LINKAGES BETWEEN DEVELOPMENT OF THE INDUSTRIAL AND AGRICULTURAL SECTORS IN BRAZIL: A PROCESS OF TECHNOLOGICAL INNOVATION

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Abstract: Brazil's industrial sector has displayed low rates of annual growth compared to those of other emerging countries such as China and several others in Asia. This paper sets out to show the strong link between industrial development and the progress of the agricultural sector in Brazil, arguing that low industrial growth is due to the lack of a long-term industrial policy. According to some researchers, the agricultural sector has relatively little capacity for adaptation and technological response compared to other economic sectors. However, the authors believe this view is distorted regarding both the importance of agriculture to the dynamism of Brazilian industry and its capacity to respond in terms of the absorption of technological innovations. Technological innovation is the main driver of the development process in all economic sectors. Its insertion into the production process fuels radical change to such an extent that it can even destroy the old process. This is why Schumpeter calls technological innovation a process of "creative destruction". The Brazilian agricultural sector experienced such a process of creative destruction with the incorporation of technological change in the 1970s and more strongly still in the early 1980s. The 1990s saw a process of technological consolidation in Brazilian agriculture, with a high level of technology adoption and a significant increase in productivity and yields for the main temporary crops.

Keywords: economic development, technological innovation.

INTRODUCTION

Brazil's industrial sector has displayed low rates of annual growth compared to those of other emerging countries such as China and several others in Asia. This paper sets out to show the strong link between industrial development and the progress of the agricultural sector in Brazil, arguing that low industrial growth is due to the lack of a long-term industrial policy. According to some researchers, the agricultural sector has relatively little capacity for adaptation

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and technological response compared to other economic sectors. However, the authors believe this view is distorted regarding both the importance of agriculture to the dynamism of Brazilian industry and its capacity to respond in terms of the absorption of technological innovations.

Technological innovation is the main driver of the development process in all economic sectors. Its insertion into the production process fuels radical change to such an extent that it can even destroy the old process. This is why Schumpeter calls technological innovation a process of “creative destruction”. The Brazilian agricultural sector experienced such a process of creative destruction with the incorporation of technological change in the 1970s and more strongly still in the early 1980s. The 1990s saw a process of technological consolidation in Brazilian agriculture, with a high level of technology adoption and a significant increase in productivity and yields for the main temporary crops.

The study described in this paper analyzed data on agricultural production in Brazil (planted areas, production volumes and yields) for the main crops and herds. Other variables were selected from the 1995-96 and 2006 agricultural censuses to characterize the production structure and adoption of technology by the sector. The data for agriculture were compared with data for industry to demonstrate the linkages between agricultural expansion and the dynamics of the industrial sector. The industrial segments selected for analysis were those linked to the production of farm inputs and agribusiness or agroindustry that uses raw materials supplied by the agricultural sector.

Food inflation in 2008, combined with the impact of the economic crisis that intensified late in the same year, demonstrated the need for rapid response by the global agricultural sector to mitigate the impact of economic deceleration, especially on the labor market (fewer jobs) and incomes (decreased earnings). As a result, the sector came under pressure to maintain a supply of food at affordable prices in order not to contribute to a deterioration in social problems such as access to the market for staple foods and other basic consumer goods. In this context, technological innovation for the agricultural sector is considered essential to a sustainable, i.e. environmentally and socially efficient, production process.

ANALYSIS OF SELECTED CROP EXPANSION

Land use in Brazil has been one of the key components in concerns regarding the environment and food production for the world. There are two main angles to this discourse. The first is environmental, itself divided into two focal points: one defends the need for production of raw material (sugarcane) for the supply of an alternative source of energy for the world (ethanol); the other warns of possible negative effects of this expansion on food production and even on the entry of this crop into areas considered environmental reserves.

The food production discourse centers its defense on increases in farm yields via technology, so that Brazil can produce increasing volumes of food without the need to occupy new spaces. This discourse considers the possibility of a

coexistence between energy production and food production in the same productive space via technology. Another key component of this discourse is the need for Brazil to leverage international market opportunities as the country with the best conditions to be the largest exporter of food and energy.

It can be seen that the first focal point of the environmental discourse and that of food are grounded in Brazil's advantages regarding the availability of land. To characterize land use and the rise in yields linked to technological progress in agriculture, we performed a survey of growth in planted areas and yields of selected crops. Our aim is to contribute to a better understanding of the real possibility that Brazil will become the world's leading exporter of energy and food without affecting its environmental reserves. The present situation resembles that seen in the 1970s, when the predominant discourse focused on the Green Revolution and the need to adopt more advanced production technologies in terms of inputs and machinery (GRAZIANO DA SILVA, 1996; GOODMAN, SORJ & WILKINSON, 1990).

As a first step in analyzing land use in Brazil by types of agricultural activity, we mapped the areas under temporary crops in the periods 1990, 2000 and 2007. The maps are shown in Figures 1, 2 and 3.

The densification of agricultural activities in Brazil and their initial movement to the Center-West can clearly be seen by comparing the maps for 1990 and 2000. in 1990 the North region had relatively few municipalities with large areas under temporary crops, as shown by the lighter colored areas of the map. By 2000 temporary crops had expanded, and this process had intensified by 2007 (Figure 3).

