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The Impact of the Rise of Modern Maize Production in Brazil and Argentina

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KEYWORDS: **Brazil, Argentina, commercial agriculture, maize.**

JEL CODES: **Q12, Q13, Q15,Q17.**

Brazil and Argentina have emerged as leading maize producers and exporters in the past two decades. In both cases the modern maize industry is associated with the expansion of soybean production and has also had an impact on national meat production. We examine how this transformation of maize production occurred, how it evolved in different ways in these two countries and how it relates to changes in their general agricultural development.

O Impacto do Aumento da Produção Moderna de Milho no Brasil e na Argentina

PALAVRAS-CHAVE: **Brasil, Argentina, agricultura comercial, milho.**

CÓDIGOS JEL: **Q12, Q13, Q15, Q17.**

O Brasil e a Argentina emergiram como principais produtores e exportadores de milho nas últimas duas décadas. Em ambos os casos, a moderna indústria do milho está associada à expansão da produção de soja e também impactou a produção nacional de carne. Examinamos como ocorreu essa transformação, a diferença dessa evolução nos dois países e como se relaciona com as mudanças gerais no desenvolvimento da atividade agropecuária.

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1. INTRODUCTION

In the past two decades the spectacular growth of maize exports by Brazil combined with continued exports of maize by Argentina has turned the South American countries into the primary zone for maize exports in the world market. In both cases corn has expanded with soy production and in both cases, it has been tied to major changes in meat production. In Brazil the availability of abundant supplies of soy and maize enabled the underpinnings of the extraordinary surge in meat exports in this very same period. In the case of Argentina, soybeans have replaced natural pasture and the increase in maize production allowed Argentina to shift from pasture feeding to stockyard feeding as never before in Argentine history. In this essay we examine how this transformation of maize production occurred, how it evolved in these two countries of Brazil and Argentina, and how it relates to their auxiliary agricultural production, both of soybeans and meat. We first analyze the maize production and exports in the recent period in these two leading South American producers, then we examine in detail how the two crops system of corn production in Brazil develops in association with the soybean crop and its impact on the pastoral industry. In the next section on Argentina, we show how the growth of maize production was also associated with soybean crops, but in a pattern different from Brazil in terms of the timing of the crop, its production by corporations renting land, and its impact on cattle and wheat production. In our conclusion we explore how these two highly productive maize systems evolved and the major factors which influenced their different patterns of growth.

2. RELEVANCE OF MAIZE PRODUCTION IN THE PAST DECADES

Maize is the largest cereal produced in the world, surpassing such other cereals of world importance as wheat, rice, and soybeans. America, the continent where maize was domesticated, accounts for half of world production. In recent years South America has emerged as the leading source of maize exports for the world market, when Argentina was joined by Brazil as a major world exporter. In the harvest of 2019-20, Argentina and Brazil together produced some 153 million tons of maize and exported 74,000 tons which represented respectively 14% of world production and 43% of world exports (USDA, 2021b: 28, 29). While Argentina has a long history of exporting maize and other grains into the world market, this is a new development for Brazil. In both cases the revolution in genetically modified seeds, the adoption of no-till farming and the association of maize with the new South American crop of soybeans, led to major change in the yield and importance of maize within their agricultural economies. It also fostered significant change in their respective cattle and chicken industries due to the increasing abundance of maize.

Although Argentina had been exporting its maize production from the end of the 19th century, in Brazil maize was a largely small farming product with a limited internal market, mostly going to animal feed. But the dramatic expansion of soybean production which began in the late 20th century soon turned to maize as the major rotating crop to be used in the soybean fields to balance soil nutrients. This led to an explosion of maize production and its association with commercial large-scale agriculture, especially of soybeans. This sudden expansion of maize, which only occurred in the past two decades, allowed Brazil for the first time to export a substantial amount of the maize it produced. It also provided the nation with an ever increasing amount of maize for animal feed, the primary domestic use of maize. This in turn permitted Brazil not only to supply the domestic market, but it allowed for the sudden growth of cattle and chicken production in this same period. By the second decade of the 21st century Brazil's maize exports finally equaled or surpassed those of Argentina. At the same time this newly abundant maize and soybean production allowed Brazil for the first time to become a major exporter of bovine and chicken meats, which grew so rapidly that Brazil became the world's largest meat and chicken exporter in this same period as the expansion of maize production (USDA, 2021a).

Brazil was thus able to develop both a modern pastoral industry based on a steady supply of animal feed made from soybeans and maize increasing its stock of bovine and swine herds but also to create industrial commercial chicken farms at the same time. Like Argentina, the feeding of cattle previously had been based on pasturing the animals on grasses. But in the case of Brazil, most ranchers had not developed the grasses and cultivated pastures that made Argentina famous in the world as an exporter of meat from the late 19th century. Instead, they relied far more on natural pastures on mostly lands unsuitable for cropping. The availability of a steady and increasingly abundant source of both soybeans and maize are fundamental in explaining the rise of Brazil as the world's largest exporter of beef and chicken in this most recent period.

In view of its enormous adaptability to physical conditions and easy planting, maize is produced by 170 different countries. Among the twenty largest producers there are countries with totally different climate and geographical characteristics, such as India, South Africa, Canada, France and Egypt. Currently the largest producers are the United States, China, Brazil, Argentina, and India in that order. What is impressive is that since 1980 the two South American countries have increased their production at a higher rate than all the other major producers, with the most recent period from 2000 to 2020 showing Brazil growing at almost twice the rate of the world increase in maize production (see Table 1).

TABLE 1

World production of maize in selected countries, 1980-2020 (1000 tons)

				% Annual Growth	
Country	**1980**	**2000**	**2020/2021**	**1980-2020**	**2000-2020**
United States	168,647	251,854	373,949	2.0%	2.0%
China	62,715	106,178	260,000	3.6%	4.6%
Brazil	20,372	32,321	110,000	4.3%	6.3%
Argentina	6,400	16,781	50,000	5.3%	5.6%
India	6,957	12,043	28,000	3.5%	4.3%
Mexico	12,374	17,557	28,000	2.1%	2.4%
Canada	5,753	6,954	14,000	2.2%	3.6%
South Africa	11,040	11,431	14,000	0.6%	1.0%
Others	102,365	136,920	640,867	4.7%	8.0%
World	396,623	592,039	1,518,816	3.4%	4.8%
% Argentina+Brazil	7%	8%	11%		

Notes: the European Union is a major producer, but is not listed as such in Faostat.

Source: Faostat (www.fao.org/faostat/en/#data/QA) and USDA (2020: 29).

TABLE 2

Corn: world supply and distribution, 2019-20 (1000 tons)

Countries/regions	**Production**	**Consumption**	**Imports**	**Exports**	**Ending Stoks**
United States	345,962	309,506	959	46,923	48,757
China	260,779	278,000	7,596		200,526
Brazil	102,000	68,500	2,003	34,187	4,792
European Union	66,718	81,000	18,607	4,807	7,177
Argentina	51,000	13,500		39,917	3,672
India	28,766	27,200		1,125	
Mexico	26,658	43,800	16,526		3,515
Canada	13,563	13,960	1,867		2,559
Others	221,084	299,153	127,476	48,075	32,127
Total	1,116,530	1,134,619	175,034	175,034	303,125
Brazil+Argentina	153,000	82,000	2,003	74,104	8,464
%Brasil+Argentina	14%	7%	1%	42%	3%

Source: USDA (2021b: 28-9).

Since maize can be grown in the most varied climates most countries are self-sufficient or produce a significant portion of domestic demand (Paliwal, 2001: 18). Thus, only 15% of world production enters international trade. In the harvest of 2020-21 the largest importers, those importing 10,000 tons or more, are the European Union, Mexico, and sev-

eral Asian and Middle Eastern countries. The United States, Brazil and Argentina are the leading exporters. Two of the largest exporters, the United States and Brazil are also the largest consumers, along with China and the European Union (see Table 2).

These two South American nations are unusual among world maize producers in the high percentage of national production which they exported and the high ratio of domestic supplies which went into animal feed. Whereas Argentina exported on average just over half their national production in the quinquennium of 2014-18, and Brazil almost a third, the world as a whole managed to export an average 15% of its production in this same period, as did the United States which remains the world's largest maize exporter. These two Latin American producers also devoted an extraordinarily high ratio of their domestic supply to animal feed –in both cases averaging three quarters of that national consumption. In contrast the United States used just 43% on average in this five-year period for its domestic consumption for feed and the world in general applied just 56% of corn production to this end (see Table 3).

3. MAIZE PRODUCTION IN BRAZIL

The recent evolution of maize production and productivity in Brazil is the result of the profound transformation and modernization of Brazilian agriculture which began in the 1960s (Klein & Luna, 2019). The government at the time was promoting import substitution industrialization and as a complement to this policy also promoted modern government management of agricultural activity. This involved a minimum price policy, the creation of regulatory stocks, the promotion of an abundant and subsidized credit system, and major government sponsored research in agriculture with the creation of Embrapa. Embrapa scientists helped revolutionize Brazilian agriculture through new seeds and new soil preparation adapted to tropical conditions (Alves, Souza & Gomes, 2013). This research permitted farmers to occupy the Cerrado region in the Center-West of the country.

