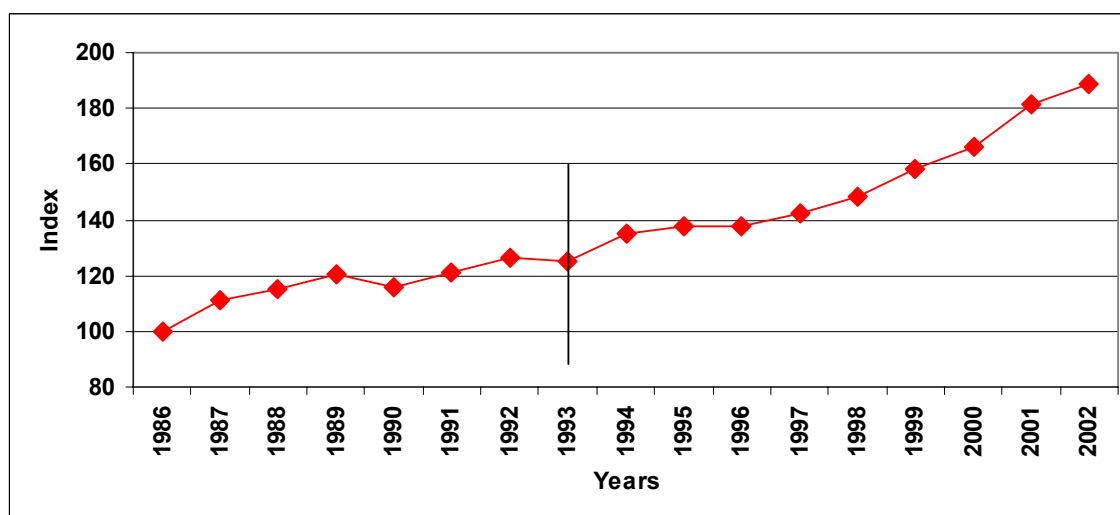
Source: Gasques et al (2004).