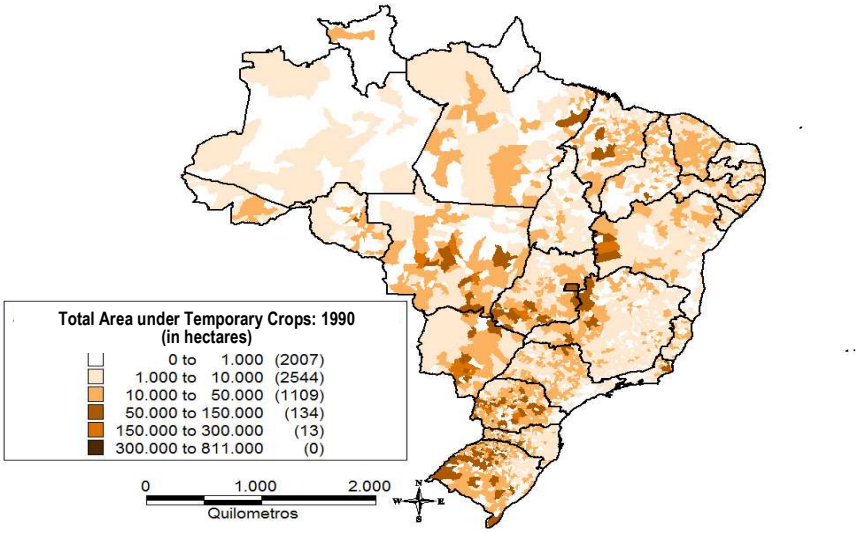

Figure 1. Brazil: total area under temporary crops, 1990
Source: IBGE (2008). Map by the authors.

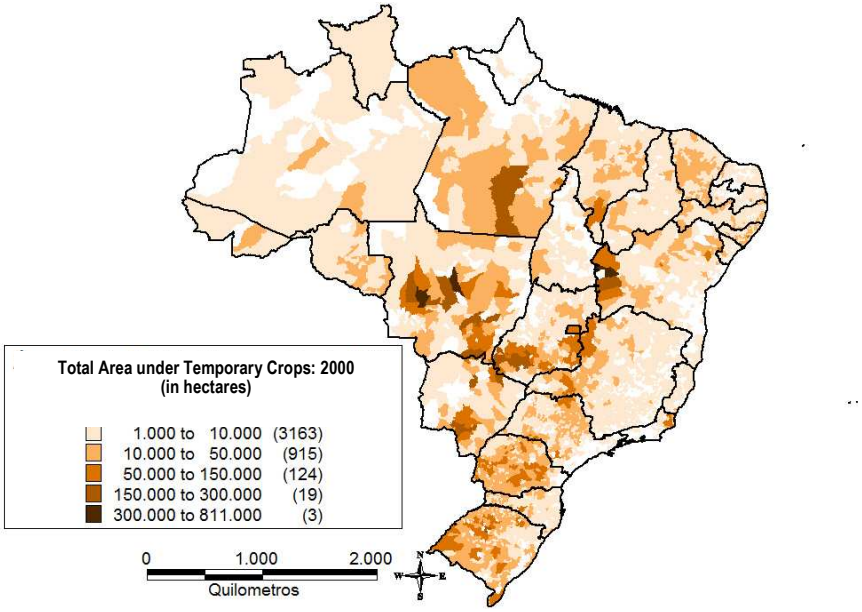

Figure 2. Brazil: total area under temporary crops, 2000
Source: IBGE (2008). Map by the authors.

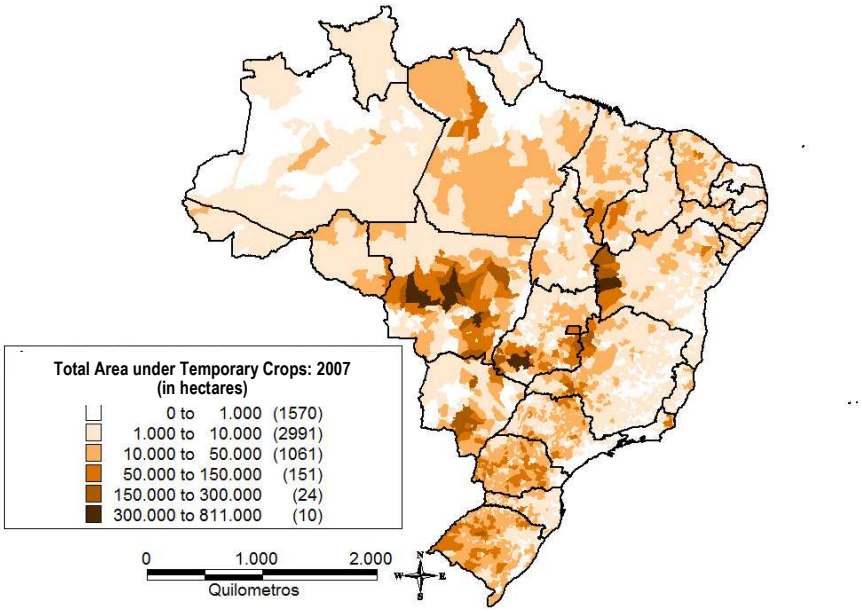

Figure 3. Brazil: total area under temporary crops, 2007
Source: IBGE (2008). Map by the authors.

This densification in the North Region is due to the incorporation of productive areas previously occupied by pastures. The entry of temporary crops into the North Region has triggered discussions among different currents of researchers. Some consider this fact natural in the Brazilian development process, arguing that the advance of agricultural production into frontier areas has not yet consolidated but is still ongoing. Another current argues that the North Region should not be used for agricultural expansion; on the contrary, its function in Brazilian development should be to act as an environmental reserve

of world interest. In other words, the North is one of the main Brazilian environmental resources and its full utilization requires conservation.

Expansion of planted areas for the crops selected for the Brazilian regions was analyzed by calculating the three-year average for the period 1990-2007 and each crop's share in the total area under temporary crops in the respective regions. Table 1 shows the areas under temporary and permanent crops as well as other selected crops for Brazil and its regions.

