Regional Brazilian Agriculture TFP Analysis: A Stochastic Frontier Analysis Approach

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Abstract: This paper investigates the evolution of agricultural sector total factor productivity (TFP) in each of Brazil’s 27 states from 1975 to 2006 and analyzes the effect of TFP on regional agriculture’s economic growth over that period. TFP was calculated using a translog panel data estimation of a stochastic frontier analysis model. The TFP effect was subdivided into technical progress, allocative alterations, scale effects, technical efficiency and random shocks. Agricultural economic growth was subdivided into change in capital stock, labor, harvested land hectarage, and TFP. Results suggest that over recent decades, TFP growth was not homogeneous among the Brazilian states and that technical progress was essential to the growth of agricultural production at the state level.

Key words: Brazilian agriculture, total factor productivity, economic growth

Resumo: Este trabalho estimou a produtividade total dos fatores (PTF) para a agricultura brasileira por meio de uma função translog com dados em painel, utilizando um modelo de fronteira estocástica. O principal objetivo foi investigar a evolução da PTF no período 1975-2006 nos estados brasileiros e no Distrito Federal e analisar a influência da PTF sobre o crescimento econômico da agricultura. O efeito da PTF foi subdividido em progresso técnico, eficiência alocativa, efeito escala, ineficiência técnica e choques aleatórios. As conclusões apontaram que o crescimento da PTF não foi homogêneo entre os estados e que o progresso técnico foi fundamental para expandir o potencial de crescimento da agricultura brasileira.

Palavras chave: agricultura brasileira, produtividade total dos fatores, crescimento econômico

Área 10 - Economia Agrícola e do Meio Ambiente

JEL classification: Q10, Q19, O47

1. Introduction

Historically, the agricultural sector – including farming input, farming output, agro-industries, and distribution – has had a significant role in the Brazilian economy[1], not only by keeping domestic food prices relatively low but also by attracting significant amounts of foreign currency investment.

In 1994, seeking to end a period of hyperinflation, Brazil’s government created the “*Plano Real*,” a monetary plan for economic stabilization. The *Plano Real* used two price anchors to dampen inflation: high actual interest rates and an overvalued exchange rate. Economists informally consider that the plan used three anchors, with the third being Brazil’s agricultural sector, the “green anchor:”. At the time, Brazilian agricultural production was growing rapidly as was international demand for agricultural products. It was thought that this rising agricultural production would keep inflation in check by keeping domestic food prices low. Despite the success of the monetary stabilization plan, overall Brazilian economic growth in the 1990s was very low.

[1] The agribusiness sector (that includes the agricultural and livestock activities, and factories, stocking, transportation, processing, industrialization and logistics) accounts for roughly 25% of the Brazilian GDP and approximately 40% of all Brazilian exports.

From 1990 to 2000, Brazilian average annual GDP growth measured in the local currency (*Reais*) was 1.9% while Brazilian average annual agricultural GDP growth was 3.1%. These figures and the fact that Brazilian prices stabilized over the 1990s confirm the importance of Brazil's agricultural sector in the country's economy, both as a inflation control mechanism and as a major contributing factor to economic growth.

Figure 1 illustrates the evolution of total Brazilian GDP and Brazilian agricultural GDP from 1980 to 2008. The Figure shows that Brazilian GDP's average annual growth rate over the period was 2.8% while the country's agricultural sector's growth rate averaged 3.8%.

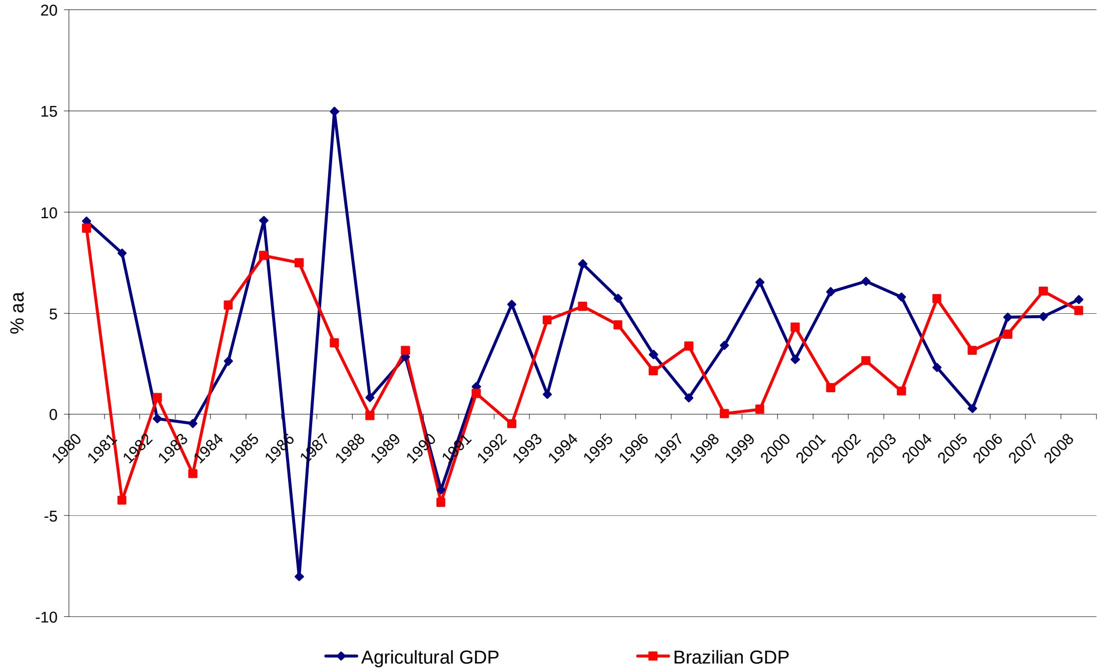

Figure 1. The evolution of Brazilian Total GDP and Brazilian Agricultural GDP – real percentage variation – 1980 to 2008
Source: IPEA (www.ipeadata.gov.br)

Results from an analysis by Barros et al. (2006) of the dynamic effects of supply and demand shocks on Brazilian agriculture suggest that Brazil's integration with external markets was important to continuous agricultural sector modernization. The authors proposed a theoretical model based on Blanchard and Quah (1989) that associated productivity with supply shocks. Their econometric model used the well-known Bernanke procedure for Structural Vector Auto Regression (SVAR) to estimate the shocks. Their estimations were that between 50% and 60% of the agricultural output forecast variance is due to productivity shocks and 20% of agricultural prices forecast variance is due to crop yield shocks.

Bonelli and Fonseca (1998) estimated Brazilian agricultural TFP from 1971 and 1996. They found that between 1979 and 1984 the annual agricultural TFP growth rate was 4.5 to 5%, with the exception of a near zero rate in 1982 and that from 1990 to 1996, the growth rate was always positive, although less than 5% per year. They also discerned three years of strong reduction in the annual TFP growth rate: 1978, 1986 and 1988[2]. Based on research carried out by Gasques and Conceição (1997), we updated Brazilian agricultural TFP to the end of 2005 and found that there have been no relevant changes in the behavior of the data.

Gasques et al. (2009) used the Tornqvist index to build a TFP historical series of Brazil's agricultural sector from 1975 to 2008 (Figure 2). Their results show strong TFP growth (244%) over the period, which led to robust growth in agricultural production. This TFP growth, according to the authors, resulted from implementation of a rural credit policy and investment by both universities and the Brazilian Agricultural Research Corporation (Embrapa) in research to develop new technologies.