**Figure 14.** Agriculture's Participation in employment – Brazil - from 1990 to 2003.



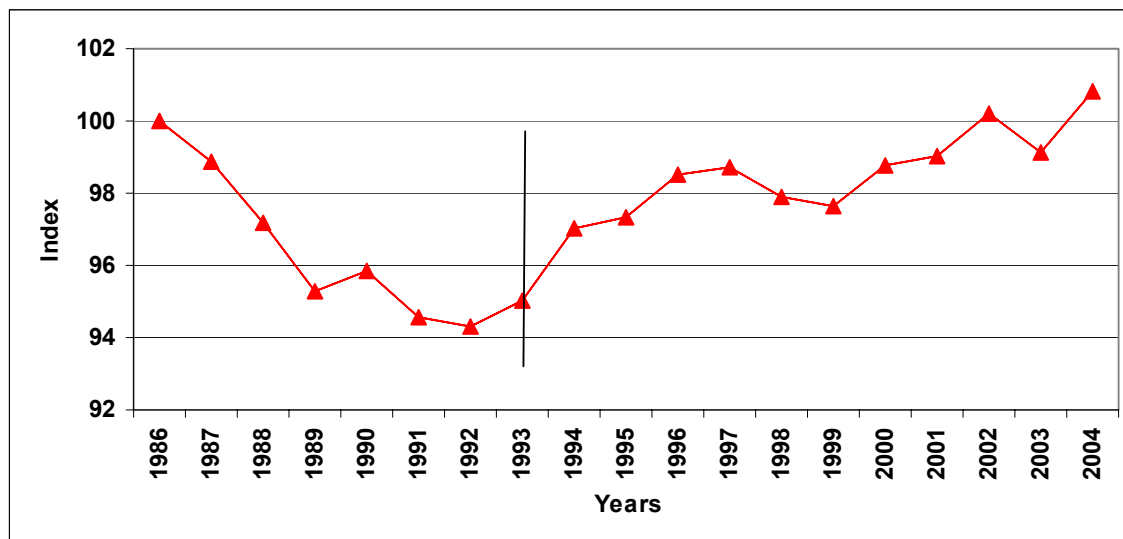
Source: IBGE

**Figure 15.** Evolution of Labor Productivity in Brazilian agriculture – from 1986 to 2002 (index 100 = 1986).



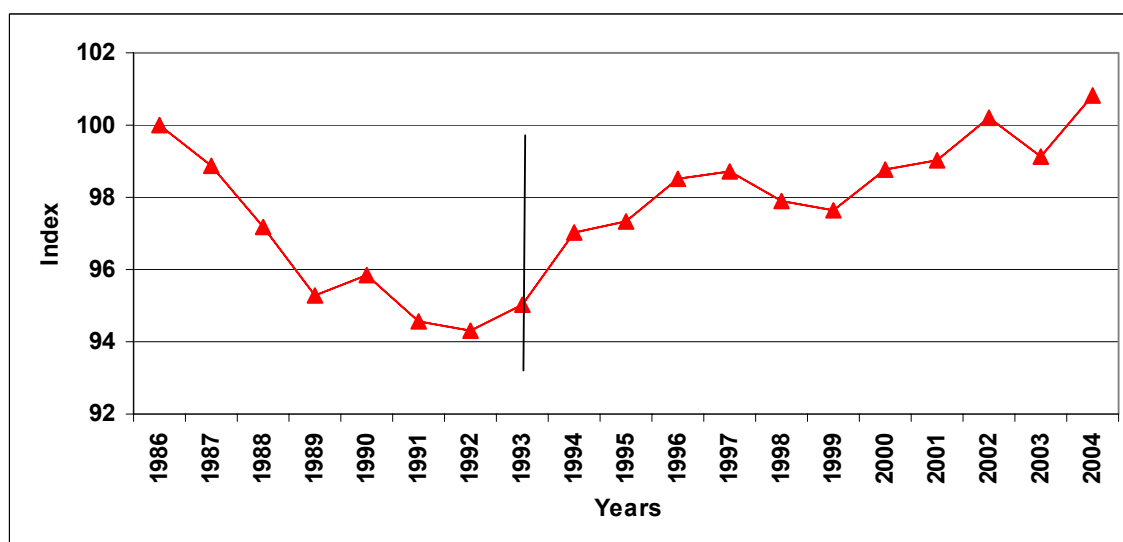
Source: Gasques et al (2004)

**Figure 16.** Evolution of Total Factor Productivity in Brazilian industrial sector – from 1986 to 2004 (index 100 = 1986).



Source: Bonelli (2001) added by personal information provided by Regis Bonelli

**Figure 17.** Evolution of Labor Productivity in the Brazilian industrial sector – from 1986 to 2002 (index 100 = 1986).



Source: IBGE

**Table 1** - data set used in regressions.

Year	Pagr (%)	Prec/Ppag	Pagr/Pind	PTagr	PTind
1986	11.20		73.83	74.04	81.38
1987	9.30		65.81	82.15	79.78
1988	9.80	43.93	58.65	85.36	77.57
1989	7.70	50.28	66.25	89.39	77.50
1990	6.92	50.28	65.17	85.80	70.41
1991	6.90	53.05	90.48	89.55	82.81
1992	6.23	55.61	64.08	93.66	85.90
1993	5.77	70.47	65.27	92.44	92.97
1994	8.63	93.51	88.63	100.00	100.00
1995	8.47	83.25	99.98	102.14	100.56
1996	7.90	80.57	99.36	101.95	106.10
1997	7.57	90.00	110.47	105.47	114.59
1998	7.83	95.18	117.38	109.84	116.38
1999	7.90	85.53	118.58	117.24	117.60
2000	7.70	90.74	123.11	123.21	121.03
2001	8.00	96.41	129.85	134.33	121.30
2002	8.20	93.39	137.05	139.63	121.73
2003	9.40	96.95	142.56	145.84	125.49
2004	9.65	90.29	134.69	152.33	129.37

Source: described in the paper.

Note: Pagr = Agriculture participation in the GDP in %; Pagr/Pind = ratio of agricultural / industrial prices; Prec/Ppag = Ratio of received/paid prices by agriculture sector in the state of São Paulo; PTagr = Labor Productivity Index in the agriculture sector; PTind = Labor Productivity Index in the industrial sector.

Chart 1. Regressions run from 1993 to 2004.