Table 1. Areas under temporary crops (TC), permanent crops (PC) and selected other crops for Brazil and regions – three-year averages, 1990-2007 (in thousands of hectares)

Crop	1990-92	1993-95	1996-98	1999-2001	2002-04	2005-07
Brazil						
TC	45,386	45,230	42,031	45,135	52,297	53,250
PC	7,007	6,069	5,847	6,251	6,373	6,433
Cotton	1,551	1,074	747	797	881	1,102
Rice	4,420	4,513	3,173	3,576	3,380	3,308
Sugarcane	4,263	4,317	4,921	4,959	5,406	6,360
Beans	5,504	5,265	4,299	4,330	4,342	4,062
Corn	13,163	13,861	12,189	12,660	12,838	13,086
Soybeans	10,239	11,301	11,728	13,584	18,835	22,027
Sorghum	165	156	274	495	741	739
% Cotton.-TC	3.4	2.4	1.8	1.8	1.7	2.1
% Rice – TC	9.7	10.0	7.6	7.9	6.5	6.2
% Sugarcane – TC	9.4	9.5	11.7	11.0	10.3	11.9
% Beans – TC	12.1	11.6	10.2	9.6	8.3	7.6
% Corn – TC	29.0	30.6	29.0	28.0	24.5	24.6
% Soybeans – TC	22.6	25.0	27.9	30.1	36.0	41.4
% Sorghum – TC	0.4	0.3	0.7	1.1	1.4	1.4
North Region						
TC	1600	1884	1818	1984	2006	2149
PC	465	472	419	530	551	542
Cotton	11	22	5	1	2	1
Rice	486	566	535	586	558	531
Sugarcane	15	17	12	16	16	23
Beans	217	262	195	190	168	173
Corn	437	561	573	623	524	546
Soybeans	17	27	37	79	237	496
Sorghum	0	0	0	0	4	14
% Cotton.-TC	0.7	1.2	0.3	0.1	0.1	0.0
% Rice – TC	30.4	30.1	29.4	29.5	27.8	24.7
% Sugarcane – TC	0.9	0.9	0.7	0.8	0.8	1.1
% Beans – TC	13.6	13.9	10.7	9.6	8.4	8.0

% Corn – TC	27.3	29.8	31.5	31.4	26.1	25.4
% Soybeans – TC	1.1	1.4	2.0	4.0	11.8	23.1
% Sorghum – TC	0.0	0.0	0.0	0.0	0.2	0.7
Northeast Region						
TC	10,651	10,389	8,487	8,855	9,784	9,474
PC	2,674	2,403	2,151	2,294	2,332	2,517
Cotton	400	358	226	175	199	335
Rice	1,200	1,237	696	761	745	766
Sugarcane	1,425	1,199	1,239	1,139	1,130	1,152
Beans	2,743	2,667	2,215	2,293	2,442	2,278
Corn	2,917	3,051	2,400	2,537	2,851	2,857
Soybeans	312	500	606	864	1,230	1,462
Sorghum	34	24	24	26	67	84
% Cotton.-TC	3.8	3.4	2.7	2.0	2.0	3.5
% Rice – TC	11.3	11.9	8.2	8.6	7.6	8.1
% Sugarcane – TC	13.4	11.5	14.6	12.9	11.6	12.2
% Beans – TC	25.8	25.7	26.1	25.9	25.0	24.0
% Corn – TC	27.4	29.4	28.3	28.7	29.1	30.2
% Soybeans – TC	2.9	4.8	7.1	9.8	12.6	15.4
% Sorghum – TC	0.3	0.2	0.3	0.3	0.7	0.9
South Region						
TC	17,254	16,453	15,676	16,314	18,513	18,290
PC	575	415	396	436	467	452
Cotton	604	288	118	58	38	28
Rice	1,098	1,244	1,048	1,180	1,217	1,221
Sugarcane	221	265	346	383	427	510
Beans	1,258	1,201	1,027	936	830	781
Corn	5,255	5,586	4,796	5,075	4,828	4,568
Soybeans	5,478	5,454	5,680	6,053	7,556	8,368
Sorghum	48	35	26	40	38	28
% Cotton.-TC	3.5	1.7	0.8	0.4	0.2	0.2
% Rice – TC	6.4	7.6	6.7	7.2	6.6	6.7
% Sugarcane – TC	1.3	1.6	2.2	2.3	2.3	2.8
% Beans – TC	7.3	7.3	6.6	5.7	4.5	4.3
% Corn – TC	30.5	34.0	30.6	31.1	26.1	25.0
% Soybeans – TC	31.8	33.1	36.2	37.1	40.8	45.8
% Sorghum – TC	0.3	0.2	0.2	0.2	0.2	0.2
Southeast Region						
TC	9,027	8,785	8,183	8,153	8,858	8,025
PC	3,123	2,667	2,762	2,852	2,899	2,817
Cotton	378	235	167	116	114	111
Rice	693	570	292	199	137	130
Sugarcane	2,366	2,578	2,984	3,034	3,335	4,067
Beans	980	896	696	707	696	622

Corn	3,056	2,928	2,531	2,453	2,429	2,417
Soybeans	1,012	1,111	1,065	1,131	1,566	1,643
Sorghum	46	46	70	112	174	178
% Cotton.-TC	4.2	2.7	2.0	1.4	1.3	1.4
% Rice – TC	7.7	6.5	3.6	2.4	1.6	1.6
% Sugarcane – TC	26.2	29.3	36.5	37.2	37.7	50.7
% Beans – TC	10.9	10.2	8.5	8.7	7.9	7.8
% Corn – TC	33.9	33.3	30.9	30.1	27.4	30.1
% Soybeans – TC	11.2	12.6	13.0	13.9	17.7	20.5
% Sorghum – TC	0.5	0.5	1.4	1.4	2.0	2.2
Center-West Region						
TC	6,854	7,719	7,866	9,830	13,136	15,316
PC	170	112	120	139	124	106
Cotton	157	171	231	447	529	628
Rice	944	896	603	850	722	661
Sugarcane	236	258	339	387	498	609
Beans	305	238	166	204	205	208
Corn	1,498	1,734	1,889	1,972	2,207	2,714
Soybeans	3,419	4,208	4,340	5,457	8,245	10,059
Sorghum	37	50	154	317	458	434
% Cotton.-TC	2.3	2.2	2.9	4.5	4.0	4.1
% Rice – TC	13.8	11.6	7.7	8.6	5.5	4.3
% Sugarcane – TC	3.4	3.3	4.3	3.9	3.8	4.0
% Beans – TC	4.5	3.1	2.1	2.1	1.6	1.4
% Corn – TC	21.9	22.5	24.0	20.1	16.8	17.7
% Soybeans – TC	49.9	54.5	55.2	55.5	62.8	65.7
% Sorghum – TC	0.5	0.6	2.0	3.2	3.5	2.8

Source: IBGE (2008). Table by the authors.