[2] Brazil's agricultural GDP fell 8% In 1986,

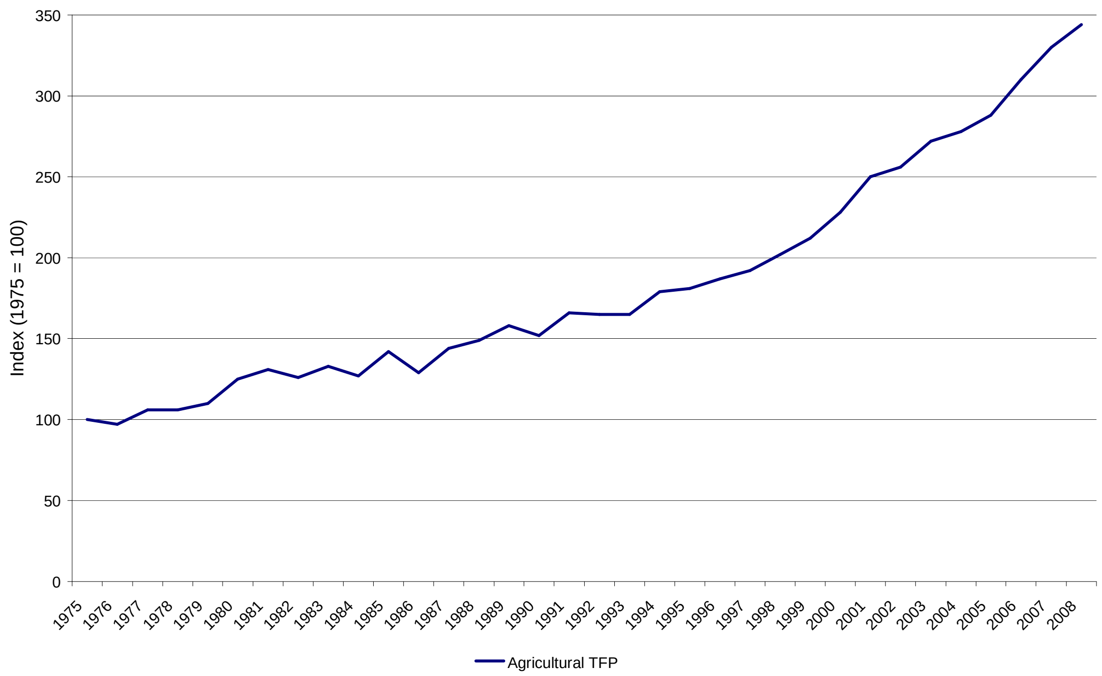

Figure 2. The Evolution of Brazilian Agriculture TFP – Index (1975 = 100) – 1975 to 2008.

Sources: Gasques et al. (2009)

Our paper presents results from a stochastic frontier analysis of the determinants of Brazilian agricultural TFP at the individual state level. As this analysis is the first to use stochastic frontier methodology to decompose components of economic growth in the Brazilian agriculture sector and the first to take the analysis to the state level, it adds new data to help explain Brazil's agricultural economy.

The next section, Section 2, contains a brief review of some literature relevant to the evolution of Brazilian agriculture. Section 3 presents the methodology, data and sample used in this study. Results are presented in Section 4, and our conclusions are given in Section 5.

2. Literature Review

Technological innovations throughout the 20th Century have allowed agricultural production to grow more rapidly than demand. This was first witnessed in the developed world and is now found in many developing countries (Antle, 1999). Technological innovation models applied to the agricultural sector fall into four general categories: models that address the (1) generation and dissemination of a technology, (2) the importance of product or process innovations, (3) the magnitude of a technology's impact of on productivity, (4) and the compatibility of the technological package with the product or its production (Bacha, 1992).

As opposed to many other economic sectors, agriculture's share in an economy trends downward over time; however, an analysis by Johnston and Mellor (1961) found that there is not a dichotomy between agriculture and other economic sectors. This downward trend is a consequence of increasing agricultural productivity. which also acts to generate capital for the expansion of other sectors. According to the authors, changes in an economy caused by agriculture stem from two basic factors: (1) the demand for food has an income elasticity less than unity; and (2) productivity gains in the agriculture sector make it possible to expand production using less labor.

Brazilian agricultural sector performance after World War II was influenced by the government's decision to stimulate production through the creation of public policy instruments intended to make abundant credit available, support prices, and ease storage constraints. Between the war's end and 1965, these Brazilian policy instruments consisted of just the National Council of Coffee (CNC) and the ineffective Guaranteed Minimum Price Policy (PGPM).

Brazil's agriculture modernization era began in 1965 with creation of the National Rural Credit System (SNCR) and reformulation of PGPM (Coelho, 2001). Both SNCR and the reformulated PGPM offered agricultural sector subsidies intended to expand the agricultural frontier and increase the grain production (Coelho, 2001). This governmental focus on agriculture ensured fast growth in the sector through the extensive use of land and constant productivity. The government's programs and, in some cases, foreign investment spurred rapid occupation of parts of Brazil's Central-West. Figure 1 illustrates the expansion of Brazilian territory devoted to agriculture and the associated growth in agricultural production between 1967 to 2008.

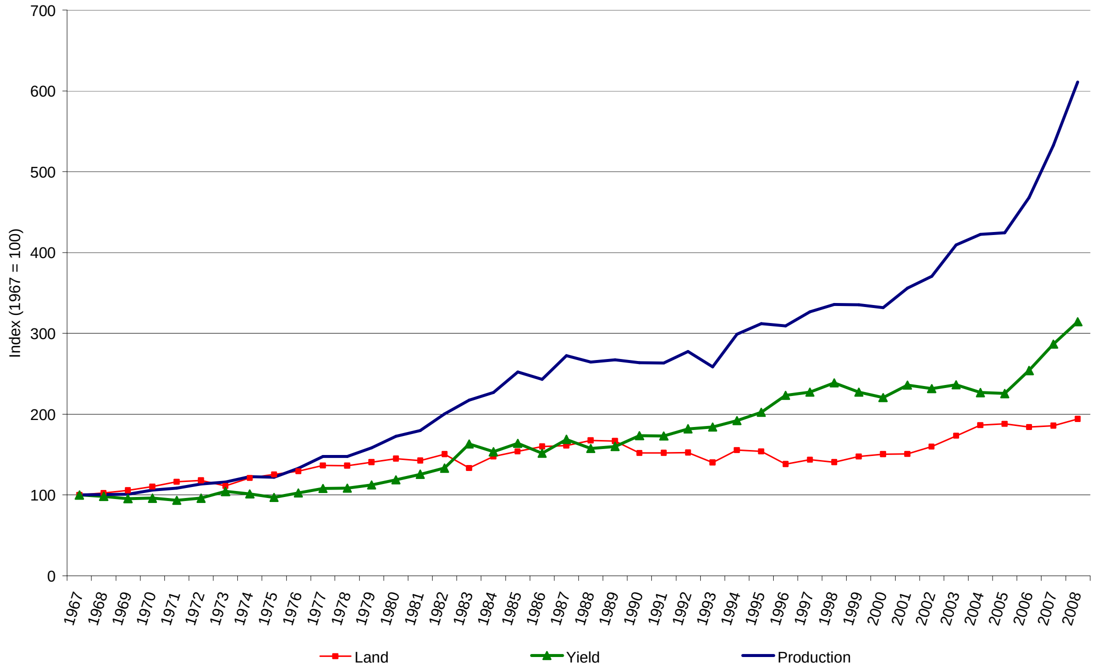

Figure 3. Agricultural hectarage, Yield, and Output Index (1967 = 100); Brazil, 1967-2008.
Source: IBGE, and elaboration of the authors

There was a change in the focus of Brazil's agricultural policies after the 1973 international oil crisis (Barros, 1979). Although the post-crisis policy instruments themselves remained unchanged, the amount of subsidization increased considerably. Barros (1979) highlights six consequences of this change in agricultural policies and guidelines:

1. Long-run policies to stimulate investment in the agricultural sector, especially infrastructure investment, were marginalized;
2. Such modernization that occurred in the agriculture sector was concentrated in only a few products and regions;
3. The agricultural sector was segmented into two sub-sectors: the internal market and the export market;
4. An increase in Brazilian agricultural product exportation, abetted by more openness and favorable conditions in the international market;
5. Pressure to increase food production;
6. Failure of the agricultural credit policy in terms of efficiency, equity and stability.

Alves and Contini (1988) concluded that Brazilian agriculture sector growth in the 1980s was greatly influenced by two factors other than labor and natural resource availability: (a) modernization, driven by technological innovation; and (b) adaptation to the demand stimulus provided by Brazil's more industrialized economy and growing urban population. To meet this new demand, the agricultural frontier had to expand. From the mid 70s to the mid 80s, Brazilian agricultural policy was reshaped to stimulate both frontier expansion and land productivity, which led to the liberalization of rural credit through use of a subsidized interest rate, the modernization of agricultural inputs and the agribusiness model, a reorganization of the national research and development system, and the expansion of rural support services (Alves & Contini,1988).