Model		Const	Prec/Ppag	Pagr/Pind	PTagr	PTind	Pagr <sub>(t-1)</sub>	Time	R <sup>2</sup>	F - Value (Significance)	DW Estat	h-Durbin																																																																																																																																																																																								
1. Normal Data	Coef.	5.275	0.0497	0.0262	0.0323	-0.0738			0.599	2.619086 (0.125998)	1.084 (Inconclusive)	--																																																																																																																																																																																								
	Probab.	0.3915	0.3548	0.5809	0.3105	0.3677							2. Normal Data and Absence of PTind	Coef.	0.8149	0.0554	-0.005165	0.0247				0.546	3.212315 (0.08302)	1.061 (Inconclusive)	--	Probab.	0.8185	0.2959	0.8728	0.4081				3. Normal Data, Absence of PTind and Inclusion of the Time Variable	Coef.	1585.3	0.0111	0.0595	0.1104			-0.7996	0.649	3.243566 (0.0834)	1.1263 (Inconclusive)	--	Probab.	0.1941	0.8477	0.305	0.135			0.1943	4. Variables in LN and time Variable at an Observed Value	Coef.	198.61	0.0351	0.7443	1.8857	-0.056527		-0.104534	0.693853	2.719683 (0.127609)	1.042 (Inconclusive)	--	Probab.	0.601	0.9716	0.2218	0.5145	0.9847		0.6046	5. Variables in LN and Time Variable at Observed Value and Exclusion of PTind	Coef.	205.255	0.0214	0.7446	1.9341			-0.108077	0.6938	3.965824 (0.05444)	1.0406 (Inconclusive)	--	Probab.	0.1513	0.9727	0.1842	0.1383			0.1482	6. Data in LN and inclusion of Lagged Dependent Variable	Coef.	-2.5931	1.5842	-0.2966	0.5925	-1.1356	0.7436		0.789	4.489419 (0.0476)	2.109 (Inconclusive)	-0.171	Probab.	0.52	0.0897	0.6816	0.1588	0.2558	0.1267		7. Variables in LN, inclusion of Lagged Dependent Variable and exclusion of the	Coef.	-6.0645	1.838	-0.8201	0.4227		0.8598		0.7336	4.819372 (0.0348)	2.0296 (Inconclusive)	-0.0464	Probab.	0.0601	0.0524	0.1935	0.2744		0.0832		8. Explanatory Variables and the Lagged Variable in LN	Coef.	-31.2022	12.5785	-3.5849	5.5891	-8.2916	6.0578		0.7743	4.11564 (0.0572)	2.02116 (Inconclusive)	indeterminable	Probab.	0.336	0.0872	0.5323	0.1018	0.2876	0.1159		9. Explanatory Variables and the Lagged Dependent Variable in LN (variable dependent on observed value) and exclusion of the Pagr/Pind	Coef.	-12.9096	9.1633		4.9761	-11.14132	4.3565		0.7577	5.473615 (0.02556)	1.7243 (Inconclusive)	indeterminable	Probab.	0.273	0.0253		0.1005	0.0791	0.0641		10. Explanatory Variables and Lagged Dependent Variable in LN (variable dependent on observed value) and exclusion of the Prec/Ppag	Coef.	18.9943		5.66145	3.8055	-12.0328	0.5838		0.6174	2.823904 (0.1095)	1.5692 (Inconclusive)	indeterminable	Probab.	0.3825	
2. Normal Data and Absence of PTind	Coef.	0.8149	0.0554	-0.005165	0.0247				0.546	3.212315 (0.08302)	1.061 (Inconclusive)	--																																																																																																																																																																																								
	Probab.	0.8185	0.2959	0.8728	0.4081								3. Normal Data, Absence of PTind and Inclusion of the Time Variable	Coef.	1585.3	0.0111	0.0595	0.1104			-0.7996	0.649	3.243566 (0.0834)	1.1263 (Inconclusive)	--	Probab.	0.1941	0.8477	0.305	0.135			0.1943	4. Variables in LN and time Variable at an Observed Value	Coef.	198.61	0.0351	0.7443	1.8857	-0.056527		-0.104534	0.693853	2.719683 (0.127609)	1.042 (Inconclusive)	--	Probab.	0.601	0.9716	0.2218	0.5145	0.9847		0.6046	5. Variables in LN and Time Variable at Observed Value and Exclusion of PTind	Coef.	205.255	0.0214	0.7446	1.9341			-0.108077	0.6938	3.965824 (0.05444)	1.0406 (Inconclusive)	--	Probab.	