Given the amplitude of the data in Table 1, we analyzed each region and the variations in planted areas for each crop. For Brazil as a whole, areas under permanent crops decreased between the initial and final periods, with an absolute loss of 573,000 hectares, corresponding to a reduction of 8% between the initial and final averages. Temporary crops expanded 17% in the same period, for a gain of 7,864,000 hectares.

As for the selected crops shown in the table, despite growth in sugarcane, land use in Brazil as whole was specifically concentrated in soybeans and corn, which together accounted for 58.21% of the total area under temporary crops on average for the period.

An analysis of the data for Brazil shows that soybeans, sugarcane and sorghum increased their share of temporary crops in the period analyzed. The area under soybeans grew in all regions of Brazil and this crop also increased its share of the total area under temporary crops, indicating that this crop has occupied most regional spaces in agricultural production.

Cotton and rice decreased sharply in all periods. Between the first and last periods, cotton decreased 29% and rice 25%. The absolute loss of area was 448,000 hectares and 1.112 million hectares respectively. Their shares of temporary crops were 3.4% for cotton and 9.7% for rice in 1990-92, falling to 2.1% and 6.2% respectively in 2005-07.

Sugarcane occupied 4.263 million hectares in 1990-92, or 9.39% of the total area under temporary crops, and 6.360 million hectares in 2010, or 11.9% of the total in the period. Absolute growth was 2.098 million hectares, corresponding to 49%. According to Szmrecsányi et. al (2008), sugarcane is one of the fastest-growing crops in terms of area and is now the third-largest in Brazil in terms of both planted and harvested areas, after soybeans and corn.

The area under dry beans (*Phaseolus vulgaris*) has also decreased (as have cotton and rice). It accounted for 12.1% of the total area under temporary crops in 1990-92, or 5.504 million hectares. By 2005-07 it had fallen to 4.062 million hectares, or 7.6% of the total. The absolute loss of area between the initial and final periods was 1.443 million hectares. Thus the area under beans decreased 26% between the first and last periods.

Soybeans rank second in terms of the speed of expansion. This crop's share of the total area under temporary crops averaged 22.6% in 1990-92, with 10.239 million hectares (less than for corn), and 41.4% in 2005-07, with 22.027 million hectares. Absolute growth between the periods was 115% or 11.788 million hectares.

Soybeans are shown as a share of the total under temporary crops in Figures 4, 5 and 6 for 1990, 2000 and 2007.

In 1990, soybeans were concentrated in the Center-West and South, with some substantial areas in Bahia and São Paulo. By 2000, the crop had entered the North and Southeast more significantly and increased its share of the total area in several states of those regions.

The data for 2007 show expansion proceeding strongly in the North. Expansion continues according to Szmrecsányi et. al (2008).

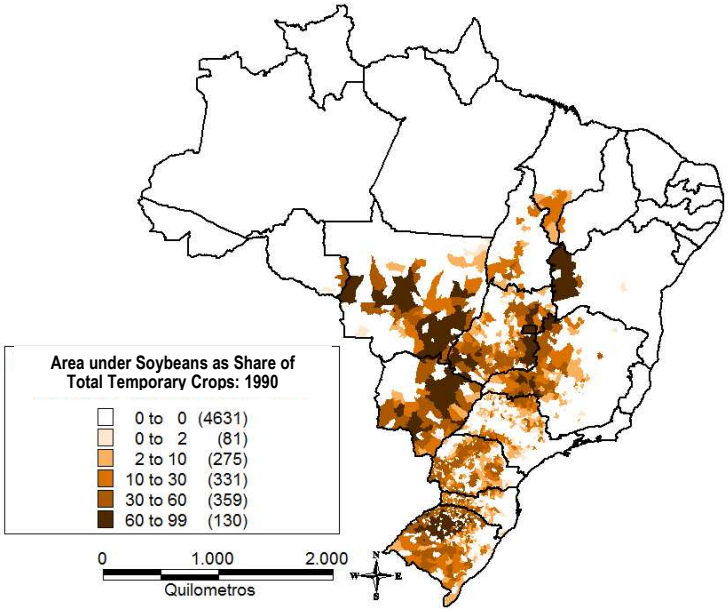

Figure 4. Brazil: area under soybeans as share of total area under temporary crops (%), 1990

Source: IBGE (2008). Map by the authors.

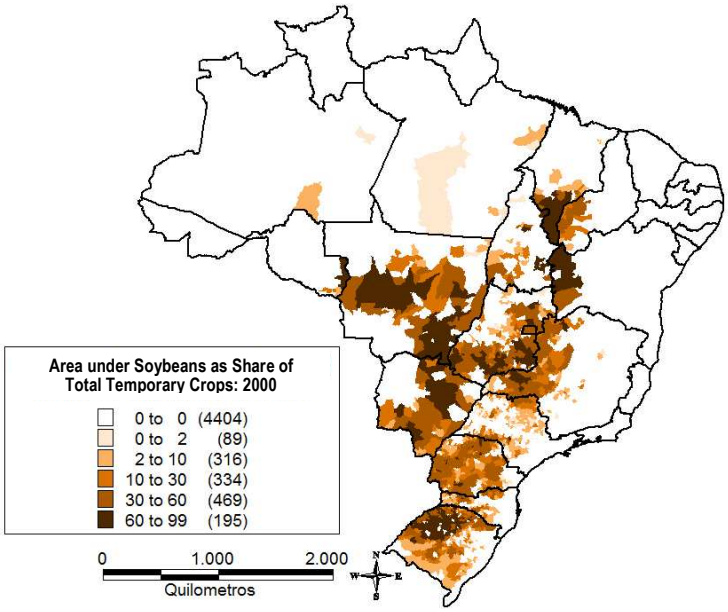

Figure 5. Brazil: area under soybeans as share of total area under temporary crops (%), 2000

Source: IBGE (2008). Map by the authors.