From the 1960s to the early 1980s the government's system of subsidies was costly both in terms of credit and the support of wheat (Fernandes Filho, 1995: 443-74; Cole, 1998). The foreign debt crisis of the 1980s and the accompanying national fiscal crisis led to an end to subsidies in the agricultural area. But agriculture, unlike industry, was able to integrate with the main international agribusiness value chains, create domestic and foreign markets to finance its operations and persistently increase productivity, allowing the country to become an active agent in the international products market in the last twenty years. It has become a leading world producer and exporter of numerous products from soybeans to boiler chickens. It was in relationship to the growth of soybean pro-

TABLE 3
Usage of corn in the domestic market of Argentina, Brazil, and the United States, 2014-18 (1000 tons)

Element	2014	2015	2016	2017	2018
Brazil					
Production	85,283	85,283	64,188	97,911	82,288
Import Quantity	388	388	2,910	1,340	941
Stock Variation	-6,130	-6,130	-1,073	7,250	-4,704
Export Quantity	29,159	29,159	22,077	29,555	23,760
Domestic supply	62,642	62,642	46,095	62,445	64,173
Feed	47,806	47,806	33,279	45,949	49,378
Seed	486	486	366	558	469
Losses	8,565	8,565	6,709	9,924	8,321
Processing	49	49	51	51	45
Other uses (non-food)	0	0	0	0	0
Food	5,736	5,736	5,690	5,964	5,960
Argentina					
Production	33,087	33,818	39,793	49,476	43,462
Import Quantity	0	3	3	14	9
Stock Variation	0	0	0	2,000	1,000
Export Quantity	15,965	16,800	24,582	23,785	23,234
Domestic supply	17,124	17,020	15,213	23,704	19,237
Feed	12,600	12,660	10,703	18,040	14,203
Seed	280	332	391	486	427
Losses	482	492	579	720	633
Processing	901	809	754	828	811
Other uses (non-food)	2,337	2,220	2,279	3,114	2,647
Food	524	507	506	516	517
USA					
Production	361,091	345,486	412,262	371,096	364,262
Import Quantity	950	1,446	1,982	1,756	1,193
Stock Variation	12,682	149	14,130	-3,886	2,043
Export Quantity	50,163	45,089	56,463	53,507	70,534
Domestic Supply	299,196	301,694	343,651	323,231	292,878
Feed	135,019	129,999	138,935	134,735	133,991
Seed	796	832	798	807	838
Losses	17,048	16,163	19,111	18,264	17,864
Processing	23,640	22,401	24,788	23,925	25,310
Other uses (non-food)	118,821	128,419	156,118	141,583	110,955
Food	3,871	3,882	3,901	3,918	3,920

Source: Faostat (www.fao.org/faostat/en/#data/FBS).

duction that maize finally became a major commercial product and was produced in such abundance that it became a major export crop for Brazil.

Maize is a traditional product of the Brazilian farmer since early colonial times and was cultivated with low productivity. For example, in one of the first agricultural censuses carried out in Brazil, that of São Paulo in 1905, some 77% of the farms produced maize, though they used only 27% of their cultivated lands to do so. Coffee of course was the major crop and accounted for 64% of total agricultural production, but maize was second valued at 16% of total output (Luna, Klein & Summerhill, 2016: table 1). In the 1920 national agricultural census some 37% of the cultivated lands were dedicated to maize production. This made it the largest single crop in terms of land usage, with coffee second and it was grown on a third of the cultivated lands. It accounted for 24% of the value of agricultural production, just behind coffee which represented 25% of total crop value in that year (DGE, 1920: XIX, table 6.). From 1919 to 1959 maize production went from 5 million tons to 9 million tons, for a growth of 2% per annum, with the greatest production coming from the Southeast and Southern Regions, with the states of Minas Gerais, São Paulo, Paraná and Rio Grande do Sul each producing well over a million tons (IBGE, 1960: 124, table XII).

TABLE 4

Yield per hectare of maize in selected American countries, 1961 (in tons)

	Countries in 1961				
	Canada	**USA**	**Argentina**	**Brazil**	**Mexico**
1961	4.6	3.9	1.8	1.3	1.0
1971	5.2	5.5	2.4	1.3	1.3
1981	5.9	6.8	3.8	1.8	1.8
1991	6.7	6.8	4.0	1.8	2.1
2001	6.6	8.7	5.5	3.4	2.6
2011	9.5	9.2	6.4	4.2	2.9
2018	9.7	11.9	6.1	5.1	3.8

Source: Faostat (www.fao.org/faostat/en/#data/QC).

But for all its importance in national consumption, Brazilian productivity in maize was quite low. In 1961 the yields per hectare of maize in Brazil were only 29% of the yields obtained in Canada and only a third of what farmers in the United States obtained. While the leading American producers continued to improve productivity throughout the last half of the 20th century, Brazil remained at a relatively stagnant level of maize production. It did not pass the 2 tons per hectare level until 2000 whereas Argentina passed that yield thirty years earlier and even Mexico reached that level by 1991. As late as 1991 it was only 27% of Canadian and US productivity in maize output (see Table 4).

Although average productivity was low, the universality of its planting meant that production was usually sufficient to cover national needs, with imports needed to meet production crises or supply imbalances in the off-season. Productivity varied by region with traditional southern Brazilian small farm producers having low yields, while new planting areas with their large farms in the Center-West had yields close to those of Canada and the United States. This can be seen in the agricultural census of 2017 which showed high variation in yield, in contrast to soybeans which was a commercial crop with the same yields no matter what the size of the farm might be (see Table 5).

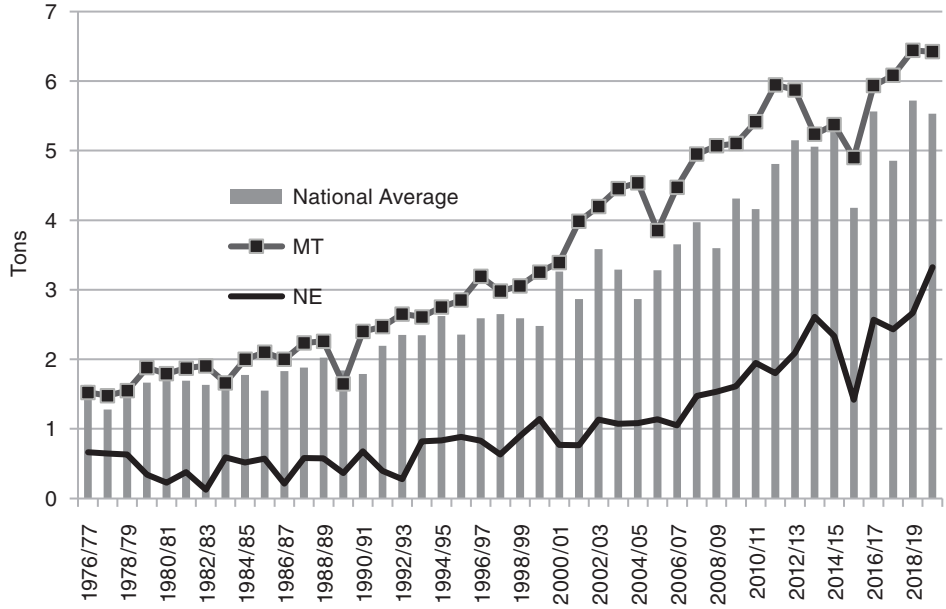
TABLE 5
Production, area planted and yield of maize and soybeans by size of farms. Agricultural census, 2017

Size of Farm	Production (tons)	Area Planted	ton/hectare
Soybeans			
Total	103,156,255	30,722,657	3.36
>0 and <1 ha	2,322	710	3.27
1 - 2 ha	20,496	6,248	3.28
2 - 5 ha	361,499	109,544	3.30
5 - 10 ha	1,029,836	309,271	3.33
10 - 20 ha	2,178,765	643,994	3.38
20 - 50 ha	4,690,006	1,372,136	3.42
50 - 100 ha	5,313,670	1,559,798	3.41
100 - 200 ha	7,196,659	2,121,796	3.39
200 - 500 ha	15,111,610	4,491,662	3.36
500+	67,251,391	20,107,499	3.34
Maize			
Total	88,099,622	15,783,895	5.58
>0 and <1 ha	473,738	356,386	1.33
1 - 2 ha	800,730	407,054	1.97
2 - 5 ha	2,180,154	678,662	3.21
5 - 10 ha	2,014,870	425,316	4.74
10 - 20 ha	2,643,354	474,249	5.57
20 - 50 ha	4,511,532	777,258	5.80
50 - 100 ha	4,743,957	815,335	5.82
100 - 200 ha	6,621,814	1,110,688	5.96
200 - 500 ha	13,536,620	2,265,094	5.98
500+	50,572,854	8,473,852	5.97

Source: IBGE, *censo agro 2017* (https://censos.ibge.gov.br/agro/2017).

This is well reflected as well in the geographically diverse patterns in yields over time. Comparing the best performing state of Mato Grosso with all the states which made up the Northeastern region, the differences were profound. Of the 103 million tons produced in the harvest of 2019-20, Mato Grosso was the largest producing state with 35 million tons, while all the Northeast states produced just 9 million tons of maize. Mato Grosso already had reached a yield of 2 tons per hectare by the harvest of 1984-85 whereas the Northeastern region did not reach that level until 1991-92. By the late 1990s Mato Grosso was up to 3 tons per hectare and reached 6.4 tons per hectare by 2019/20 or double what was achieved by the Northeastern region in that crop year (see Graph 1).