Gasques and Conceição (2001) analyzed the structural transformation of Brazilian agriculture over past decades and note that the main features of this transformation follow an almost worldwide trend: a declining share of agriculture in the gross domestic product (GDP) and a decrease in the percentage of workers occupied in the rural labor force. The authors also estimated that Brazilian agricultural production growth was greatly influenced by an increase in total factor productivity between 1985 and 1995 (Gasques and Conceição, 2001).

From 1976 to 1994 Brazil's agricultural total productivity index increased 91.56%, with labor productivity being the main factor driving this increase; although, increased land productivity made an important contribution (Gasques and Conceição, 1997). Table 1 shows the growth rate of Brazilian agricultural GDP, TFP, labor, land, capital, and inputs between 1975 and 2008 and for sub-periods within that period. TFP growth was found to be very strong over the entire period and for the sub-periods, especially from 2000 to 2008. Between 2000 and 2008, the TFP growth rate reached 4.98 % and was the most important variable explaining agricultural GDP performance, according to Gasques et al. (2009).

Table 1. Growth Rate of Brazilian Agricultural GDP, Labor, Land, Capital, Inputs and TFP – 1975 to 2008 and sub-periods.

Period	1975-2008	1980-1989	1990-1999	2000-2008
Labor	-0.40	1.22	-0.49	-0.08
Land	0.12	0.46	-0.23	0.44
Capital	0.30	0.53	0.03	0.79
Inputs	0.01	1.11	-0.35	0.58
TFP	3.66	2.25	3.37	4.98
GDP Growth	3.68	3.38	3.01	5.59

Sources: Gasques et al. (2009)

In 1990, the inauguration of a new Brazilian government and domestic macroeconomic turbulence reduced investment in Brazil's agricultural sector. That year, the volume of SNCR credit fell from the previous year in real terms while the public sector fiscal imbalance, having reached a maximum point of inefficiency, was distorting and constraining development in various economic sectors. It was thought that the credit subsidies still awarded would act as a compensatory variable to counteract these macroeconomic distortions' effect on agriculture; but due to the concentrated distribution of this assistance, its benefit was minimized (Barros, 1991).

Overall public expenditure on agriculture was reduced in the 1990s. Gasques and Villa Verde (2003) found that by 2000/2001, changes in agricultural policy had reduced governmental expenditures on agriculture to the lowest levels in fifteen years. Homem de Melo (1998) argues that the increase in agricultural productivity over the 1990s may be considered as compensation for an unfavorable macroeconomic environment, an environment that included high interest rates and an overvalued currency.

Using the growth accounting method, Bonelli and Fonseca (1998) estimated the TFP of Brazilian agriculture from 1971 to 1996. Their results showed that Brazilian agricultural TFP grew 25% from 1988 to 1996. Gasques et al. (2004) found that the annual growth rate of Brazilian agricultural TFP was 4.88% per year in the 1990s and 6.04% per year at the beginning of the 2000s. O´Donnel (2009) estimated that the annual rate of technical progress in global agriculture is less than 1%. Weiping and Ying (2007) investigated the sources of TFP in Chinese agriculture from 1985 to 2003 and found TFP growth was slowing for all products other than wheat. Some of the main studies of agricultural productivity across countries and regions include those of Hayami and Ruttan (1970, 1971), Kawagoe and Hayami (1983, 1985), Kawagoe, Hayami and Huttan (1985), Lau and Yotopoulos (1989), Capalbo and Antle (1988), Bureau et. al (1995) e Fulgini and Perrin (1993, 1997), Boskin and Lau (1992), Rao (1993), Battese and

Rao(2001) and Battese , Rao and Walujadi (2001), and Bravo-Ortega and Lederman (2004). Bravo-Ortega and Lederman's (2004) report of the agricultural TFP growth for a selected sample of countries is the main source of data shown in Table 2.

Table 2 shows the TFP growth rate for several countries but is impaired because the periods over which growth was measured were not the same for all countries. Over the longest period, 1960 to 2000, Brazil's TFP growth rate was only surpassed by that of Australia, the United States and India. Brazil's TFP growth rate of 4.98% in the 2000 - 2008 period was the highest TFP growth for any country over any period, followed by Brazil's rate for the 1975 - 2008 period and China's rate for the 2000 - 2006 period.

Table 2. TFP Growth Rate of Selected Countries

Country	Period	TFP Growth	Reference	Method
Argentina	1960-2000	1.84	Bravo-Ortega and Lederman (2004)	Panel data Translog estimation
Bolivia	1960-2000	1.18	Bravo-Ortega and Lederman (2004)	Panel data Translog estimation
Brazil	1960-2000	1.93	Bravo-Ortega and Lederman (2004)	Panel data Translog estimation
Brazil	1975-2008	3.66	Gasques et al (2009)	Tornqvist index
Brazil	2000-2008	4.98	Gasques et al (2009)	Tornqvist index
Chile	1960-2000	1.20	Bravo-Ortega and Lederman (2004)	Panel data Translog estimation
Colombia	1960-2000	1.43	Bravo-Ortega and Lederman (2004)	Panel data Translog estimation
Cuba	1960-2000	1.17	Bravo-Ortega and Lederman (2004)	Panel data Translog estimation
Ecuador	1960-2000	1.28	Bravo-Ortega and Lederman (2004)	Panel data Translog estimation
El Salvador	1960-2000	0.53	Bravo-Ortega and Lederman (2004)	Panel data Translog estimation
Guatemala	1960-2000	0.79	Bravo-Ortega and Lederman (2004)	Panel data Translog estimation
Haiti	1960-2000	0.97	Bravo-Ortega and Lederman (2004)	Panel data Translog estimation
Honduras	1960-2000	0.78	Bravo-Ortega and Lederman (2004)	Panel data Translog estimation
Mexico	1960-2000	1.85	Bravo-Ortega and Lederman (2004)	Panel data Translog estimation
Nicaragua	1960-2000	0.79	Bravo-Ortega and Lederman (2004)	Panel data Translog estimation
Paraguay	1960-2000	0.74	Bravo-Ortega and Lederman (2004)	Panel data Translog estimation
Peru	1960-2000	1.36	Bravo-Ortega and Lederman (2004)	Panel data Translog estimation
Venezuela	1960-2000	1.35	Bravo-Ortega and Lederman (2004)	Panel data Translog estimation

Table 2. TFP Growth Rate of Selected Countries (continued)

Australia	1960-2000	2.12	Bravo-Ortega and Lederman (2004)	Panel data Translog estimation
Austria	1960-2000	0.69	Bravo-Ortega and Lederman (2004)	Panel data Translog estimation
Canada	1960-2000	1.23	Bravo-Ortega and Lederman (2004)	Panel data Translog estimation
Denmark	1960-2000	0.66	Bravo-Ortega and Lederman (2004)	Panel data Translog estimation
Finland	1960-2000	0.25	Bravo-Ortega and Lederman (2004)	Panel data Translog estimation
France	1960-2000	1.77	Bravo-Ortega and Lederman (2004)	Panel data Translog estimation
Germany	1960-2000	1.39	Bravo-Ortega and Lederman (2004)	Panel data Translog estimation
Greece	1960-2000	1.62	Bravo-Ortega and Lederman (2004)	Panel data Translog estimation
Ireland	1960-2000	0.72	Bravo-Ortega and Lederman (2004)	Panel data Translog estimation
Italy	1960-2000	1.73	Bravo-Ortega and Lederman (2004)	Panel data Translog estimation
Japan	1960-2000	1.40	Bravo-Ortega and Lederman (2004)	Panel data Translog estimation
Netherlands	1960-2000	1.16	Bravo-Ortega and Lederman (2004)	Panel data Translog estimation
Portugal	1960-2000	1.41	Bravo-Ortega and Lederman (2004)	Panel data Translog estimation
Spain	1960-2000	1.89	Bravo-Ortega and Lederman (2004)	Panel data Translog estimation
United Kingdom	1960-2000	1.67	Bravo-Ortega and Lederman (2004)	Panel data Translog estimation
United States	1975-2006	1.95	Gasques et al (2009) apud USDA (2007)	-
United States	1960-2000	2.11	Bravo-Ortega and Lederman (2004)	Panel data Translog estimation
China	1960-2000	1.67	Bravo-Ortega and Lederman (2004)	Panel data Translog estimation
China	2000-2006	3.20	Gasques et al (2009) apud OCDE (2009)	-
India	1960-2000	1.98	Bravo-Ortega and Lederman (2004)	Panel data Translog estimation
Papua New Guinea	1960-2000	-0.36	Bravo-Ortega and Lederman (2004)	Panel data Translog estimation
Sierra Leone	1960-2000	-0.18	Bravo-Ortega and Lederman (2004)	Panel data Translog estimation
South Africa	1960-2000	1.64	Bravo-Ortega and Lederman (2004)	Panel data Translog estimation
Zambia	1960-2000	-0.26	Bravo-Ortega and Lederman (2004)	Panel data Translog estimation

Source: Gasques et al. (2009) and Bravo-Ortega and Lederman (2004).