0.1513	0.9727	0.1842	0.1383			0.1482	6. Data in LN and inclusion of Lagged Dependent Variable	Coef.	-2.5931	1.5842	-0.2966	0.5925	-1.1356	0.7436		0.789	4.489419 (0.0476)	2.109 (Inconclusive)	-0.171	Probab.	0.52	0.0897	0.6816	0.1588	0.2558	0.1267		7. Variables in LN, inclusion of Lagged Dependent Variable and exclusion of the	Coef.	-6.0645	1.838	-0.8201	0.4227		0.8598		0.7336	4.819372 (0.0348)	2.0296 (Inconclusive)	-0.0464	Probab.	0.0601	0.0524	0.1935	0.2744		0.0832		8. Explanatory Variables and the Lagged Variable in LN	Coef.	-31.2022	12.5785	-3.5849	5.5891	-8.2916	6.0578		0.7743	4.11564 (0.0572)	2.02116 (Inconclusive)	indeterminable	Probab.	0.336	0.0872	0.5323	0.1018	0.2876	0.1159		9. Explanatory Variables and the Lagged Dependent Variable in LN (variable dependent on observed value) and exclusion of the Pagr/Pind	Coef.	-12.9096	9.1633		4.9761	-11.14132	4.3565		0.7577	5.473615 (0.02556)	1.7243 (Inconclusive)	indeterminable	Probab.	0.273	0.0253		0.1005	0.0791	0.0641		10. Explanatory Variables and Lagged Dependent Variable in LN (variable dependent on observed value) and exclusion of the Prec/Ppag	Coef.	18.9943		5.66145	3.8055	-12.0328	0.5838		0.6174	2.823904 (0.1095)	1.5692 (Inconclusive)	indeterminable	Probab.	0.3825		0.1569	0.2903	0.1893	0.8081																	
3. Normal Data, Absence of PTind and Inclusion of the Time Variable	Coef.	1585.3	0.0111	0.0595	0.1104			-0.7996	0.649	3.243566 (0.0834)	1.1263 (Inconclusive)	--																																																																																																																																																																																								
	Probab.	0.1941	0.8477	0.305	0.135			0.1943					4. Variables in LN and time Variable at an Observed Value	Coef.	198.61	0.0351	0.7443	1.8857	-0.056527		-0.104534	0.693853	2.719683 (0.127609)	1.042 (Inconclusive)	--	Probab.	0.601	0.9716	0.2218	0.5145	0.9847		0.6046	5. Variables in LN and Time Variable at Observed Value and Exclusion of PTind	Coef.	205.255	0.0214	0.7446	1.9341			-0.108077	0.6938	3.965824 (0.05444)	1.0406 (Inconclusive)	--	Probab.	0.1513	0.9727	0.1842	0.1383			0.1482	6. Data in LN and inclusion of Lagged Dependent Variable	Coef.	-2.5931	1.5842	-0.2966	0.5925	-1.1356	0.7436		0.789	4.489419 (0.0476)	2.109 (Inconclusive)	-0.171	Probab.	0.52	0.0897	0.6816	0.1588	0.2558	0.1267		7. Variables in LN, inclusion of Lagged Dependent Variable and exclusion of the	Coef.	-6.0645	1.838	-0.8201	0.4227		0.8598		0.7336	4.819372 (0.0348)	2.0296 (Inconclusive)	-0.0464	Probab.	0.0601	0.0524	0.1935	0.2744		0.0832		8. Explanatory Variables and the Lagged Variable in LN	Coef.	-31.2022	12.5785	-3.5849	5.5891	-8.2916	6.0578		0.7743	4.11564 (0.0572)	2.02116 (Inconclusive)	indeterminable	Probab.	0.336	0.0872	0.5323	0.1018	0.2876	0.1159		9. Explanatory Variables and the Lagged Dependent Variable in LN (variable dependent on observed value) and exclusion of the Pagr/Pind	Coef.	-12.9096	9.1633		4.9761	-11.14132	4.3565		0.7577	5.473615 (0.02556)	1.7243 (Inconclusive)	indeterminable	Probab.	0.273	0.0253		0.1005	0.0791	0.0641		10. Explanatory Variables and Lagged Dependent Variable in LN (variable dependent on observed value) and exclusion of the Prec/Ppag	Coef.	18.9943		5.66145	3.8055	-12.0328	0.5838		0.6174	2.823904 (0.1095)	1.5692 (Inconclusive)	indeterminable	Probab.	0.3825		0.1569	0.2903	0.1893	0.8081																																						