GRAPH 1
Maize yields by hectare for Mato Grosso (MT) and the Northeastern States (NE), 1976-2020 (in tons)



Source: Conab (1976-2020).

Although this huge regional difference persists, over time there has been a slow but steady tendency to reduce this gap between regions. Some formerly marginal areas in the North and Northeast are now highly productive, such as the area called Matopiba[1]. In general,

1. Matopiba is a region that comprises the Cerrado biome in the states of Maranhão, Tocantins, Piauí, and Bahia, and accounts for a large part of the Brazilian production of grains and fiber.

TABLE 6

Cultivated area, production and productivity of maize by states and regions, 2019-20

Region/States	Area (1000 há)	Production (1000 tons)	Produtivity (kg/há)
NORTE	**804.8**	**3,518.7**	**4,372**
Roraima	15.0	90.0	6,000
Rondonia	197.9	1,004.1	5,074
Acre	32.4	80.2	2,476
Amazonas	11.2	28.4	2,535
Amapá	1.4	1.4	972
Pará	264.6	834.8	3,155
Tocantins	282.3	1,479.8	5,242
NORDESTE	**2,627.3**	**8,736.9**	**3,325**
Maranhão	452.4	2,196.3	4,855
Piauí	467.6	2,195.2	4,695
Ceará	519.5	640.0	1,232
Rio Grande do Norte	59.7	34.3	574
Paraíba	107.6	89.0	827
Pernambuco	235.8	188.2	798
Alagoas	38.4	61.4	1,600
Sergipe	153.7	849.7	5,528
Bahia	592.6	2,482.8	4,190
CENTRO-OESTE	**9,283.5**	**56,836.0**	**6,122**
Mato Grosso	5,455.6	34,954.5	6,407
Mato Grosso do Sul	1,855.0	8,783.0	4,735
Goiás	1,911.7	12,616.9	6,600
Distrito Federal	61.20	481.60	7,869
SUDESTE	**2,054.5**	**11,764.0**	**5,726**
Minas Gerais	1,171.2	7,524.3	6,424
Espiríto Santo	11.5	33.2	2,891
Rio de Janeiro	1.1	3.6	3,295
São Paulo	870.7	4,202.9	4,827
SUL	**3,757.2**	**21,663.1**	**5,766**
Paraná	2,629.8	14,947.8	5,684
Santa Catarina	336.0	2,779.7	8,273
Rio Grande do Sul	791.4	3,935.6	4,973
NORTE/NORDESTE	**3,432.1**	**12,255.6**	**3,571**
CENTRO-SUL	**15,095.2**	**90,263.1**	**5,980**
BRASIL	**18,527.3**	**102,518.7**	**5,533**

Source: Conab (1976-2020: Milho 1ª Safra, Milho 2ª Safra, Milho 3ª Safra).

among all farmers, even family farms producing for the national market, there is a slow but steady increase in yields in such basic crops as rice and beans as well as maize. Thus, most states producing over 500,000 tons per annum of maize were now achieving between 4 and 6 tons per hectare. Only the insignificant producing states are still at minimally productive levels (see Table 6).

From 9 million tons in 1991 Brazilian maize production reached 102 million in 2020. This massive growth of output permitted Brazil to satisfy all its necessities and begin to export maize by the 21st century. This very recent emergence of Brazil as a world class exporter is due to several major developments. There was since the 1960s major improvements in Brazilian agriculture in general, including the improvement of crop treatments, new seeds, both hybrid or genetically modified ones, and the ability to occupy new territories, such as Cerrado thanks to the work of Embrapa which played a fundamental role in how to treat these previously unproductive soils. Finally, the expansion of soybean crops into the tropical Center-West region was fundamental. Maize was now used as the major alternative crop to soybeans. Alternate cropping was fundamental in the tropical agriculture of the Center-West region to prevent plagues, as the repetition of the same crop increases the chances of crop infestation. Thus, as the Center-West become the world's largest producer of soybeans, maize production expanded there as well on highly commercial large size farms, especially as Brazil was able to develop two crops a year.

The second major change was the adoption of no-till, or Direct Planting Agriculture, especially as it applied to maize in these new regions (Oliveira *et al.*, 2015: 41). Brazil was one of the pioneering countries in the adoption of this technology, and today the United States, Brazil and Argentina respectively are the leading countries in the world in terms of area cultivated using this cultivation process, which in addition to direct benefits in the sustainability of agriculture, presents economic results that justified its wide adoption in Brazil (Motter & Almeida, 2015; Oliveira *et al.*, 2015: 40-4; Camargo, Angelo & Oliveira, 2016; Kassam *et al.*, 2015: 3). By the 2017 agricultural census 32.8 million hectares were planted through this process, involving 557 agricultural establishments[2]. It was this technology which contributed to the extraordinary expansion of a second crop in the dry season. The no till system is faster, reducing the risk of water deficit, in addition, it maintains the coverage of the soil surface and allows greater water infiltration into the soil and reduces evaporation (Cruz *et al.*, 2006: 42-53; Cruz *et al.*, 2002: 7; Cruz *et al.*, 2010).

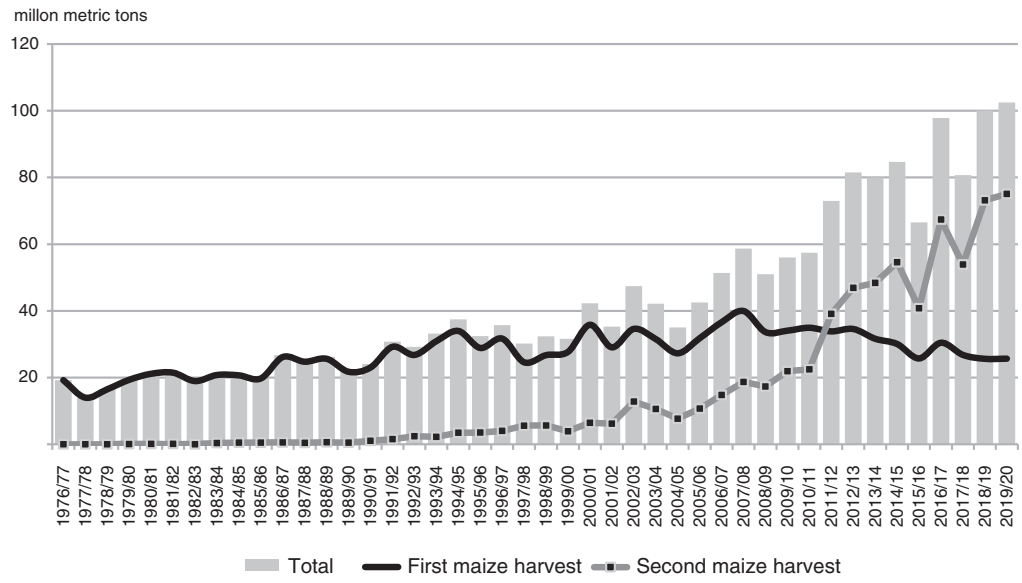
The third change was the wholesale adoption what has been called double cropping or tropical soybean-maize succession cropping generically called the *safrinha*, or the lit-

2. IBGE, *Sidra,* table 6640 (https://sidra.ibge.gov.br/tabela/6640).

tle harvest in which this no-till planting was crucial (Simão, 2016: 4). The traditional maize harvest was produced in the wet season from October to December. This new second harvest was planted directly over the harvested crop of the wet season in the dry season and without irrigation from January to March or April using the no till planting technique *(plantio direto)*. The first crop was most often quick growing soybeans (or *soja precoce*). Although there were early experiments of this type of double planting in the Southern states in the 1980s and 1990s, they were less viable for this production than zones closer to the equator. The serious adoption of this system on a large scale came after 2000 and was most fully developed in the hotter Center West region (Montesdeoca, 2014; Cruz, Pereira Filho & Pereira, 2020). Suddenly Brazil was producing two harvests of maize every year, with the *safrinha*, or second harvest, becoming ever more important over time and finally dominating national production. In 2000 only 15% of the maize came from the *safrinha*. By 2011-12 it was over half the total production and by harvest of 2019-20 this second harvest accounted for 73% of the crop (see Graph 2).

GRAPH 2

Total output of first and second maize harvest, 1976-77 to 2019-20



Source: Conab (1976-2020).

A final significant factor that was crucial was the use of new hybrid seeds. Both in family farms and in non-family farms, these certified or transgenic GM seeds were fundamental in maize production. Although the majority of farms producing maize were family farms, in the case of seeds used, there was little difference between the two types of

farms. Both family farms and non-family farms used certified or transgenic seeds in approximately a quarter of both these two types of establishments. Moreover in both cases those using these seeds produced the bulk of maize harvested. In the case of family farms, those using these seeds accounted for 81% of family farm maize production and among the non-family farms the ratio was 90%. Thus certified or transgenic seeds were another key factor in the expansion of maize production in this period (see Table 7). As of 2017 GM seeds were planted on 50.2 million hectares of cultivated land, of which GM maize was planted on 15.6 million hectares and GM soybeans on 33.7 million hectares. By this year Brazil was the world's second largest consumer of GM seeds in the world after the United States (ISAAA, 2017: 6, 15).