Over the current decade, Brazilian agriculture has been benefited by vigorous TFP growth, improvement in the global economy, especially in the emerging countries, and an increase in global commodity prices, which offset the Brazilian currency's overvaluation. Between 2004 and 2008, the Brazilian effective exchange rate became 27% overvalued while the CRB[3] index increased approximately 147%.

3. Methodology

Section 3 presents the stochastic frontier model used in this study. The model is based on research carried out by Pires and Garcia (2004) and their references to Battese and Coelli (1992), Bauer (1990), and Kumbhakar (2000). Our study is intended to is provide multi-year data on various components of economic growth in the Brazilian agriculture sector decomposed at the state level, not to propose new methodology.

Following Pires and Garcia (2004), we assume that Brazilian agriculture has a stochastic frontier described by equation (1):

$$y = f(t, x, \beta) \cdot \exp(v) \cdot \exp(-u) \qquad (1)$$

Where:

$y =$ the vector for the agricultural product of all Brazilian states;

$x =$ the vector for the production factor (labor, capital and land);

$\beta =$ the vector of parameters;

$v, u =$ terms that represent different error components, assuming that $v \sim N(0, \sigma^2)$ and $u \sim N(\mu, \sigma_u^2)$, then, the distribution of u is normal-truncated.

In regards to vectors v and u, Pires and Garcia (2004) explain that:

"The first refers to the random part of the error, while the second represents technical inefficiency, i.e., the part that is a downward deviation from the production frontier (which can be inferred by the negative sign and the restriction $u \geq 0$ *" (p. 4)*

This two errors approach was proposed independently by Aigner, Lovell and Schmidt (1977) and Meeusen and van den Broeck (1977).

Battese and Coelli (1992) formulated a parametrization that Pires and Garcia (2004) assumed to take the technical efficiency component as a time-variant, then:

$$u_{it} = \exp[-\eta(t - T)] \cdot u_i \qquad u_{it} \geq 0 \quad i = 1, \ldots, N \text{ and } t \in \tau(i) \qquad (2)$$

Where η signals the behavior of technical efficiency over the time, and $\tau(i)$ contains all periods in the panel. The model admits a *translog* function that has two production factors, labor (L), capital (K) and land (T), as shown in the equation (4).

$$\ln y_{it} = \beta_0 + \beta_1 \cdot t + \beta_k \cdot \ln K_{it} + \beta_L \cdot \ln L_{it} + \beta_T \cdot \ln T_{it} + \frac{1}{2} \cdot \beta_{tt} \cdot t^2 + \frac{1}{2} \cdot \beta_{KK} (\ln K_{it})^2 + \frac{1}{2} \cdot \beta_{LL} (\ln L_{it})^2 +$$
$$\frac{1}{2} \cdot \beta_{TT} \cdot (\ln T_{it})^2 + \frac{1}{2} \cdot \beta_{KL} (\ln K_{it}) \cdot (\ln L_{it}) + \frac{1}{2} \cdot \beta_{TK} (\ln K_{it}) \cdot (\ln T_{it}) + \frac{1}{2} \cdot \beta_{TL} (\ln T_{it}) \cdot (\ln L_{it}) + \beta_{Kt} [(\ln K_{it}) \cdot t] + \qquad (4)$$
$$\beta_{Lt} [(\ln L_{it}) \cdot t] + \beta_{Tt} [(\ln T_{it}) \cdot t] + v_{it} + u_{it}$$

The technical progress is expressed by the differentiation of equation (2):

$$\frac{\dot{y}}{y} = \frac{\partial \ln f(t, K, L, T, \beta)}{\partial t} + \varepsilon_K \cdot \frac{\dot{K}}{K} + \varepsilon_L \cdot \frac{\dot{L}}{L} + \varepsilon_T \cdot \frac{\dot{T}}{T} - \frac{\partial u}{\partial t} \qquad (5)$$

Considering that RTS is the returns to scale, $RTS = \varepsilon_K + \varepsilon_L + \varepsilon_T$, and ε_K, ε_L and ε_T are output elasticities, and:

$$\lambda_k = \frac{\varepsilon_K}{RTS}, \ \lambda_L = \frac{\varepsilon_L}{RTS}, \ \lambda_T = \frac{\varepsilon_T}{RTS} \qquad (6)$$

[3] calculated by the Commodity Research Bureau

Pires and Garcia (2004) present the Divisia index as in the equation (7)[4]:

$$g_{PTF} = \frac{\dot{y}}{y} - s_k \frac{\dot{K}}{K} - s_L \cdot \frac{\dot{L}}{L} - s_T \cdot \frac{\dot{T}}{T} \qquad (8)$$

The authors also show that, after the estimation of equation (4) and the algebraic manipulation of (5), (6) and (7), we can find the change rate in total factor productivity:

$$g_{PTF} = TP - \dot{u} + (RTS - 1) \cdot [\lambda_K \cdot g_K + \lambda_L \cdot g_L + \lambda_T \cdot g_T] + [(\lambda_k - s_K) \cdot g_K + (\lambda_L - s_L) \cdot g_L + (\lambda_T - s_T) \cdot g_T] \qquad (9)$$

Where:

TP $= \frac{\partial \ln f(t, K, L, T, \beta)}{\partial t}$ is the technical progress;

$\dot{u}$ = change in the technical efficiency;

$(RTS - 1) \cdot [\lambda_K \cdot g_K + \lambda_L \cdot g_L + \lambda_T \cdot g_T]$ = change in the scale of production;

$[(\lambda_k - s_K) \cdot g_K + (\lambda_L - s_L) \cdot g_L + (\lambda_T - s_T) \cdot g_T]$ = change in allocative efficiency.

3.1 Data and Sample

This paper's basic data sources are the Brazilian Rural Statistical Yearbook and the Brazilian Agricultural Census, both published by the Brazilian Institute of Geographic and Statistics (IBGE). During the period under study, the decennial Census was published in only 1975, 1985, 1995 and 2006[5]. All information concerning capital stock, labor, land, and each production factor's respective share of income was obtained from the Brazilian Agricultural Census. GDP figures were taken from the Brazilian Rural Statistical Yearbook. We used data taken at the city level when possible. Brazil has 27 states and 5,564 cities. Thirty cities were disregarded because at least one piece of necessary information was missing. The final sample was formed by 5,534 cities. Economic growth in states that did not exist in 1975 was estimated using aggregated data from cities within the newly formed states' boundaries.

The capital stock variable used in this paper is the total number of properties held by farmers (which include rural constructions and buildings, equipment, machinery and lands). Labor force data refers to people employed in agriculture. Land use data refers to the harvested area expressed in hectares.

To calculate the portion of product derived from each production factor, the following variables were used: investment in rural constructions and buildings, equipment, machinery comprised the capital stock portion, investments in land comprised the land portion, and salaries paid comprised the labor portion. As all these data were not available at the city level, we were often forced to use data at the state level.

Both capital stock and GDP were deflated by the IBGE's implicit GDP deflator expressed in *Reais* (R$ - prices of 2000). The data were organized in a panel model to estimate equation (4) using *Stata/SE® 10.0* software, and the results were then used to decompose the local (cities) agricultural TFP. Results for each Brazilian state[6] are derived by following equation (9). Results are presented in Section 4.

[4] The terms s_K and s_L are the share of capital and labor in income, respectively.

[5] The last edition of the Brazilian Agricultural Census was published 1 year later than normal.

[6] Results for the agricultural TFP at a state level is a weighted average (based on the local GDP share on the state share) of the local agricultural TFP.

4. Results and Discussion

For models estimated by maximum likelihood, Greene (2003) suggests a Likelihood Ratio Test (LR). The objective is to test the complete model, represented by equation (4), and the restricted models (see: following paragraph). The null hypothesis, shown in Table 3, is that the column-model is contained in the line-model. According to Greene (2003, p. 491), if the computed value is larger than the critical value, the null hypothesis cannot be rejected.