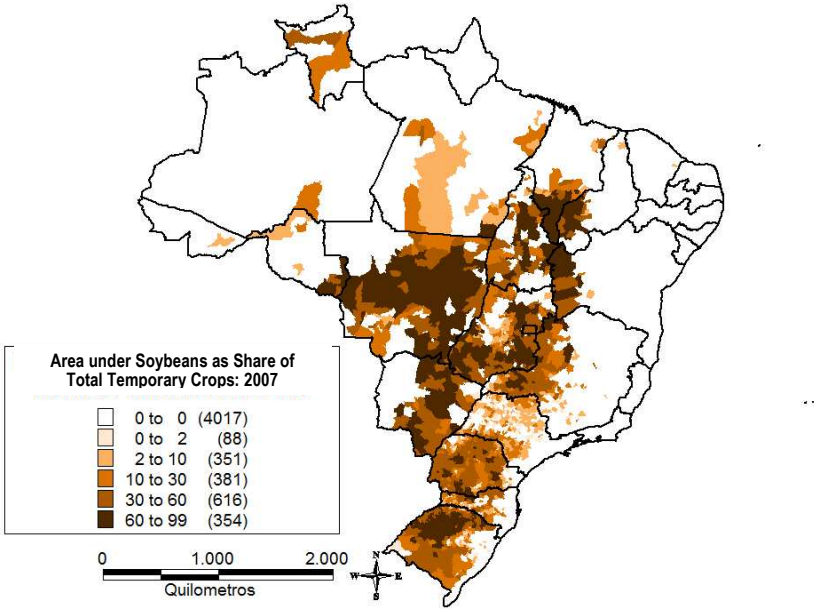

Figure 6. Brazil: area under soybeans as share of total area under temporary crops (%), 2007

Source: IBGE (2008). Map by the authors.

Corn has decreased as a share of the total area under temporary crops in Brazil owing to a loss of planted area. In absolute terms, in the first period analyzed this crop covered an area of 12,623,240 hectares. The absolute loss of area between the initial and final averages was 540,510 hectares, or 4.1%.

Sorghum is another crop that has performed positively. The area under sorghum increased from 165,150 hectares in 1990-92 to 772,500 hectares in 2005-07. The absolute increase in area between the two periods was 607,340 hectares, corresponding to growth of 367.74%, the fastest rate of expansion for all the crops analyzed here.

In the North Region, the area under both temporary crops and permanent crops has expanded. The area under temporary crops increased 549,000 hectares and the area under permanent crops grew 77,000 hectares during the entire period analyzed. Among temporary crops, soybeans led this growth, rising from an average of 17,000 hectares to an average of 496,000 hectares, with an absolute increase of 479,000 hectares. Its share of the total area under temporary crops in the region rose from 1.1% to 23.1%. The rate of growth between 1990-92 and 2005-07 was 2,795%.

In contrast with the North, the Northeast displayed a decrease in the area under both temporary and permanent crops. The absolute loss of area under temporary crops between 1990-92 and 2005-07 was 1.177 million hectares. The loss of area under permanent crops between the same periods was 157,000 hectares. These losses corresponded to 11% and 6% respectively. The areas under cotton, rice, sugarcane, beans and corn decreased, while the areas under soybeans and sorghum increased. In absolute terms, the area under cotton decreased 65,000 hectares between 1990-92 and 2005-07, the area under rice decreased 434,000 hectares, the area under sugarcane

decreased 273,000 hectares, the area under beans decreased 465,000 hectares, and the area under corn decreased 60,000 hectares. In contrast, the area under soybeans increased 1.150 million hectares and the area under sorghum increased 50,000 hectares.

In the South Region, the area under temporary crops increased absolutely between 1990-92 and 2005-07, incorporating 1.036 million hectares into the agricultural production process, while the area under permanent crops decreased 123,000 hectares. A breakdown by crop shows absolute gains in planted area for rice, sugarcane and soybeans, up 124,000 hectares, 289,000 hectares and 2.890 million hectares respectively, and absolute losses for cotton, beans, corn and sorghum, down 576,000 hectares, 477,000 hectares, 687,000 hectares and 20,000 hectares respectively.

In the Southeast, the area under both temporary and permanent crops decreased. In the former case, the absolute decrease amounted to 1.002 million hectares between 1990-92 and 2005-07; in the latter, to 306,000 hectares. Sugarcane expanded most, with an absolute gain of 1.700 million hectares. Soybeans and sorghum gained 631,000 hectares and 132,000 hectares respectively. As for the other crops analyzed here, they all decreased in area between the first and last periods. Cotton lost 267,000 hectares, rice lost 563,000 hectares, beans lost 358,000 hectares, and corn lost 639,000 hectares.

It is important to note with regard to this region that the area under sugarcane expanded far more than elsewhere. Its share of the total area under temporary crops rose from 26.2% in 1990-92 to 50.7% in 2005-07.

The Center-West Region, considered the agricultural frontier in the 1970s, demonstrated its vocation for agriculture between 1990-92 and 2005-07 with growth of 8.458 million hectares. It can clearly be seen that this region is responsible for the expansion displayed by Brazil in the total area under temporary crops. Soybeans and corn are the main crops in the region, with planted areas expanding 6.639 million hectares and 1.216 million hectares respectively. Cotton, sugarcane, and sorghum also expanded in absolute terms, growing 471,000 hectares, 373,000 hectares and 397,000 hectares respectively in the same period.

A key point to make about all regions is that soybeans continue to expand fastest except in the Southeast. This crop has attractive features that explain the entry of growers with differing characteristics. It is often see as exclusive to large producers who use advanced technology, but an analysis of the data shows that in fact it has attracted small producers in all regions of Brazil.

The factors that favor the growing of soybeans in Brazil are (i) the significant adaptability of the crop achieved by researchers in Brazil, especially at Embrapa, enabling soybeans to be grown in any region, and (ii) the diversification of markets for soybeans and soya products. Domestic demand is guaranteed by the large processing industry that produces edible oil and animal feed, among many other soy-based products. International demand is guaranteed by the lack of trade barriers of any kind to bulk exports of soybeans. Given this favorable context, the expansion of this crop in all regions of Brazil makes sense.