TABLE 7

Types of seeds used in maize production in Brazil by type of farming unit, 2017

Seeds Used	All Farms	Non-Family Farm	Family Farm
Total	1,655,450	312,495	1,342,955
Common, self-produced	910,449	159,178	751,271
Common, aquired	336,735	67,285	269,450
Certified	195,334	41,281	154,053
Transgeneric	212,932	44,751	168,181
Cultivated Area			
Total	15,783,895	13,038,855	2,745,039
Common, self-produced	1,026,910	368,506	658,403
Common, aquired	1,715,398	1,275,764	439,634
Certified	5,019,183	4,441,876	577,307
Transgeneric	8,022,405	6,952,709	1,069,695
Quantity Produced (tons)			
Total	88,099,622	77,127,610	10,972,012
Common, self-produced	2,157,531	1,350,772	806,759
Common, aquired	7,977,022	6,685,691	1,291,330
Certified	28,633,312	25,960,236	2,673,076
Transgeneric	49,331,758	43,130,912	6,200,846

Source: IBGE, *Sidra*, table 6958 (https://sidra.ibge.gov.br/tabela/6958).

This recent growth of a second maize harvest has enabled Brazil to become a significant exporter of maize in the world market, becoming the second largest exporter after the United States only recently. Brazil exported a small amount and in most years imported a small amount through most of the 20th century. Even as recently as the 1980s and 1990s there was a recurring deficit in the maize trade with national production insufficient for domestic needs and with the country taking in imports of corn usually on an annual ba-

sis. It was only in the harvest of 2000-01 that Brazil produced enough corn to begin to seriously export its surplus and supply the internal market. Thereafter both internal consumption and production began to expand at an ever-rapid place. In the quinquennium of 1996-97 both consumption and production averaged 34.2 million tons and by the quinquennium of 2016-17 to 2020-21 average consumption had almost doubled to 65.9 million tons, but national production had more than tripled to 98.4 million tons (USDA, 2001-2021).

This growth of production provided for an ever-increasing usage of maize in the internal market. Given the small consumption of maize as a human food, most of the growing demand came from the animal feed market. In the case of Brazil, in the seven years period from 2001-07 animal feed accounted for over two thirds of domestic demand, and of this animal feed, 58% went for poultry feed, some 15% for swine feed and 7% for feeding cattle (Cruz, 2010: 21, table 2). Over time this pattern slowly changed as exports and production increased. Thus in the period from 2010-11 to 2019-20 period, exports increased from 18% to 35% of annual production, production almost doubled and animal feed declined from 72% of that production to just 56% of total production. Consumption of animal feed actually increased from 39 million tons to 51 million tons in the same period, but exports and production increased even faster. There was however little change in the share of animal feed as poultry in this ten year period averaged 58% of the total feed consumed, swine increased to 28% and the cattle feed to 8%. Of the poultry consumed feed, most (on average 85%) went to feed boiler or meat chickens and 15% for egg laying hens (see Table 8). It is estimated that 60% of the cost of producing chicken and pigs is made up of the cost of feed, which is essentially composed of soybeans and maize (Copetti, 2021). This consumption of feed for chickens and for a lesser extent for cattle, led to an explosion of the stock of these animals. Brazil's chicken stocks went from 690 million in the decade of the 1990s to 1.3 billion in the decade of the 2010s. In the same period the stock of cattle went from 141 million head to 213 million head[3]. This growth of stocks permitted Brazil to greatly expand chicken and beef exports. Total meat exports went from 1.2 million tons to 6.1 million tons from 2000 to 2019, with chicken export volume going from 900 thousand tons to almost 4 million tons. These meat exports took off in the new century thanks to the availability of national soybean and maize production. This explains the high correlations between maize production and the chicken meat exports in the period 2000-19, while production of these two crops fundamental for animal feeding were very strongly correlated with each other (see Graph 3)[4].

3. http://www.fao.org/faostat/en/#data/QA

4. In the period 2000-19 the correlation of maize production with chicken meat production was .91, and with chicken meat exports was .80, and .92 with soybean production.

TABLE 8

Categories of consumption of total maize available in Brazil, 2010-19 (in tons)

Category	2010/11	2011	2012	2013	2014	2015	2016	2017	2018	2019
Initial Stock	11,547	9,212	11,223	14,078	17,881	14,201	8,074	8,074	17,017	16,961
Total Production	**53,749**	**70,907**	**83,462**	**82,760**	**87,153**	**73,887**	**100,687**	**100,687**	**94,529**	**91,241**
Production 1st safra	33,023	35,208	37,126	33,417	30,948	28,851	33,782	33,782	27,682	27,682
Production 2nd safra	20,725	35,699	46,336	49,343	56,205	45,037	66,905	66,905	66,847	63,559
Imports	656	830	911	791	370	2,903	1,400	1,325	600	600
Substitute consumption	2,400	2,500	2,000	2,000	2,000	1,000	700	700	300	300
TOTAL OFFER	**68,352**	**83,450**	**97,597**	**99,628**	**107,403**	**91,990**	**110,861**	**110,786**	**112,446**	**109,102**
Total Demand										
Animal Consumption	38,828	40,298	43,453	47,177	49,454	48,067	49,720	49,720	50,680	50,680
Boiler Chickens	19,127	19,796	21,479	23,520	24,578	24,086	24,617	24,617	25,165	25,165
Egg Chickens	3,275	3,390	3,661	3,917	4,074	3,992	4,377	4,377	4,536	4,536
Pigs	10,670	10,937	11,648	12,556	13,247	12,584	13,141	13,141	13,267	13,267
Cattle	3,188	3,427	3,684	3,979	4,158	4,075	4,189	4,189	4,231	4,231
Outros animais	2,568	2,748	2,981	3,205	3,397	3,329	3,396	3,396	3,481	3,481
Industrial Consumption	4,636	4,868	5,209	5,990	6,589	6,523	6,653	6,653	6,786	6,786
Human Consumption	1,873	1,892	1,882	1,873	1,863	1,845	1,882	1,882	1,919	1,919
Other Uses	2,849	3,545	4,257	4,014	4,227	3,584	3,876	3,876	3,914	3,914
Losses	1,075	1,418	1,669	1,655	1,743	1,582	2,014	2,014	1,891	1,825
Seeds	393	404	425	381	403	443	439	419	451	429
EXPORTS	9,486	19,802	26,625	20,655	28,924	21,873	29,261	29,261	32,000	32,000
Total Demand	59,139	72,226	83,519	81,744	93,203	83,917	93,844	93,825	97,642	97,554
Final Stock	9,212	11,223	14,077	17,884	14,201	8,074	17,017	16,961	14,804	11,548

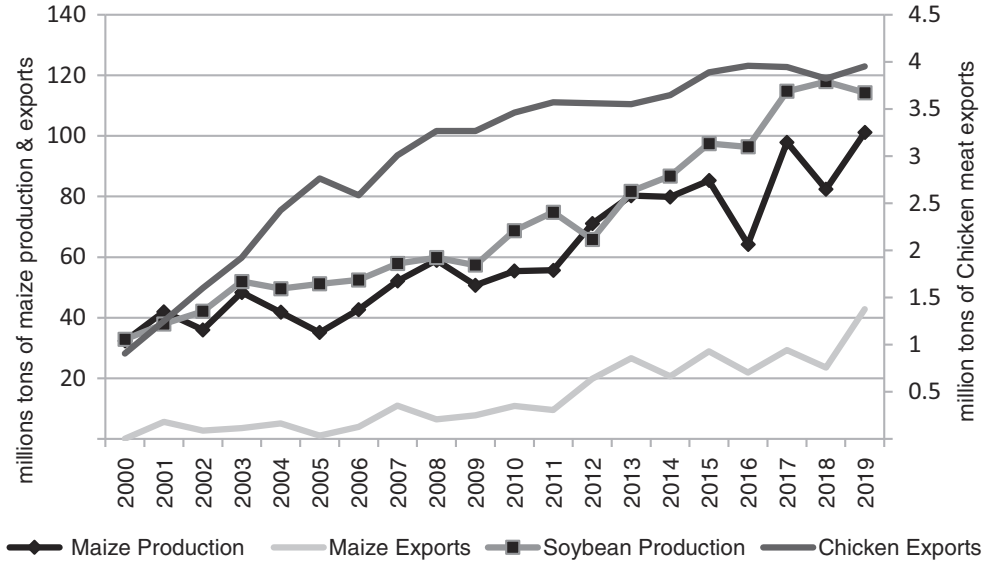
Source: Associação Brasileira das Industrias do Milho, "Estatística" (www.abimilho.com.br/estatistica).

These meat and chicken exports only began to be significant after 2000 when production finally outpaced the growth of national corn consumption. Once started these exports have been on a secular trend of growth, reaching 29 million tons in 2017 and 39 million tons in 2020, second to the United States and just ahead of the 34 million tons which Argentina will export –both of them together producing 15 million tons more than the United States (USDA, 2020: 30-1). In turn the estimate of Brazilian maize production for the harvest year 2020-21 is expected to produce 110 million tons of maize, and the national market will now consume an estimated 70 million tons, up from just 30 million tons in 2000.

This exceptional increase in production occurred with relative stability of the planted area, thanks to the extraordinary growth in productivity, which doubled in the 21st cen-

tury, from 2.7 tons/hectare to 5.6 tons, doubling in the period of 17 years. This type of stability was found in all grains, including soybeans (Klein & Luna, 2021). Thus increasing productivity led to higher output with little expansion in land use (see Graph 4).