The restricted models were defined in accordance with Jones (2000): for a Cobb-Douglas function with technological variables like $Y = f(K, AL)$, the technology is "Harrod neutral"; other possibilities are $Y = f(A \cdot K, L)$ and the technology is "Solow neutral," or $Y = A \cdot f(K, L)$ and the technology is "Hicks neutral". Table 3 shows the results for the likelihood ratio tests. The full translog model, represented by equation (4), was selected as the most appropriated model.

Table 3. Likelihood ratio tests results

Model	Full translog	Harrod neutral	Solow neutral	Hicks neutral	Translog TP[1]	Cobb-Douglas[2]	Cobb-DouglasTP[3]
Full translog	-	280,62 $\chi^2(1)$	827,15 $\chi^2(1)$	1361,80 $\chi^2(2)$	1695,08 $\chi^2(5)$	2283,51 $\chi^2(10)$	2386,10 $\chi^2(11)$
Harrod neutral	-	-	NC[4]	1081,18 $\chi^2(1)$	1414,41 $\chi^2(4)$	2002,89 $\chi^2(9)$	2105,48 $\chi^2(10)$
Solow neutral	-	-	-	534,65 $\chi^2(1)$	867,92 $\chi^2(4)$	1456,36 $\chi^2(9)$	1558,95 $\chi^2(10)$
Hicks neutral	-	-	-	-	332,28 $\chi^2(3)$	921,71 $\chi^2(8)$	1024,30 $\chi^2(9)$
Translog TP[1]	-	-	-	-	-	NC[4]	691,02 $\chi^2(6)$
Cobb-Douglas[2]	-	-	-	-	-	-	102,59 $\chi^2(1)$
Cobb-DouglasTP[3]	-	-	-	-	-	-	-

[1] Translog function without technical progress;
[2] Cobb-Douglas function with technical progress;
[3] Cobb-Douglas function without technical progress.
[4] The likelihood ratio test is not applicable.
Source: The authors

Results shown in Table 4 are all statically significant at 1% except for coefficient β_{KL}. The negative signs of coefficients β_{kt} and β_{Lt} mean that the non-neutral part of technical progress is labor and capital saving; on the other hand, technical progress increases as the amount of land harvested increases ($\beta_{Tt} > 0$), which means that technical progress is more intense in states with a large supply of fallow land that can be opened to agriculture.

Table 4. Time-variant efficiency model results

Number of observations: 18,325						
Log likelihood = -15,919.244 Prob > χ^2 = 0.0000						
Lny	**Coefficients**	**Standard Errors**	**z**	**P>|z|**	**[95% Conf. Interval]**	
β_t	1.250237	0.045885	27.25	0.000	1.160304	1.340169
β_k	0.275491	0.041972	6.56	0.000	0.193228	0.357755
β_L	0.597959	0.033017	18.11	0.000	0.533247	0.662671
β_T	-0.31893	0.03744	-8.52	0.000	-0.39231	-0.245550
β_{tt}	0.029552	0.012192	2.42	0.015	0.005655	0.053448
β_{kk}	0.020684	0.004618	4.48	0.000	0.011633	0.029734
β_{LL}	0.010366	0.003222	3.22	0.001	0.00405	0.016681
β_{TT}	0.050691	0.004473	11.33	0.000	0.041924	0.059458
β_{KL}	-0.00198	0.006004	-0.33	0.741	-0.01375	0.009783
β_{TK}	-0.0347	0.005196	-6.68	0.000	-0.04489	-0.024520
β_{TL}	0.011571	0.00695	1.67	0.096	-0.00205	0.025192
β_{kt}	-0.05913	0.003531	-16.75	0.000	-0.06605	-0.052210
β_{Lt}	-0.12301	0.004249	-28.95	0.000	-0.13134	-0.114680
β_{Tt}	0.070116	0.003976	17.64	0.000	0.062324	0.077908
β_0	1.584759	0.309937	5.11	0.000	0.977294	2.192223
μ	1.70578	0.119855	14.23	0.000	1.470869	1.940691
η	-0.25224	0.012781	-19.74	0.000	-0.2773	-0.227190
$\ln\sigma^2$	-0.75538	0.017713	-42.65	0.000	-0.7901	-0.720670
ilgt γ	-0.08194	0.042326	-1.94	0.053	-0.1649	0.001020
σ^2	0.469831	0.008322	-	-	0.4538	0.486429
γ	0.479527	0.010564	-	-	0.458869	0.500255
σ_u^2	0.225297	0.008466	-	-	0.208705	0.241889
σ_v^2	0.244534	0.003104	-	-	0.238451	0.250618

Source: The authors

Results from the estimated model allowed decomposition of agricultural TFP and agricultural economic growth indicators for the 27 Brazilian states are listed in Table 5. The general average of all factors for the 27 states is consistent with results from other Brazilian agricultural TFP research, such as Gasques et al. (2009). For example, Gasques et al. (2009) estimated TFP growth of 3.66% for the 1975-2008 period while the average TFP growth estimated by our model is 3.1%. Our estimations of the changes in capital accumulation, harvested hectarage, and agricultural labor force are also similar to results from other studies.

Table 5. Results of agricultural TFP decomposition for the Brazilian States.

State	Agricultural economic growth	Capital accumulation	Change in agricultural labor force	Change harvested area	Change in TFP	Change in TFP: Technical progress	Change in TFP: Technical efficiency	Change in TFP: Scale effects	Change in TFP: Allocative efficiency	Random shocks
Rondônia	1.2%	0.5%	-1.9%	-1.9%	8.3%	9.7%	-2.8%	-0.8%	2.1%	-3.7%
Acre	3.8%	2.8%	-1.6%	0.7%	6.4%	5.7%	-2.0%	1.0%	1.6%	-4.5%
Amazonas	6.0%	1.3%	-2.0%	3.1%	9.9%	7.1%	-1.4%	1.4%	2.8%	-6.3%
Roraima	0.5%	-0.2%	-1.0%	2.0%	10.3%	10.2%	-2.3%	0.3%	2.0%	-10.8%
Pará	3.4%	3.9%	-0.9%	0.9%	6.1%	5.8%	-2.3%	1.7%	0.8%	-6.6%
Amapá	2.2%	3.1%	-1.8%	3.4%	11.2%	6.7%	-2.0%	2.1%	4.4%	-13.6%
Tocantins	5.7%	3.4%	-1.4%	1.2%	2.9%	2.5%	-3.0%	2.2%	1.2%	-0.4%
Maranhão	1.7%	2.1%	-1.1%	-0.4%	3.3%	3.9%	-2.3%	0.8%	0.9%	-2.3%
Piauí	1.8%	1.4%	-0.5%	0.5%	1.5%	3.1%	-3.3%	1.0%	0.7%	-1.1%
Ceará	1.4%	1.1%	-0.5%	-1.2%	1.0%	2.5%	-2.8%	0.4%	0.9%	1.1%
Rio Grande do Norte	2.3%	1.1%	-1.3%	-2.0%	-0.9%	2.3%	-3.1%	0.0%	-0.1%	5.5%
Paraíba	0.2%	-0.2%	-1.5%	-1.6%	0.0%	3.2%	-3.2%	-0.7%	0.6%	3.6%
Pernambuco	0.9%	0.2%	-1.1%	-0.8%	1.2%	3.4%	-2.6%	-0.1%	0.5%	1.4%
Alagoas	0.7%	1.5%	-1.0%	-0.2%	0.4%	3.4%	-2.9%	0.5%	-0.6%	0.0%
Sergipe	1.7%	0.7%	-0.9%	0.5%	1.5%	4.0%	-3.3%	0.3%	0.5%	-0.1%
Bahia	3.1%	2.4%	-0.6%	1.4%	3.8%	4.9%	-3.0%	1.6%	0.4%	-3.9%
Minas Gerais	3.2%	1.4%	-0.7%	0.0%	2.5%	3.2%	-2.6%	0.9%	1.0%	-0.1%
Espírito Santo	3.3%	1.9%	-0.8%	0.0%	4.4%	4.6%	-2.0%	0.9%	0.9%	-2.1%
Rio de Janeiro	-0.7%	-0.7%	-1.0%	-1.8%	2.9%	5.2%	-2.5%	-0.7%	0.9%	0.0%
São Paulo	2.4%	0.4%	-1.4%	0.2%	1.6%	3.7%	-2.7%	0.1%	0.6%	1.5%
Paraná	-0.4%	0.8%	-2.1%	0.0%	2.7%	4.8%	-2.9%	-0.2%	1.0%	-1.8%
Santa Catarina	2.4%	1.5%	-1.7%	-0.8%	3.4%	4.1%	-2.4%	0.1%	1.6%	0.0%
Rio Grande do Sul	-1.3%	0.2%	-2.1%	-1.1%	3.1%	5.3%	-2.8%	-0.9%	1.5%	-1.5%
Mato Grosso do Sul	1.5%	0.5%	-1.8%	-0.3%	4.0%	5.3%	-2.8%	0.1%	1.5%	-1.0%
Mato Grosso	6.4%	1.9%	-1.8%	3.4%	7.9%	8.5%	-2.3%	1.5%	0.3%	-5.0%
Goiás	2.1%	1.0%	-1.3%	0.2%	2.8%	3.6%	-2.8%	0.5%	1.5%	-0.6%
Distrito Federal	4.9%	4.3%	2.8%	7.1%	0.8%	1.3%	-2.5%	4.3%	-2.3%	-10.2%
Average	**2.4%**	**1.3%**	**-1.3%**	**0.2%**	**3.1%**	**4.3%**	**-2.7%**	**0.5%**	**1.0%**	**-0.8%**