Even in regions like the Southeast, where sugarcane has expanded significantly, it is important to note that soybean growing has also expanded in terms of planted area, especially owing to its popularity as the main crop rotated with sugarcane. The area under soybeans has grown vigorously and continuously, displaying the fastest rate of expansion even in the North Region, considered an important environmental frontier to be protected. The next section analyzes the dynamics of agricultural land use in Brazil by focusing on the geometric growth rate (GGR) for planted area and productivity.

EVOLUTION IN PLANTED AREA AND YIELD FOR CROPS ANALYZED

Table 2 shows geometric growth rates (GGR) for planted area and crop yields in the period 1990-2007. Brazilian discourse in the agricultural sector focuses on the availability of an abundant supply of arable land and hence the relative lack of pressure for an increase in yields. For this reason, we have calculated GGR for planted area and yield to demonstrate the behavior of these variables during the period analyzed.

The data shown in Table 2 confirm the conclusions mentioned above regarding the expansion of soybean growing in all regions analyzed and the importance of the Center-West Region for the agricultural production process in Brazil. However, a number of comments should first be made about the GGR data.

It can be seen that agriculture in Brazil is expanding mainly by the addition of new areas, with crop yields rising more slowly.

The area under corn is decreasing, as evidenced by the negative GGR for the total planted area in Brazil as a whole and regionally in the Northeast, South and Southeast, yet corn displays the highest GGR for yield. This improvement in yield has enabled corn production to rise in Brazil.

Sorghum displays the highest GGR for planted area in all regions except the South, indicating that this crop has become important to Brazilian agriculture. If this growth continues long enough, there may be a swapover between corn and sorghum, which produce two harvests per year and compete as offseason crops in the Center-West and North.

The highest planted area GGR for sugarcane is in the Center-West. However, sorghum, soybeans and corn also display high rates in the same region, with planted area GGRs of 21.12%, 7.48% and 3.02% respectively. This may indicate a high level of competition for land in the region.

Table 2. Geometric growth rates (GGR) for planted area and crop yield – Brazil and regions, selected crops (1990-2007).

Crop	Planted area GGR (%)	Yield GGR (%)
Brazil		
Temporary crops	1.47	-
Permanent crops	-0.28	-
Cotton	2	7.6
Rice	-2.1	3.8
Sugarcane	2.28	1.13
Dry beans (*P. vulgaris*)	-2	3.07
Corn	-0.33	3.61
Soybeans	5.32	2.20
Sorghum	12.92	1.51
North		
Temporary crops	1.57	-
Permanent crops	1.40	-
Cotton	-21.1	6
Rice	0.4	2.46
Sugarcane	1.68	2.10
Dry beans (*P. vulgaris*)	2.3	1.95
Corn	1.00	2.24
Soybeans	24.67	2.93
Sorghum	69.09	5.13
Northeast		
Temporary crops	-0.42	-
Permanent crops	-0.48	-
Cotton	-2.6	12.85
Rice	-3.4	2.62
Sugarcane	-1.36	1.44
Dry beans (*P. vulgaris*)	1	1.01
Corn	-0.30	5.58

Soybeans	10.74	4.30
Sorghum	7.55	4.51
South		
Temporary crops	0.72	-
Permanent crops	-1.00	-
Cotton	-22	1.5
Rice	0.57	2.52
Sugarcane	5.27	0.87
Dry beans (*P. vulgaris*)	-3.4	4.4
Corn	-1.00	3.90
Soybeans	2.94	1.76
Sorghum	-1.80	1.10
Southeast		
Temporary crops	0.20	-
Permanent crops	-0.23	-
Cotton	-8.5	4.92
Rice	-12.4	2.45
Sugarcane	3.00	0.71
Dry beans (*P. vulgaris*)	-2.8	4.44
Corn	-1.67	4.25
Soybeans	3.58	2.32
Sorghum	11.15	-0.23
Center-West		
Temporary crops	5.68	-
Permanent crops	-1.68	-
Cotton	10.62	6.84
Rice	-2.6	4.85
Sugarcane	6.27	0.72
Dry beans (*P. vulgaris*)	-2	7.27
Corn	3.02	2.52
Soybeans	7.48	2.10
Sorghum	21.12	3.30

Source: IBGE (2008). Table by the authors.

The area under cotton displays negative growth rates in all regions except the Center-West, indicating that cotton growing in those regions may have given way to other crops. The rates are as follows: Northeast -0.48%, Southeast -8.5%, South -22%, North -21.1%. In Brazil as a whole, the area under cotton rose 2%. In the Center-West the growth rate was 10.62%. This was the second-highest rate of expansion for all crops grown in the region. This suggests that the Center-West has the potential to influence the expansion of cotton growing in Brazil.

Turning to crop yields, it is important to note that the Northeast, which displays the fastest GGR for cotton, with 12.85%, benefited from the research done by Embrapa Algodão. Established in 1975, Embrapa Algodão is one of the decentralized units of Empresa Brasileira de Pesquisa Agropecuária (Embrapa). Headquartered in Campina Grande, Paraíba, this research center has contributed significantly to technological innovation and the development of products and services for growers of cotton, castor beans, peanuts, sesame and sisal throughout Brazil. The Center-West has also benefited from the research and technology produced by this unit of Embrapa, as evidenced by the 6.84% rise in cotton yields in the region, the second-highest among all regions for this crop.

Cotton yields rose in other regions and Brazil as a whole during the period analyzed, with the following GGR: Brazil 7.6%, North 6%, South 1.5%, Southeast 4.92%.

The area under rice decreased in Brazil overall and in the Northeast, Southeast and Center-West. It increased in the North and South but at low rates that were insufficient to offset the decreases elsewhere. Common dry beans decreased in all regions except the Northeast, as shown in Table 2. The key points in the table are the increases in yield for several crops, some of which have improved significantly, such as cotton, beans in some regions, and rice. These gains are an important factor in economizing land use in Brazil.