GRAPH 3
Brazilian production and exportation of maize, and total exports of beef and chicken meat, 2000-19

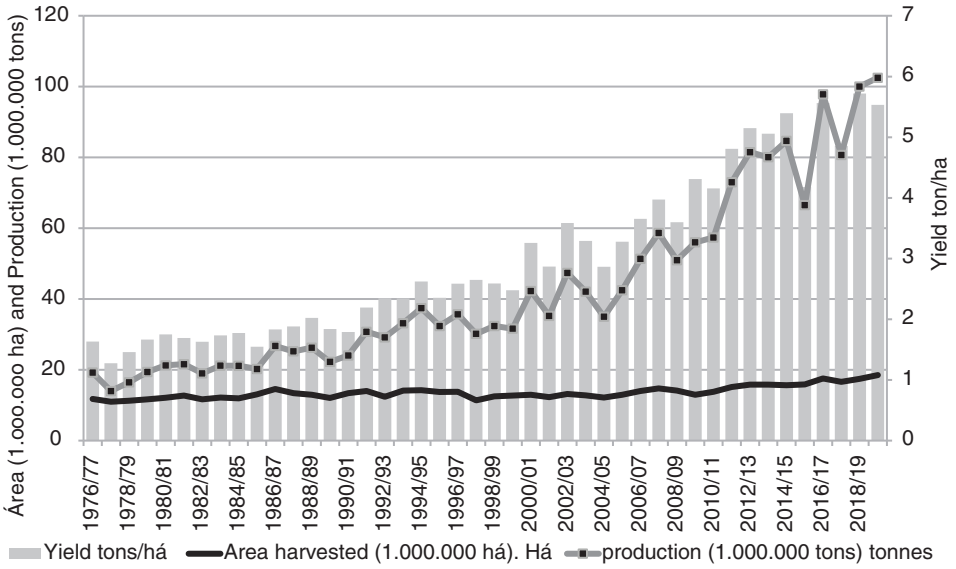


Source: Faostat (http://www.fao.org/faostat/en/#data/QA).

The structure of maize production is rather complex. According to the agricultural census of 2017, a total of 1.3 million family farms planted maize using 2.7 million hectares, and produced 11 million tons in the harvest. These family farms represent 81% of all farming units producing maize, accounted for 17% of the total land planted in maize crops and produced 12% of total maize production. In other words, maize was spread throughout Brazilian agriculture, but its production was concentrated in the 312 thousand non-family producers, who occupied 83% of the land dedicated to corn production and accounted for 88% of maize produced[5].

5. IBGE, *Sidra,* table 6959 (https://sidra.ibge.gov.br/tabela/6959).

GRAPH 4
Maize in Brazil. Area, production and yield, 1976-2019



Source: Conab (1976-2020).

In other words, maize represents a crop open to all types of agricultural producers, unrelated to the size of the property, or whether it was a family or non-family farming unit. The vast majority of producers in fact are made up of small farmers, but today maize production is overwhelmingly produced by large farms with extensive cultivated areas. These productive farms are modern and competitive, explaining Brazil's ability to participate aggressively in the world maize market. Except for the production of soybeans, in which even small family farms achieve close to international levels of productivity (Klein & Luna, 2021: table 6), this pattern of large, middle and marginal farms is the norm in much of Brazilian agriculture. In general it is the middle and larger farms which are using modern agricultural technology, the latest in modified seeds and are fully integrated with international value chains, competing on equal terms with the major participants in world agribusiness. It is the small units, the majority of the farms, which in most cases are subsistence units only marginally producing for the domestic market.

It is these large commercial producers, now mostly producing soybeans as well as corn, who are the primary movers in this market. Their extraordinary increase in maize output has led to profound changes in both national and international markets for Brazilian meat production as maize has been, along with soybeans, the primary input into animal feed. This has allowed Brazil to become a leading world exporter of both beef and boiler chicken

meat as well as satisfying a national population that was growing at over 2% per annum through most of this period (Klein & Luna, 2019: chap. 3).

4. THE CASE OF ARGENTINA

Argentina, like Brazil, is one of the world's largest producers and exporters of grains, but the agricultural history of the two countries differs profoundly. At the beginning of the 20th century, Brazil had a significant production of some products such as coffee, rubber, sugar, and cocoa, but it also had a rudimentary food agriculture which had low productivity and offered the nation low food security. In contrast, Argentina represented one of the most important world producers of grains and meat in the world and maintained a secure national food supply (Barsky & Gelman, 2001; Scobie, 1964; Arriaga. 1999; Cortés, 1979; Gallo, 1983; Adelman, 1994; Hora, 2001; Giberti, 1981). In 1929 Argentina exported more than 13 million tons of grain, 6.6 million tons of wheat, 5 million tons of maize, 1.2 million tons of flax and about one million tons of other winter cereals. Argentina was considered the "Granary of the World", accounting for about half of the world market for cereals and flax. Availability of high-quality land, the massive influx of immigrants to agricultural work, an adequate network of railways and storage, as well as the improvement of maritime transport, were the essential elements explaining Argentina's position in the world grain market (Arriaga, 1999: 11; Ferreres, 2011: 4).

Like all countries, Argentina was strongly affected by the 1929 crisis, international market prices fell dramatically, causing a 40 to 50% drop in the value of the country's exports. In response, the government intervened in the market for the first time (Hora, 2012: 146-65; Cadenazzi, 2002; Barsky, 1988: 32). In 1933 it created a Regulatory Agency for Grains (Junta Reguladora de Granos) which was to act in support of market prices. To make the system operational, the government started to operate a national storage system to hold grains off the market. In 1935 the intervention process was deepened by the creation of the National Commission for Grains and Elevators, which involved the government in the whole process of production and commercialization of grains and seeds (Arriaga, 1999: 14). This direct intervention in the production and commercialization of grains continued until the 1950s. During this period there was relative stability in the productivity of the main grains produced in Argentina (Campos & Sanches Júnior, 2017: 124). From then on, the government started to operate with less interventionist mechanisms. In 1956, the National Institute of Agricultural Technology (INTA) was created to provide basic agricultural research and it proved to be of fundamental importance in the modernization of Argentine agriculture, playing a role similar to Embrapa in Brazil. Initially it incorporated all existing experimental stations which had been in existence from the be-

ginning of the century, and its funding was based on the collection of a 1.5% tax on agricultural exports (Pellegrini, 2014; Campos & Sanches Júnior, 2017: 125).

While government intervention in the agricultural market has waxed and waned over time, this dynamic has been a fundamental part of the national agricultural scene for some time. Since the middle of the twentieth century Argentine agricultural development has been influenced by these continuous periods of intervention followed by commercial liberation. Thus in 1973 the government again introduced a broad system of state intervention in the production and commercialization of grains. The State fixed prices and even established quotas on exports. This system lasted until 1977, when it returned to the free market. The decades of the 1970s and 1980s were a period of profound political and economic crisis in Argentina. Inflation reached levels of hyperinflation; orthodox and heterodox measures were tried and failed. There was great instability in the gross domestic product, which between 1971 and 1990 increased by only 0.6% on average. The agricultural sector fell by 4.7 points between 1983 and 1989, declining to a share of 10.7% of GDP (Souza, 2007: 113; Lavarello, Gutman & Rios, 2010; World Bank, 1989).

The 1970s and 1980s also represented the oil crisis and the debt crisis, in which most countries in Latin America were forced to turn to the International Monetary Fund and adopted the "Washington Consensus" which included a de-regulation of the local market. In the case of Argentina, this process took place under the Menem government, which took office in July 1989. The government passed an Economic Emergency Law which suspended all subsidies, privileges and special regimes. It adjusted tariffs and devalued the national currency. During the 1990s successive agreements were signed with the IMF, but at the end of the 1990s Argentina was still facing a deep crisis (Cunha & Ferrari, 2006; Souza, 2007; Vianini, 2012).