Source: The authors

TFP growth was found in all states except Rio Grande do Norte. Regionally, Brazil's North (Rondônia, Acre, Amazonas, Roraima, Pará, Amapá and Tocantins) showed the greatest TFP growth, which is consistent with the agricultural frontier's expansion in this area over recent decades. Thirty years ago, agricultural activity in the North was practically nil. Study estimates of technical progress and allocative efficiency are very similar to the results for TFP growth.

Spolador and Lima (2009) found that the number of applicants for rural credit and the amount of subsidized rural credit awarded increased in the states of Brazil’s Central-West (Goiás, Mato Grosso, Mato Grosso do Sul) and North due to expanded livestock activities in this previously unexplored area. Their results also suggest that recently completed or proposed infrastructure projects, both logistical and energy supply related, also increased the demand for rural credit in these regions by improving their potential for economic growth. These projects were promoted by both national and local governments favoring agricultural frontier expansion. Recent research evaluating the modernization of Brazilian agriculture shows that occupation of unexplored areas in the Central-West and North has brought new capital investments and labor-saving technological advances to the regions

Our results show that the agriculturally important states of Bahia, Minas Gerais, São Paulo and Mato Grosso experienced significantly elevated economic growth in their agricultural sectors over the study period. The increase shown in each state’s TFP was both large and positive, with the technical progress component of TFP being the most positive influence on GDP. These four states and the states of Paraná and Rio Grande do Sul account most of Brazil’s agricultural GDP Of these major agricultural producers, Mato Grosso showed the largest increase in both TFP and technical progress. Although Mato-Grosso, Brazil’s most important soy-bean producing state, is in Brazil’s Central-West, the TFP and technical progress increases found there are very similar to the large increases estimated for states in Brazil’s North.

The study’s the technological efficiency indicator is negative for all states from 1975 thru 2005. However, over that period all states show agriculture sector technological progress and all but three states showed agriculture sector economic growth. These results suggest that the technological efficiency indicator’s negative value should be analyzed as the gap distance of each state from the technological frontier: the technological frontier’s expansion was larger and more rapid than the increase in technical efficiency[7].

The large agricultural sectors of Paraná and Rio Grande do Sul, both in Brazil’s South, show negative economic growth over the entire study period while their TFP and technical progress indicators show reasonable growth. This apparently contradictory result was strongly influenced by the two latter sub-periods within the entire study period (see Annex): 1985-1995 and 1995-2006. By the end of the two sub-periods, both states showed a reduction in capital accumulation, labor force and harvested territory, which strongly negatively affected economic growth in their agricultural sectors. There were two factors that may have significantly influenced these results: adverse climatic conditions and an aberration in our study’s panel data source.

According to the Brazilian Rural Statistical Yearbook, 1985 and 2005 were adverse years for agricultural activities, which reduced agricultural GDP in some states. Grain harvests were especially affected by bad climatic conditions in Brazil’s South during both the 2004/2005 and 2005/06 harvest seasons. Coincidentally, data for the decennial Brazilian Agricultural Census was collected in 1985 and 2005. As figures from the Census are the basis of the study’s panel data, this timing coincidence greatly influenced the study’s econometric results, especially for Paraná and Rio Grande do Sul.

At the end of the first sub-period, 1975 to 1985, Paraná and Rio Grande do Sul showed agricultural economic growth of 2.8% and 2.7% respectively. Over the entire study period, despite the negative results for economic growth in Paraná’s and Rio Grande do Sul’s agriculture sectors, the model was able to capture TFP growth and above average technical progress in both states.

Rio de Janeiro also showed negative agricultural economic growth over the study period, which was expected. Agricultural activity in the state is not significant, and the state’s relevance in the country’s agricultural GDP has been diminishing over recent decades.

An analysis of data derived from our study’s application of the stochastic frontier model strongly indicates that TFP expansion based on technical progress was the major determinant of the Brazilian agriculture sector’s economic growth from 1975 to 2005. At a regional level, the agricultural

[7] In some empirical applications of the time-varying model as Battese and Tessema (1993), the inclusion of time-varying parameters in the stochastic frontier resulted in the conclusion that technical inefficiency exists. This is the case found in this paper.

economies of states on Brazil's agricultural frontier grew at higher rates than those of states in other Brazilian regions.

The 1995-2005 sub-period presented the highest levels of technological progress (7.4%) and TFP growth (4.5%) of all sub-periods, as shown in Table 6. In general, those ten years were a period of Brazilian economic recovery and growth brought about relative economic openness, monetary stabilization, and after the 1999 adoption of a flexible exchange rate mechanism, decreasing interest rates. The international market was also a positive influence on the performance of Brazilian agriculture during that sub-period, particularly following the commodity price surge that began in 2003.

Table 6. The results for agricultural TFP decomposition by period.

Year	Economic growth	Capital accumulation	Labor expansion	Land expansion	Change in TFP	Technical progress	Technical efficiency	Scale effects	Allocative efficiency	Randon shocks
1975-1985	7.1%	7.0%	0.6%	0.1%	2.5%	-0.2%	-2.1%	3.8%	1.0%	-3,0%
1985-1995	-0.8%	-1.3%	-1.3%	-1.0%	2.2%	5.7%	-2.7%	-1.2%	0.4%	0,5%
1995-2005	1.0%	-1.8%	-3.3%	1.5%	4.5%	7.4%	-3.3%	-1.1%	1.5%	0,1%
1975-2005	2.4%	1.3%	-1.3%	0.2%	3.1%	4.3%	-2.7%	0.5%	1.0%	-0,8%

Source: The authors

5. Conclusion

The study put forward in this paper analyzes the growth of Brazilian agriculture from 1975 to 2005, estimating a stochastic frontier to decompose the agricultural sector's Total Productivity Factor (TFP) at the state level. Results from the study suggest that expansion of the agricultural frontier in Brazil's North and Central-West regions was made possible by strong technical progress supporting positive TFP growth. States that have traditionally had an extremely large share in Brazilian agriculture's GDP also showed technical progress and TFP growth. One of these states, Mato Grosso, showed more than twice the average agriculture sector economic growth, more than twice the average TFP growth and almost twice the average technical progress over the study period.

The study's econometric model captured the expected reduction in all states' agricultural labor force and the reduction in harvested hectarage in states where agriculture's share of GDP has diminished due to economic diversification. Study results also highlighted the increase in harvested hectarage in the North region states brought on by agricultural frontier expansion.

The study also reflected the significant macroeconomic advances made in Brazil from 1995 thru 2005. Our technical progress and TFP indicators saw their greatest increases during that period, a period in Brazil that saw monetary stabilization, spreading economic openness, and a return to economic growth.

Changes in the international marketplace increasingly impact Brazil's agricultural economy. Since 2005, rising international commodity prices and an increase in the international commodity trade should have provided a boon to the agricultural economies of the 27 Brazilian states. The methodology used in the current study could be applied to provide data on the impact of these changes on each state.

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Table 7. The results for the agricultural TFP decomposition by period and State in percentage values.