4. Variables in LN and time Variable at an Observed Value	Coef.	198.61	0.0351	0.7443	1.8857	-0.056527		-0.104534	0.693853	2.719683 (0.127609)	1.042 (Inconclusive)	--																																																																																																																																																																																								
	Probab.	0.601	0.9716	0.2218	0.5145	0.9847		0.6046					5. Variables in LN and Time Variable at Observed Value and Exclusion of PTind	Coef.	205.255	0.0214	0.7446	1.9341			-0.108077	0.6938	3.965824 (0.05444)	1.0406 (Inconclusive)	--	Probab.	0.1513	0.9727	0.1842	0.1383			0.1482	6. Data in LN and inclusion of Lagged Dependent Variable	Coef.	-2.5931	1.5842	-0.2966	0.5925	-1.1356	0.7436		0.789	4.489419 (0.0476)	2.109 (Inconclusive)	-0.171	Probab.	0.52	0.0897	0.6816	0.1588	0.2558	0.1267		7. Variables in LN, inclusion of Lagged Dependent Variable and exclusion of the	Coef.	-6.0645	1.838	-0.8201	0.4227		0.8598		0.7336	4.819372 (0.0348)	2.0296 (Inconclusive)	-0.0464	Probab.	0.0601	0.0524	0.1935	0.2744		0.0832		8. Explanatory Variables and the Lagged Variable in LN	Coef.	-31.2022	12.5785	-3.5849	5.5891	-8.2916	6.0578		0.7743	4.11564 (0.0572)	2.02116 (Inconclusive)	indeterminable	Probab.	0.336	0.0872	0.5323	0.1018	0.2876	0.1159		9. Explanatory Variables and the Lagged Dependent Variable in LN (variable dependent on observed value) and exclusion of the Pagr/Pind	Coef.	-12.9096	9.1633		4.9761	-11.14132	4.3565		0.7577	5.473615 (0.02556)	1.7243 (Inconclusive)	indeterminable	Probab.	0.273	0.0253		0.1005	0.0791	0.0641		10. Explanatory Variables and Lagged Dependent Variable in LN (variable dependent on observed value) and exclusion of the Prec/Ppag	Coef.	18.9943		5.66145	3.8055	-12.0328	0.5838		0.6174	2.823904 (0.1095)	1.5692 (Inconclusive)	indeterminable	Probab.	0.3825		0.1569	0.2903	0.1893	0.8081																																																											
5. Variables in LN and Time Variable at Observed Value and Exclusion of PTind	Coef.	205.255	0.0214	0.7446	1.9341			-0.108077	0.6938	3.965824 (0.05444)	1.0406 (Inconclusive)	--																																																																																																																																																																																								
	Probab.	0.1513	0.9727	0.1842	0.1383			0.1482					6. Data in LN and inclusion of Lagged Dependent Variable	Coef.	-2.5931	1.5842	-0.2966	0.5925	-1.1356	0.7436		0.789	4.489419 (0.0476)	2.109 (Inconclusive)	-0.171	Probab.	0.52	0.0897	0.6816	0.1588	0.2558	0.1267		7. Variables in LN, inclusion of Lagged Dependent Variable and exclusion of the	Coef.	-6.0645	1.838	-0.8201	0.4227		0.8598		0.7336	4.819372 (0.0348)	2.0296 (Inconclusive)	-0.0464	Probab.	0.0601	0.0524	0.1935	0.2744		0.0832		8. Explanatory Variables and the Lagged Variable in LN	Coef.	-31.2022	12.5785	-3.5849	5.5891	-8.2916	6.0578		0.7743	4.11564 (0.0572)	2.02116 (Inconclusive)	indeterminable	Probab.	0.336	0.0872	0.5323	0.1018	0.2876	0.1159		9. Explanatory Variables and the Lagged Dependent Variable in LN (variable dependent on observed value) and exclusion of the Pagr/Pind	Coef.	-12.9096	9.1633		4.9761	-11.14132	4.3565		0.7577	5.473615 (0.02556)	1.7243 (Inconclusive)	indeterminable	Probab.	0.273	0.0253		0.1005	0.0791	0.0641		10. Explanatory Variables and Lagged Dependent Variable in LN (variable dependent on observed value) and exclusion of the Prec/Ppag	Coef.	18.9943		5.66145	3.8055	-12.0328	0.5838		0.6174	2.823904 (0.1095)	1.5692 (Inconclusive)	indeterminable	Probab.	0.3825		0.1569	0.2903	0.1893	0.8081																																																																																
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Source: elaborated by the authors.