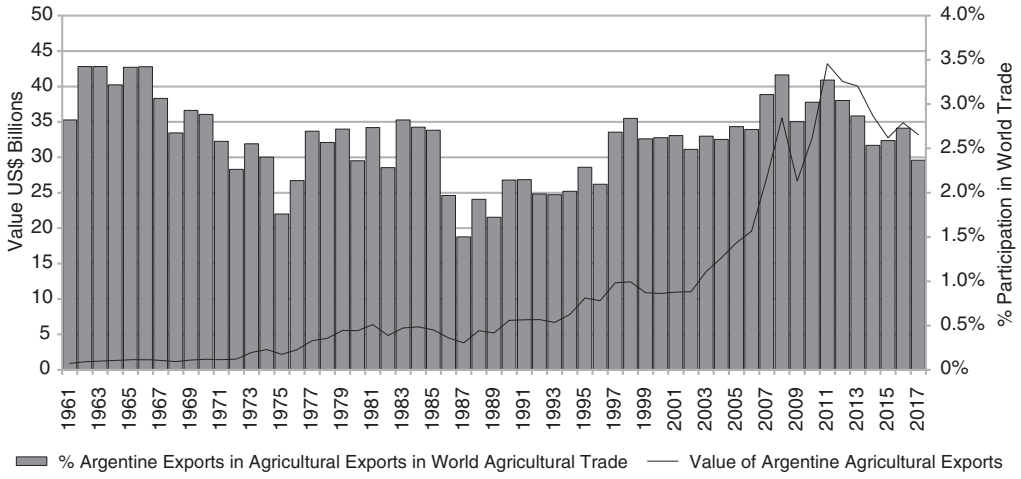
This type of interventionism in agriculture, particularly taxes or quotas on exports, as well as the low performance of the Argentine economy in general, and the successive external crises, affected the performance of the country's agriculture both in terms of production and productivity. The most affected segment would be meat, since its export was continually restricted by the government in order to keep national prices low by cutting off exports and forcing sales to be turned toward the internal market. All these constant interventions had an impact on the productivity of the factors of production in Argentine agriculture which showed little change from 1980-90 and 2001-09, especially when compared with Brazil (Fuglie, 2012; Lema, 2015; Lema, n.d.; Feitosa, Silva & Abreu, 2010; Ferreira *et al.*, 2016; Morais *et al.*, 2016). In these three decades Brazil had an average annual TFP (Total Factor Productivity) growth of 3%, while Argentina declined in the 1980s and only achieved a modest growth in the next two decades. This low perfor-

mance of Argentine agriculture especially compared to most developing countries in the period is explained in particular by the performance of livestock, which has had a TFP indicator since 1961 far below agricultural production, harming the results of agriculture as a whole (Fuglie, 2012: tabela A 16.2).

At the beginning of the 21st century, the world economic scenario changed, with significant growth in international trade and rapid expansion of international commodity prices, caused in large part by Asian performance, in particular by China's extraordinary growth. But at the same time the election of an anti-liberal and state developmental government brought a resumption of interventionist policies (Frenkel & Rapetti, 2011; Colombini, 2016). After a period of strong growth in the international market, the 2008 crisis and the dampening of international commodity prices, created new problems for several Latin American countries, especially for Argentina, which again showed extreme external weakness. Even the supposedly liberal Macri government was forced to promote wide intervention of the economy, including price freezes.

GRAPH 5

Total value of Argentine agricultural exports (in US$) and its participation in total world agricultural trade, 1961-2017



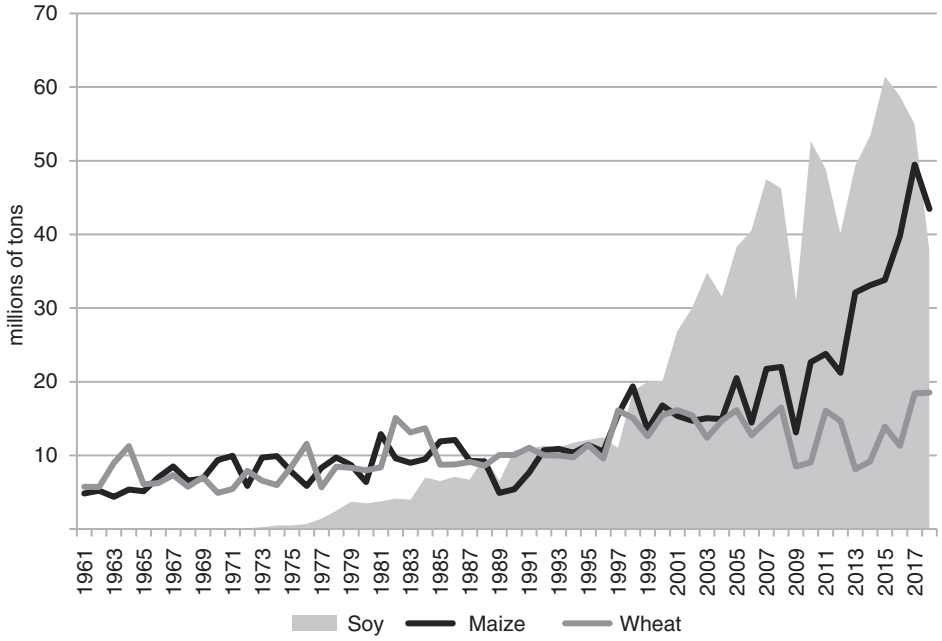
Source: Faostat (http://www.fao.org/faostat/en/#data/QA).

Argentine exports thus suffered the impacts of the world economic crises as well as the successive domestic crises. After a long period of relative stagnation in the 1970s and 1980s, there was both significant growth and abrupt declines throughout the last decade of the century. Finally in the first years of the 21st century Argentine agricultural pro-

duction and exports grew impressively due to the growth of international trade and the commodities price boom of the first two decades in the new century. Agricultural exports growth went from 10 billion dollars in 2000 to 31 billion dollars in 2018, but this expansion paralleled the expansion in world agricultural trade so that Argentina position fell to just 2% of world agricultural trade (see Graph 5). In the same period, Brazil increased its exports from 12 billion to 83 billion, reaching, and doubled its share in world exports to almost 6% in 2018.

GRAPH 6

Volume of maize, soy and wheat production in Argentina, 1961-2018 (in tons)

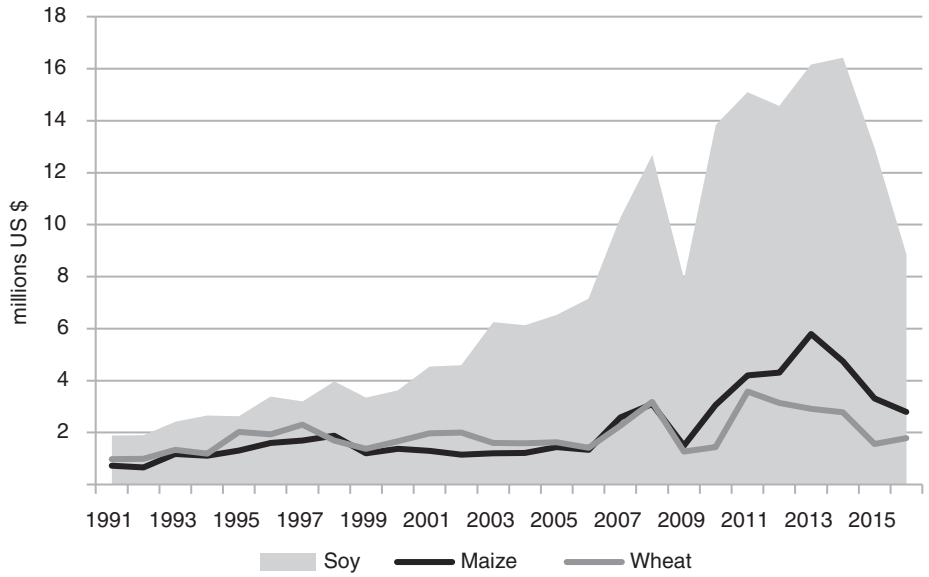


Source: Faostat (http://www.fao.org/faostat/en/#data/QA).

For most of its history agriculture remained both the predominant industry of Argentina and its primary export sector. But there have been important changes in the mix of these export crops with soybeans and their products and maize displacing wheat and meat in importance in the most recent period. In this period soybean production expanded greatly, but so did maize with output of the two highly correlated (.93). In contrast soybean growth was only moderately correlated with wheat expansion (see Graph 6). This growth was reflected in the value of these three crops which showed even more impressive differences. By 2017 the value of soybeans alone was five times that of wheat and three times larger than maize (see Graph 7).

GRAPH 7

Value of soy, wheat and maize crops in Argentina, 1991-2016 (in current US$)



Source: Faostat (http://www.fao.org/faostat/en/#data/QA).

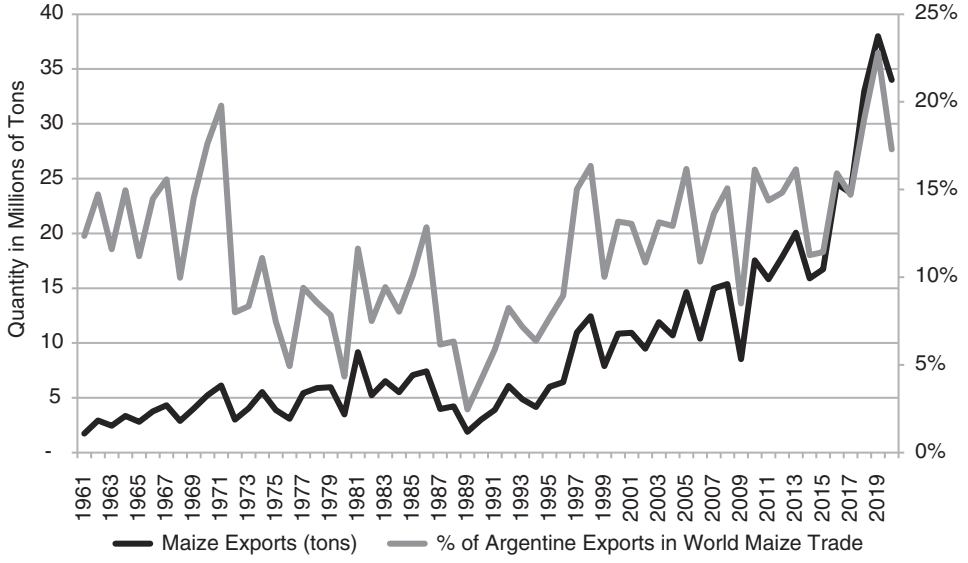
Although this growth has been propelled by the soy complex (meal, oil and beans) which reached 14 billion dollars (2018), maize was the second most important Argentine agricultural export in value. In that year it reached 4.4 billion dollars which was double the value of wheat exports and represented 7% of the value of total goods exported[6]. By the harvest of 2019-20 maize production reached 51 million tons, of which some 40 million tons was exported. This represented 23% of world exports of maize in that year (see Graphs 8). By this time, depending on the harvest, Argentina had become the world's second or third largest exporter of maize along with Brazil, and the world's fourth largest producer of this crop after the United States, China and Brazil. In that year the US share was just 27%, while together Brazil and Argentina accounted for 43% of the world maize export market (USDA, 2021b: 30).