State	Period	Economic growth	Capital accumulation	Labor expansion	Land expansion	Change in TFP	Technical progress	Technical efficiency	Scale effects	Allocative efficiency	Randon shocks
Rondônia	1975-1985	-0.44	-0.77	-0.71	-2.68	-2.51	0.15	-4.07	-0.59	1.99	6.24
Rondônia	1985-1995	-2.85	0.57	-1.68	-1.01	20.17	21.09	-1.48	-0.61	1.17	-20.91
Rondônia	1995-2005	6.92	1.61	-3.42	-2.05	7.20	7.92	-2.92	-1.06	3.26	3.58
Rondônia	1975-2005	1.21	0.47	-1.94	-1.92	8.29	9.72	-2.82	-0.75	2.14	-3.70
Acre	1975-1985	3.05	3.30	0.96	-0.64	3.41	1.96	-1.71	2.00	1.15	-3.99
Acre	1985-1995	-2.53	1.46	-1.43	-0.32	6.51	7.53	-1.78	0.10	0.67	-8.76
Acre	1995-2005	10.76	3.61	-4.33	3.03	9.13	7.54	-2.40	0.89	3.09	-0.69
Acre	1975-2005	3.76	2.79	-1.60	0.69	6.35	5.68	-1.96	1.00	1.64	-4.48
Amazonas	1975-1985	8.89	6.82	1.08	1.72	4.27	2.06	-1.24	3.44	0.01	-4.99
Amazonas	1985-1995	0.92	-1.10	-1.46	-2.91	4.25	4.56	-1.36	-0.97	2.02	2.15
Amazonas	1995-2005	8.11	-1.76	-5.59	10.44	21.07	14.61	-1.62	1.70	6.38	-16.05
Amazonas	1975-2005	5.97	1.32	-1.99	3.08	9.86	7.08	-1.41	1.39	2.80	-6.30
Roraima	1975-1985	-1.41	1.20	-2.49	-2.19	18.02	17.69	-1.74	-0.70	2.77	-15.95
Roraima	1985-1995	3.94	-1.13	2.46	7.22	0.09	3.50	-2.25	1.95	-3.11	-4.71
Roraima	1995-2005	-1.09	-0.64	-2.86	1.12	12.94	9.54	-2.76	-0.33	6.49	-11.66
Roraima	1975-2005	0.48	-0.19	-0.96	2.05	10.35	10.24	-2.25	0.31	2.05	-10.77
Pará	1975-1985	11.71	9.74	2.47	1.84	-6.71	-10.37	-1.33	5.51	-0.51	4.36
Pará	1985-1995	-2.51	0.31	-1.60	0.50	16.49	19.13	-2.69	-0.34	0.40	-18.22
Pará	1995-2005	1.02	1.66	-3.51	0.33	8.48	8.76	-2.79	0.08	2.43	-5.94
Pará	1975-2005	3.41	3.90	-0.88	0.89	6.09	5.84	-2.27	1.75	0.78	-6.60
Amapá	1975-1985	9.62	11.72	0.04	2.94	5.73	0.08	-1.44	5.46	1.62	-10.81
Amapá	1985-1995	-1.66	0.11	-0.97	-1.00	3.33	5.57	-2.35	-0.54	0.65	-3.13
Amapá	1995-2005	-1.23	-2.61	-4.36	8.13	24.54	14.36	-2.24	1.36	11.05	-26.93
Amapá	1975-2005	2.24	3.07	-1.76	3.36	11.20	6.67	-2.01	2.10	4.44	-13.63
Tocantins	1975-1985	9.04	7.87	0.83	0.25	2.45	-0.59	-2.36	4.47	0.92	-2.37
Tocantins	1985-1995	-0.16	-0.29	-1.00	-2.89	-2.61	0.00	-2.93	-1.01	1.33	6.64
Tocantins	1995-2005	8.32	2.59	-3.98	6.23	8.91	8.20	-3.63	2.99	1.35	-5.44
Tocantins	1975-2005	5.73	3.39	-1.38	1.20	2.92	2.54	-2.97	2.15	1.20	-0.39
Maranhão	1975-1985	3.22	8.87	0.76	-2.02	0.40	-3.18	-1.80	4.35	1.04	-4.79
Maranhão	1985-1995	-1.45	-1.13	-1.00	2.40	4.52	7.12	-2.28	-0.37	0.04	-6.24
Maranhão	1995-2005	3.21	-1.34	-2.98	-1.60	4.94	7.80	-2.91	-1.52	1.57	4.19
Maranhão	1975-2005	1.66	2.13	-1.07	-0.41	3.29	3.91	-2.33	0.82	0.88	-2.28
Piauí	1975-1985	4.13	7.64	1.93	2.49	2.03	-0.30	-2.48	4.92	-0.12	-9.95
Piauí	1985-1995	-0.87	-1.55	-1.30	0.32	0.17	4.43	-3.41	-1.09	0.24	1.49
Piauí	1995-2005	2.06	-1.80	-2.22	-1.18	2.24	5.28	-4.11	-0.97	2.04	5.03
Piauí	1975-2005	1.77	1.43	-0.53	0.55	1.48	3.14	-3.33	0.95	0.72	-1.14
Ceará	1975-1985	6.66	7.89	1.62	-1.92	0.52	-2.50	-2.24	4.43	0.82	-1.45
Ceará	1985-1995	-2.50	-1.92	-0.68	-0.58	1.27	4.85	-2.79	-1.21	0.42	-0.58
Ceará	1995-2005	0.06	-2.68	-2.39	-1.19	1.09	5.16	-3.51	-2.00	1.44	5.22
Ceará	1975-2005	1.41	1.10	-0.48	-1.23	0.96	2.50	-2.85	0.41	0.89	1.06
Rio Grande do Norte	1975-1985	7.06	7.71	0.92	-0.34	0.05	-1.18	-2.37	3.77	-0.18	-1.28
Rio Grande do Norte	1985-1995	-2.46	-1.79	-1.29	-1.77	-1.63	2.66	-3.07	-1.48	0.25	4.02
Rio Grande do Norte	1995-2005	2.25	-2.76	-3.53	-3.99	-1.22	5.42	-3.90	-2.41	-0.34	13.75
Rio Grande do Norte	1975-2005	2.28	1.05	-1.30	-2.03	-0.93	2.30	-3.11	-0.04	-0.09	5.50

Table 7. The results for the agricultural TFP decomposition by period and State in percentage values (continued).