It is also important to note that according to various estimates Brazil has additional areas that are suitable for sugarcane growing. Furthermore, technological progress could increase beef yields and free up pasture for cropping. Thus the expansion of sugarcane growing areas could create minimal pressures on traditional food production. This technological change is especially important for the Center-West, where land use for agriculture is expanding, as shown in Tables 1 and 2.

DYNAMICS OF BRAZIL'S GDP

To understand the impact of this growth in production on the overall development of the Brazilian economy, it is important to stress the behavior of gross domestic product (GDP) year by year, as plotted in Figure 7.

The chart clearly shows that the period of economic stability achieved thanks to control of inflation was not reflected by the key macroeconomic variable of

national GDP growth. The graph evidences acute instability due mainly to external dependency. Adjustments were imposed on the nation's economic sectors and on producers generally in obedience to the economic stabilization policy. The option for stability to the detriment of development translated into a heavy burden for all sectors of production across Brazil. For Brandão (2007, p. 160), "in the 1990s Brazil's productive sectors were abruptly and acutely exposed to international competition in the context of sweeping technological and organizational changes".

Exposure to competition without planning and without a policy to strengthen the capacity of domestic producers, who had been accustomed to protected markets, fueled a process of destruction in several industries, especially textiles and toys. In agriculture, some crops were also affected, such as cotton, which expanded toward the end of the first decade of the new millennium only thanks to incentives introduced by state governments in Mato Grosso and Goiás, and also wheat, supported by a process of technological development to adapt to different parts of the country. The destruction of entire segments of agriculture and manufacturing was only one of the effects of the neoliberal policy initiatives implemented, culminating with the abolition of the existing instruments to promote and coordinate a national industrial policy.[4]

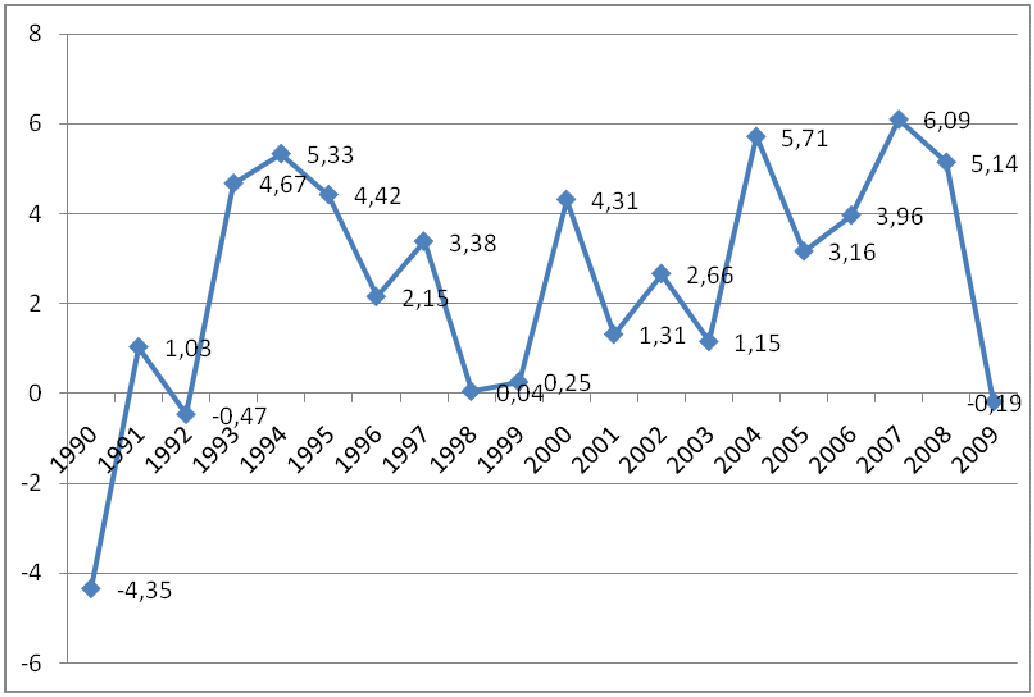

FIGURE 7. Annual variation in total GDP, 1990-2009.

Source: Ipeadata (2010)

[4] For a more extensive discussion, see Brandao (2007), Carneiro (2002), and Cano (2000). The latter conducted a very detailed survey of the impact of neoliberal policies in selected Latin American countries, demonstrating their insertion into the new economic order.

An analysis of real industrial GDP growth in the period 1990-2009 shows that this sector was worst hit by the period of economic instability. The agricultural expansion analyzed above had the effect of reversing the tendency for GDP to contract by guaranteeing aggregate demand for the industrial products required for agricultural modernization.

Figure 8 shows the annual variation in Brazil's industrial output for the period 1990-2009.

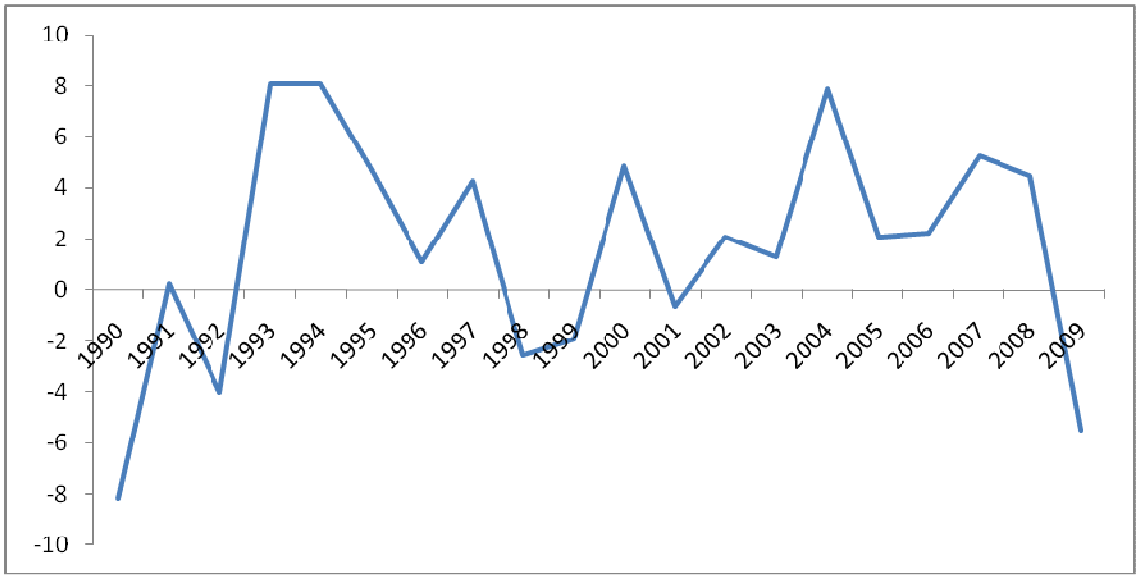

FIGURE 8. Annual variation in industrial GDP, 1990-2009.