Maize has been grown in Argentina since pre-Columbian times, historically adopting traditional methods of production. Although advances in seed development began in the 1930s, particularly in the United States, and Argentina played a predominant role in the international market, little was done in the latter country until the middle of the last cen-

6. Observatory of Economic Complexity (OEC), https://oec.world/en/profile/country/arg?redirect=btrue

tury (Vessuri, 2003). Thus, in the 1950s when in the United States more than two thirds of the maize planted came from hybrid seeds, in Argentina, this percentage did not exceed a tenth of planted maize (Rossi, 2007). This would be one of the factors explaining the extraordinary difference in maize productivity between the two countries with Argentina only obtaining a third of the yield obtained in the United States in the early 1960s. Today Argentine yields are up to 70% of the United States maize farmers.

GRAPH 8
Exports of Argentine maize and their importance in the world maize trade, 1961-2020

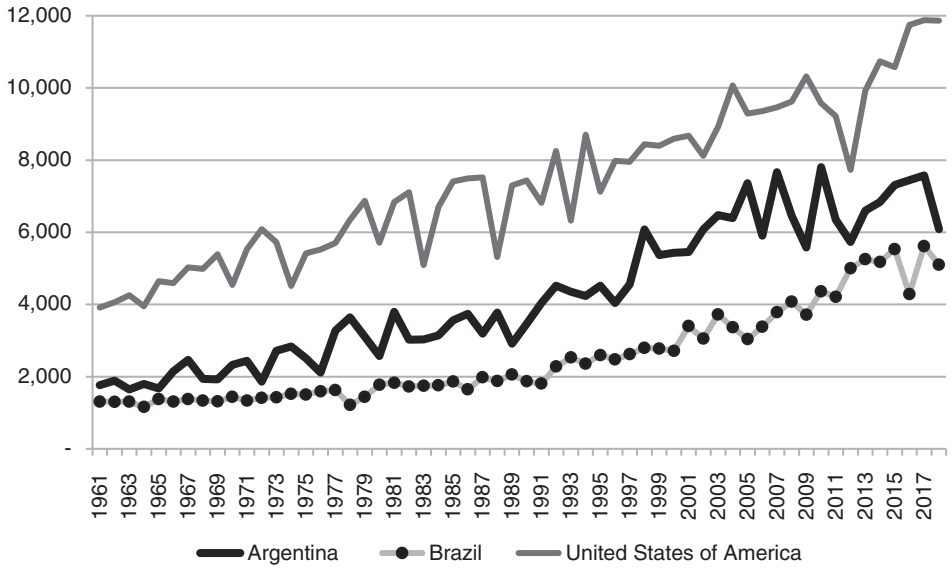


Source: Faostat (http://www.fao.org/faostat/en/#data/QA) and USDA (2021b: 30).

Since the 1950s, studies in Argentina on the development of hybrids have intensified, in processes led initially by the Ministry of Agriculture and later by INTA. The research then developed and the people trained in this field were subsequently used by private companies that dedicated themselves to the production of hybrids in the country (Rossi, 2007). Gradually the hybrid seed market was consolidated, with the growing participation of multinationals in the sector and new varieties emerged, but until the eighties simple hybrids predominated and Argentina produced most of these seeds (MAGyP, 2016; ASA, 2017; Agrovoz, 2020). From the 1990s, hybrids with tolerance to herbicides also appeared and in 1998 the commercialization of genetically modified organisms (GMOs) was approved. Although there was significant growth in maize productivity, particularly since the 1990s, the levels reached by Argentina have always been well below the levels of productivity in

the United States, but they have narrowed over time. Moreover, Argentine yields have consistently been better than those obtained by Brazil (see Graph 9).

GRAPH 9
Maize yield in Argentina, Brazil and USA, 1961-2017 (kg/ha)



Source: Faostat (http://www.fao.org/faostat/en/#data/QA).

Until the end of the 1980s, Argentine agriculture still had the traditional characteristics of production. Although technological improvements had occurred, they were predominantly concentrated in processes, such as mechanization, but still with little use of fertilizers. In livestock, natural pastures still predominated. There were some timid advances, but with little impact on agricultural productivity, making Argentina less competitive on the international market. On the other hand, the low intensity of the crops, in many ways largely preserved the quality of the soils (Reboratti, 2010: 64; Balsa, 2004). The great transformation occurred with the introduction of genetically modified seeds in soybean cultivation. In 1996, a genetically modified soybean called RR soy, produced by Monsanto, was launched in the United States and in the same year it was approved by the Argentine authorities. This seed was glyphosate-resistant, which was the active ingredient in Herbicide Roundup, which could now be used to control weeds. Since then, the use of this gm seed has had an explosive expansion. At the same time in 1998 two transgenic maize seeds were approved, one resistant to lepidopteran insects and the other resistant to the herbicide glufosinate. In 2004, glyphosate-tolerant maize, the so-called RR maize, was launched, which was as successful with maize production as it had been with soybean pro-

duction. With the launch of RR maize, hybrid use became almost universal, reaching over 95% of farm producers (Rossi, 2007).

Thus from the final years of the 20th century until the middle of the second decade of this century, there was also an important growth in the area planted with maize and increasing yields per hectare[7]. Comparing the yields obtained by maize, wheat and soybeans in the average of the last three years (2017-19), with the average yields obtained in the 1999-2001 trienniums, maize multiplied by 3.3, soy by 2.2 and wheat by 1.3 (Barsky & Gelman, 2001: 37, graph 2; MAGyP, 2020a) This was clearly due to the introduction of genetically modified seed.

According to data from ArgenBio, there are currently 61 genetically modified organisms in Argentina, of which 34 are for maize (ArgenBio, 2020). Although there was a slower penetration of genetically modified maize crops, when compared to soybeans, growth has been continuous and accelerated in the 2017-18 crop. Genetically modified Hidrido Bt2 RR maize represented 25% of hybrids in the 2012-13 crop, 36% in the following crop, reached 57% in the 2016-17 crop and increased to 77% in the 2017-18 crop. The use of RR products, both in soybeans and in maize, is directly associated with no-tillage, which reached practically the totality of maize planting in Argentina by 2020 (Cap, 2012). No-till planting evolved gradually from the late 1980s and reached 38% of all corn grown being under no-till farming system by the end of that century. Two years later it was used on two thirds of the corn harvest and by 2010-12 it was over 90% (Nocelli, 2018: 8).

Given the large agricultural research establishment, the nation was able to develop its own management techniques to adapt this technological advance to the specific conditions of the country (Alapin, 2009; *Siembra Directa*, 2011; Nocelli, 2018). The planting was widely accepted because it gave positive results in output, reduced time of planting and improved soil quality. In addition, the use of no-tillage planting led to crop rotation and increased use of fertilizers (*Siembra Directa*, 2011: 4). As in Brazil, the no tillage planting (called *siembra directa* in Argentina) and new seeds led to the growth of the first and second harvest maize plantings. The first was called the *siembra temprana* and the second the *siembra tardía*. Throughout the harvests of the 2010s, we see a relative balance between the two harvests. In 2017-18 for example, the early harvest produced 54% of to-

7. Studies that seek to demonstrate the relative profitability of the various crops, present very unstable results in Argentina, due to the strong fluctuations in the exchange rate, the variation in land rental prices, and the erratic policy of confiscation in exports, which affect various products differently. For the 2017-18 harvest, see Emilio (2019) and Agrositio (2020).

tal maize production and the second harvest 46%, little different from earlier years or later years. In that same year 99% of the maize produced was from hybrids and 55% of the farms were considered to be operating at a high technical level and another 41% at a medium technical level (Gago, Gianatiempo & Lópes, 2018).

In Argentina maize matures in different ecological zones at different rates. In the south-eastern region of the province of Buenos Aires it grows in 110-115 days. It takes between 113-125 days in the central Pampa region and in the subtropical areas 125-130 days (Gear, 2006: 5). In Argentina the key problem was declining fertility of soils from single cropping. Maize turns out to be an excellent crop for maintaining soil quality and thus double cropping was developed with maize being the first crop and soybeans the second –the reverse of the double cropping in Brazil (Gear, 2006: 7).

In the 2019-20 harvest, 9.5 million hectares of maize were planted, of which 7.7 million were harvested, from which total production of 58 million tons was obtained, with a yield of 7.6 tons per hectare harvested. Córdoba accounted for 33% of production and Buenos Aires for 27%. If we include Santa Fe, these three provinces accounted for 72% of the national production. The highest productivity occurred in four provinces –the three largest producers and Entre Rios. These same provinces, but with Buenos Aires in the lead, are also the areas with the highest production of soybeans, as well as wheat (see Table 9).