State	Period	Economic growth	Capital accumulation	Labor expansion	Land expansion	Change in TFP	Technical progress	Technical efficiency	Scale effects	Allocative efficiency	Randon shocks
Paraíba	1975-1985	4.37	5.26	-0.07	0.45	0.76	0.87	-2.48	2.54	-0.18	-2.03
Paraíba	1985-1995	-2.18	-2.22	-1.65	-2.98	-1.42	3.02	-3.10	-2.06	0.72	6.09
Paraíba	1995-2005	-1.45	-3.65	-2.82	-2.25	0.55	5.81	-4.00	-2.51	1.25	6.73
Paraíba	1975-2005	0.25	-0.20	-1.51	-1.60	-0.04	3.24	-3.19	-0.67	0.60	3.59
Pernanbuco	1975-1985	6.11	6.07	1.34	-0.44	0.17	-0.90	-2.03	3.49	-0.38	-1.03
Pernanbuco	1985-1995	-1.22	-1.84	-1.43	-0.63	0.98	4.58	-2.67	-1.35	0.41	1.70
Pernanbuco	1995-2005	-2.29	-3.59	-3.32	-1.36	2.57	6.60	-3.25	-2.31	1.53	3.41
Pernanbuco	1975-2005	0.87	0.21	-1.14	-0.81	1.24	3.42	-2.65	-0.05	0.52	1.36
Alagoas	1975-1985	8.24	5.99	2.03	1.62	-0.02	-0.48	-2.33	4.22	-1.42	-1.37
Alagoas	1985-1995	-2.76	-0.41	-2.17	-1.12	0.33	4.74	-2.83	-1.19	-0.39	0.60
Alagoas	1995-2005	-3.49	-1.18	-2.92	-1.02	0.87	5.97	-3.55	-1.46	-0.09	0.77
Alagoas	1975-2005	0.67	1.47	-1.02	-0.17	0.39	3.41	-2.90	0.52	-0.64	0.00
Sergipe	1975-1985	8.94	6.18	1.05	0.79	1.48	0.56	-2.60	3.38	0.15	-0.56
Sergipe	1985-1995	-1.30	-1.61	-0.38	0.52	0.12	4.04	-3.29	-0.71	0.08	0.03
Sergipe	1995-2005	-2.45	-2.56	-3.35	0.21	2.94	7.53	-4.12	-1.71	1.25	0.32
Sergipe	1975-2005	1.73	0.67	-0.89	0.51	1.52	4.04	-3.34	0.32	0.49	-0.07
Bahia	1975-1985	10.26	10.29	2.27	1.67	0.37	-3.32	-2.35	6.29	-0.25	-4.35
Bahia	1985-1995	-4.56	-1.52	-1.50	-0.47	6.22	10.09	-2.98	-1.19	0.31	-7.30
Bahia	1995-2005	3.68	-1.70	-2.62	3.05	4.92	7.80	-3.71	-0.27	1.09	0.02
Bahia	1975-2005	3.12	2.36	-0.61	1.41	3.84	4.85	-3.01	1.61	0.38	-3.87
Minas Gerais	1975-1985	11.50	8.77	1.45	-0.20	3.26	-1.92	-1.97	5.05	2.10	-1.78
Minas Gerais	1985-1995	-1.40	-1.64	-0.94	-0.12	1.18	4.73	-2.49	-1.05	-0.01	0.12
Minas Gerais	1995-2005	-0.63	-2.82	-2.52	0.30	2.93	6.67	-3.25	-1.41	0.92	1.48
Minas Gerais	1975-2005	3.16	1.44	-0.67	-0.01	2.46	3.16	-2.57	0.86	1.00	-0.06
Espírito Santo	1975-1985	10.00	10.85	1.18	0.43	3.76	-2.21	-1.65	6.17	1.45	-6.21
Espírito Santo	1985-1995	0.21	-2.17	-0.87	-1.07	5.26	8.20	-1.78	-1.54	0.38	-0.95
Espírito Santo	1995-2005	-0.31	-3.05	-2.67	0.53	4.12	7.85	-2.66	-2.07	1.01	0.75
Espírito Santo	1975-2005	3.30	1.88	-0.79	-0.04	4.38	4.61	-2.03	0.85	0.95	-2.14
Rio de Janeiro	1975-1985	3.81	2.87	0.93	-1.10	1.73	0.74	-1.67	1.66	0.99	-0.62
Rio de Janeiro	1985-1995	-3.43	-2.17	-2.09	-2.79	3.62	7.68	-2.81	-2.13	0.88	0.00
Rio de Janeiro	1995-2005	-2.52	-2.94	-1.95	-1.64	3.29	7.12	-3.12	-1.49	0.78	0.72
Rio de Janeiro	1975-2005	-0.71	-0.75	-1.04	-1.84	2.88	5.18	-2.53	-0.65	0.88	0.04
São Paulo	1975-1985	8.55	6.31	0.05	0.77	2.34	1.04	-2.12	3.45	-0.04	-0.92
São Paulo	1985-1995	0.68	-1.66	-1.32	-1.30	0.04	3.92	-2.71	-1.51	0.35	4.93
São Paulo	1995-2005	-2.13	-3.42	-2.99	1.19	2.54	6.03	-3.29	-1.73	1.55	0.55
São Paulo	1975-2005	2.37	0.41	-1.42	0.22	1.64	3.66	-2.71	0.07	0.62	1.52
Paraná	1975-1985	2.77	6.04	-0.92	-0.70	4.14	2.40	-2.20	2.56	1.39	-5.79
Paraná	1985-1995	-2.63	-1.20	-1.75	-1.43	0.67	4.80	-2.91	-1.65	0.43	1.09
Paraná	1995-2005	-1.40	-2.42	-3.64	2.17	3.16	7.15	-3.57	-1.59	1.18	-0.66
Paraná	1975-2005	-0.42	0.80	-2.10	0.01	2.66	4.78	-2.89	-0.23	1.00	-1.79
Santa Catarina	1975-1985	6.14	5.91	0.39	0.04	3.17	0.16	-1.82	3.15	1.69	-3.37
Santa Catarina	1985-1995	0.43	-0.16	-1.04	-1.03	1.72	4.28	-2.49	-0.67	0.60	0.93
Santa Catarina	1995-2005	0.60	-1.35	-4.43	-1.30	5.35	7.93	-2.92	-2.31	2.65	2.34
Santa Catarina	1975-2005	2.39	1.47	-1.69	-0.77	3.41	4.12	-2.41	0.06	1.65	-0.03
Rio Grande do Sul	1975-1985	2.75	4.17	-0.38	-0.71	3.57	2.21	-2.08	1.92	1.52	-3.90
Rio Grande do Sul	1985-1995	-2.22	-1.24	-1.46	-1.81	2.00	5.58	-2.73	-1.61	0.76	0.30
Rio Grande do Sul	1995-2005	-4.37	-2.29	-4.43	-0.74	3.84	8.09	-3.52	-2.86	2.13	-0.75
Rio Grande do Sul	1975-2005	-1.28	0.21	-2.09	-1.09	3.14	5.29	-2.78	-0.85	1.47	-1.45

Table 7. The results for the agricultural TFP decomposition by period and State in percentage values (continued).

State	Period	Economic growth	Capital accumulation	Labor expansion	Land expansion	Change in TFP	Technical progress	Technical efficiency	Scale effects	Allocative efficiency	Randon shocks
Mato Grosso do Sul	1975-1985	6.42	6.88	-0.38	-0.29	6.74	3.25	-2.18	3.50	2.16	-6.52
Mato Grosso do Sul	1985-1995	2.74	-1.41	-0.93	-2.07	0.90	4.03	-2.90	-1.22	0.99	6.26
Mato Grosso do Sul	1995-2005	-4.65	-3.90	-4.08	1.56	4.42	8.50	-3.45	-2.00	1.37	-2.65
Mato Grosso do Sul	1975-2005	1.51	0.52	-1.80	-0.27	4.02	5.26	-2.84	0.09	1.51	-0.97
Mato Grosso	1975-1985	3.22	5.26	-0.99	3.53	11.44	10.60	-1.29	2.99	-0.86	-16.03
Mato Grosso	1985-1995	5.70	-0.16	-1.09	-0.79	4.83	7.27	-2.29	-0.57	0.42	2.92
Mato Grosso	1995-2005	10.27	0.57	-3.46	7.43	7.50	7.62	-3.42	2.03	1.26	-1.77
Mato Grosso	1975-2005	6.40	1.89	-1.85	3.39	7.92	8.50	-2.33	1.48	0.27	-4.96
Goiás	1975-1985	3.13	5.89	0.71	-1.94	3.13	-0.91	-2.08	3.10	3.01	-4.66
Goiás	1985-1995	1.56	-0.85	-0.92	-1.18	1.09	4.29	-2.91	-0.83	0.54	3.42
Goiás	1995-2005	1.57	-1.97	-3.68	3.72	4.08	7.46	-3.50	-0.74	0.85	-0.57
Goiás	1975-2005	2.08	1.03	-1.30	0.20	2.76	3.62	-2.83	0.51	1.47	-0.61
Distrito Federal	1975-1985	8.55	15.67	4.06	15.00	4.81	-0.01	-1.91	11.68	-4.96	-30.99
Distrito Federal	1985-1995	10.28	-1.38	-0.88	1.93	5.08	8.61	-2.43	-0.96	-0.14	5.52
Distrito Federal	1995-2005	-4.21	-1.53	5.32	4.39	-7.38	-4.57	-3.08	2.20	-1.93	-5.02
Distrito Federal	1975-2005	4.87	4.25	2.84	7.11	0.84	1.35	-2.47	4.31	-2.34	-10.16
Brasil	1975-1985	7.09	6.99	0.61	0.05	2.49	-0.21	-2.06	3.80	0.96	-3.05
Brasil	1985-1995	-0.81	-1.27	-1.26	-0.99	2.25	5.70	-2.65	-1.23	0.43	0.46
Brasil	1995-2005	1.03	-1.82	-3.32	1.51	4.52	7.35	-3.31	-1.06	1.53	0.15
Brasil	1975-2005	2.44	1.30	-1.33	0.19	3.08	4.28	-2.67	0.51	0.97	-0.82