Source: Ipeadata (2010)

A comparison of Figures 7 and 8 shows that industrial GDP affected total GDP at all times of positive and negative inflection. The next figure, in which agricultural GDP is plotted for the same period, highlights its counterbalancing effect with regard to the downturns in industrial GDP.

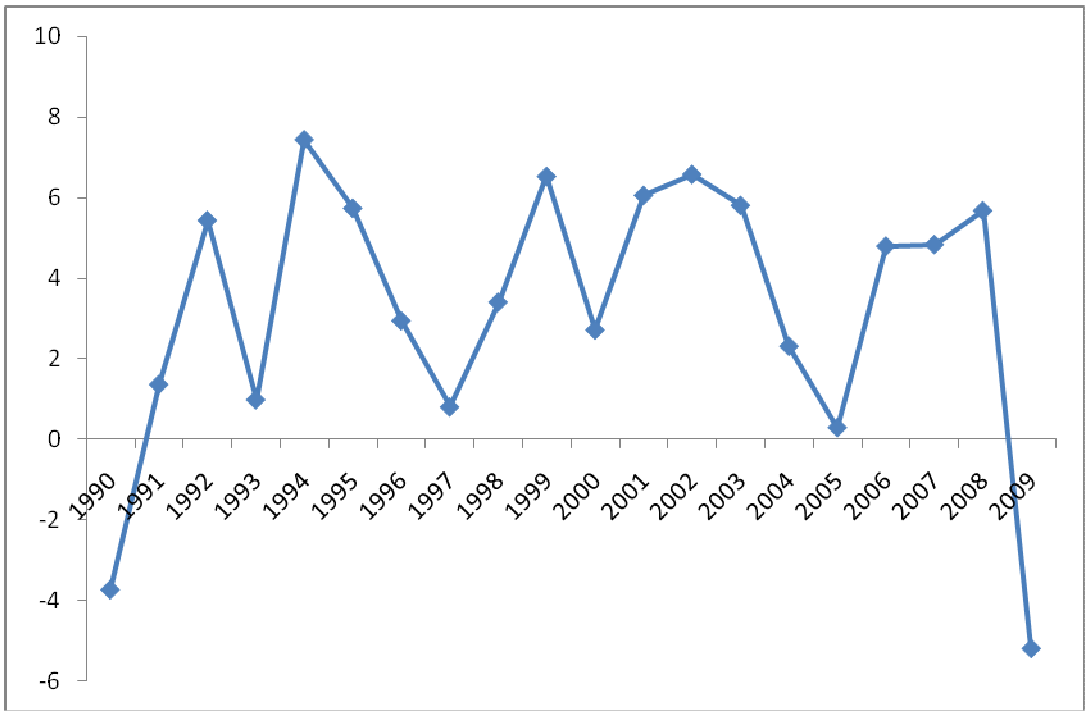

FIGURE 9. Annual variation in agricultural GDP, 1990-2009.

Source: Ipeadata (2010)

CONCLUSIONS

Because of its abundant supply of available arable land, Brazil is considered one of the most viable opportunities for rapid growth in production of food and other agricultural products to meet rising world demand. Another possibility often noted in the debate is the use of degraded pasture for food cropping or the occupation of new areas freed up by rising productivity in livestock farming and meat production, via animal densification and technological innovation.

The introduction of new technology in Brazilian agriculture is not limited to specific products but a necessity across the entire sector. Another factor that favors the process of technological innovation is the demonstration effect of technology, whereby innovations are rapidly disseminated among producers. Thus in contrast with industry, which normally seeks to conserve a specific technological process, the adoption of technology in agriculture is disseminated more evenly among all producers.

The need to guarantee profitability in agricultural activities has led to an increasingly intensive use of technology, and thus this sector is an important source of demand for the industrial sector. In order to respond to the pressure of demand, the agricultural sector resorts increasingly to technologies such as machinery and modern inputs (seeds and fertilizer), which in turn tends to drive up productivity in the sector.

The technological changes that have occurred in recent decades in the agricultural sector have given Brazil the wherewithal to become the “world’s granary”, a figure of speech that was as commonplace as it was empty of

content until the very recent past. In addition to a stock of arable land amounting to some 70 million hectares plus 200 million hectares of pasturelands, some 30% of the land is said to be degraded and deforested, so that it could be reabsorbed with little environmental impact for activities with higher productivity. Brazil has qualified human resources and research and education institutions capable of fueling the technological innovation process, which is a key driver of development. It also has the public and social institutions necessary for the regulation of increasingly complex processes and conflicts, with an industrious workforce and vigorous entrepreneurship among agricultural and industrial producers, who are increasingly aware of both opportunities and conditioning factors, and of the explicit and implicit responsibilities and demands imposed by the new paradigms and by the new institutional framework that is gradually emerging and which it is neither desirable nor possible to escape.

Our conclusion is therefore that Brazil's industrial development has benefited from the expansion of agriculture and the dynamics of this sector since 2003. Agribusiness finds itself in a context of major economic changes, especially globalization, biotechnology, the emergence of new forms of processing and commercialization, and the economic and political transformations that influence patterns of consumption and international trade. The Brazilian industrial sector can appropriate and create networks of research and innovation that multiply the positive effects of these technological changes, benefiting efforts to meet the demands that the agricultural sector will have to satisfy.

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