Another basic difference in maize production is that in Argentina corporations rent land to produce maize, contracting out to specialized firms to plant, maintain and harvest the crop. The owner of the land is thus not the producer of the crop. This unusual renting system is of minor importance in Brazil were almost all producers are farm land owners, although contracting services are sometimes used for planting and harvesting. The growing of soybeans, especially in the Pampa region, has led to a very rapid rise in land prices. Because of this price inflation, producers have increasingly turned to renting or leasing land, a long tradition in Argentina which was a well-established practice in traditional grain production (Flichman, 1977: 89). By the agricultural census of 1969, the larger the farm size, the greater was the importance of renters, and by the end of the 20th century renter-producer produced half the crops in the province of Buenos Aires (Llovet, 1988). It is estimated that in the census of 2002 some 70% of the farmland in the rich Pampa region was rented, and then usually for just one planting season (Piñeiro & Villarreal, 2005: 34). This was both a response to increasing land costs and the uncertainties of government policies. Beginning in the 1990s appeared a new type of renter, which was unique to Argentina, of *pooles de siembra* or planting pools established primarily for soybean and maize production which gathers together small amounts of capital of diverse origin in an in-

vestment fund and during a fixed period of one or more seasons it rents lands and then contracts with third party services to plant, maintain and then harvest the crop[8].

TABLE 9
Area planted and production of maize by province in Argentina, 2019-20

Province	Area Planted hectares	Area Harvested hectares	Producción in tons	Yield tons/hectare
Córdoba	2,924,573	2,467,227	19,196,764	7.8
Buenos Aires	2,472,520	1,923,178	15,595,357	8.1
Santa Fe	1,120,960	872,060	7,370,856	8.5
Santiago Del Estero	811,060	760,760	5,653,025	7.4
Entre Ríos	488,300	421,370	2,872,233	6.8
La Pampa	529,500	290,832	2,364,777	8.1
Salta	303,655	280,759	1,878,683	6.7
San Luis	375,500	328,600	1,327,270	4.0
Chaco	279,602	227,236	1,306,732	5.8
Tucumán	89,110	83,960	429,564	5.1
Misiones	31,150	30,130	149,809	5.0
Catamarca	16,200	14,950	91,326	6.1
Corrientes	12,099	11,000	69,301	6.3
Formosa	45,000	13,700	61,650	4.5
Jujuy	5,244	4,744	28,464	6.0
Total	9,504,473	7,730,506	58,395,811	7.6

Source: MAGyP (2020b).

These service companies emerged because of the high cost of the ever more complex machinery and the need for specialized workers. This led to the full development of planting, irrigating and harvesting companies, called *contratistas de cosecha* independent of the producer (Bisang, Anlló & Campi, 2008: 176). In maize production these companies provide three basic services. The first is preparing the soil and sowing the seeds *(siembra)*, the second is spraying *(pulverización)* the fields with water as well as pesticides, herbicides and whatever nutrients are needed, and finally harvesting *(cosecha)*. Of these three tasks, the most expensive is the harvest followed by the sowing of the seeds. For technical reasons the costs per hectare of harvesting maize is 1.4 times more costly than harvesting soybeans. Also the larger the maize farm, the higher the returns in servicing the maize crop (Moltoni, Duro & Masia, 2015: 2, 4). For all their fixed machine

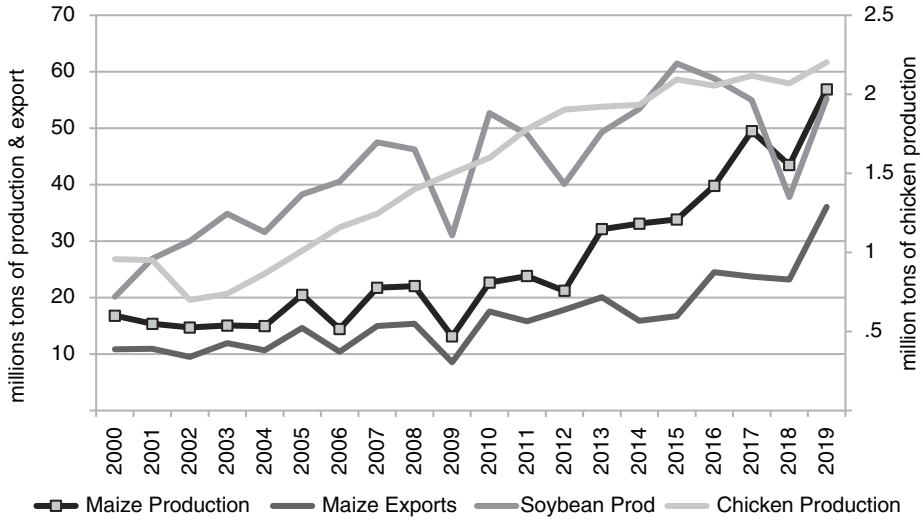
8. On the origins of this system (Lódola & Fossati, 2003: 7). For a detailed analysis of these pool arrangements, see Caligaris (2015), Murmis and Murmis (2012), Ortega (2017), and Dagotto (2008).

and labor costs, *contratistas* are estimated to account for less than 14% of the total costs of production to the renter or landowner who contracts their services (Villulla & Chen, 2015: 112-13). Moreover, it is the *contratistas* who provide most of the labor with the renters usually employing just a professional agronomist and a head peon. Sometimes one company does all three services, but most often there are three separate companies providing the services. A great many of these are family run companies with almost all the workers coming from the owner's family. Even so the costs of owning and running the required machinery are substantial and their usage requires constant renovation of machines (Muzlera, 2010). Given these costs, it is these *contratistas* who purchases most of the farm machinery sold in Argentina (Garavello, 2017). By 2002 it was estimated that two thirds of all grain farms used these services and by 2012-13 they worked on 23.5 million hectares (Moltoni, Duro & Masia, 2015: 1). As of the census of 2002 some 47% of the 134,000 agricultural enterprises (known as EAP or farms) of the Pampa region used such firms (Piñeiro & Villarreal, 2005: 34). This *contratista* system accounts for about a quarter of Argentine GDP and over half of the value of all exports in the second decade of the 21st century (Bisang, Anlló & Campi, 2008: 172). For the small farmers who are also producers of maize, an alternative has been their incorporation into complex value chains with processing companies providing inputs for payments in maize after harvesting, a system not that dissimilar from what some producers do in Brazil (Gutman, 2008).

Finally, this growth in maize production permitted Argentine meat producers to shift a growing share of cattle production from pastures to feedlots (Arelovich, Bravo & Martínez, 2011: 39), so as to free pasture lands for soybean and maize production (Klein & Luna, 2021). The breeding of livestock in confined areas has greatly expanded throughout Argentina and usually comes at a negative cost of local environmental conditions with the abandonment of good pastures lands to agricultural production (Horak, Assef & Miserendino, 2019). Also, the transition from pasture to crops and the shift of animals to feedlots has led to the increased the emission of environmentally negative gases into the atmosphere (Castesana *et al.*, 2018). While maize and soy meal animal feed permitted a shift in the system of beef feeding in Argentina, it had little impact on beef exports which from 1980 were small in volume and quite erratic. This long decline is due both to the massive shift to soybean production and the reduction of herds, as much as to negative government policies hostile to beef exports (Graziani, 2018). But this growth of maize production led to a major increase in maize exports, and it also had an impact on chicken production in the same period. Chickens, the primary consumers of animal feed, of which maize was a basic ingredient, experienced an extraordinary growth in numbers which went from a stock of 109 million to 120 million birds in the period 2000-19 and was correlated with the growth of maize output (see Graph 10). By the harvest of

2019-20 some three quarters of internally consumed corn went for animal feed (Bolsa de Comercio de Rosario, 2020)[9].

GRAPH 10
Argentine production, and exportation of maize and exports of chicken meat, 2000-19



Source: Faostat (http://www.fao.org/faostat/en/#data/QA).

5. CONCLUSION

By the beginning of the third decade of the 21st century the evolution of these two maize producers had reached the point that together they now exported more maize than the United States, the world leader in maize exports. This major growth of modern maize was based in both countries on similar developments. Both quickly and massively adopted GMO maize seeds, both associated maize with the booming soybean expansion, and both adopted direct or no-till planting and double cropping. But the structure of production was different in both nations, with Brazil evolving through traditional land ownership and production, and Argentina developing a high capitalism system of pooled capital producers, rented land and service providers to do the planting, maintenance and harvesting of crops. In both cases maize went from being a traditional crop of low yield production

9. For the two decades 2000-19 the correlation in Argentina between maize and soybean production was .69 and .83 for the relation between maize output and chicken meat production. Both significant but lower correlations than in Brazil.

to a highly commercialized product capable of competition in the world market. Moreover, in both nations, more rapidly in terms of Brazil and more delayed in terms of Argentina, this boom in maize production would have a major impact internally. In the case of Brazil it lead to a brand new export product, that of meat. In the case of Argentina it permitted farmers and cattlemen to shift from cattle to the more profitable and less state controlled soybean production and permitted a steady shift toward stockyard feeding on an ever larger scale, which potentially could lead to greater exports of meat, at least as trends in the last five years have indicated. That of course could change with the changing government policies toward Argentine beef exports, one of the more sensitive exports of the country.

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