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Agricultural Productivity in Argentina

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Abstract

The main objective of this paper is to estimate the Total Factor Productivity (TFP) growth in the Argentine agricultural sector. First, the paper examines trends and changes in aggregate agricultural production, sources of growth and productivity over the period 1913-2010. It then analyzes the productivity growth in the two main subsectors in argentine agriculture, grains and livestock, for the period 1961-2010. TFP was calculated using the Törnqvist index, which is a discrete approximation to the Divisia index. The data used to estimate the output and input indexes are prices and quantities for 4 grain crops, livestock, and for four inputs —labor, land, capital and fertilizers. The results for aggregate agricultural sector show that the annual rate of annual for the period 1913-2010 was 1.8% and 0.3%, for products and inputs respectively. Therefore, the TFP grew at an average annual rate of 1.5%. Finally, the paper examines the dominant growth profile, either extensive (factor accumulation and utilization) or intensive (productivity gains), in particular during the last two decades, in the grain and livestock subsectors.

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1 INTRODUCTION

Since the late nineteenth century, Argentina has being an important global supplier of agricultural raw materials and food. From 1960 to 2010, data from FAO shows that Argentina represents in average 1.5% and 4.3% of the global area of cereals and oilseed respectively, and the 1.6% and 4.1% of the global cereal and oilseed production (FAOSTAT, 2015). Through the last decades, the country experienced an important change in land use, and hence in its productivity. Land dedicated to livestock, dairy and even new areas were slowly changing to oilseed production. Currently, Argentina performs similar yields of wheat, corn and soybeans than its major competitors. The beef and dairy sector also changed, especially in allocated area, location and individual productivity. Historically, these both production systems were based on pasture and grassland. However, as cattle was moving into new and marginal areas, farmers started to use grains to feed its herds. Therefore, the evolution of productivity has became an important topic to examine national capabilities of the agricultural sector to increase production, but also to help in identifying factorial and non-factorial sources of its growth.

Recent literature about TFP in agriculture suggest that there is much less research made over Latin America and the Caribbean (LAC), and especially about Argentina. Ludeña (2010) reports that most of the studies on TFP refer to groups of countries and time series prior 2000, and only one until 2007. Especially in LAC there are few references for specific country studies, for example in Argentina (Lema and Brescia, 2003; Lema and Parellada, 2000, Lema and Battaglia, 1998), in Brazil (Rada, Buccola and Fuglie, 2010; Pereira et al., 2002; Gasques and Conceição, 2001; Day Avila and Evenson, 1995), in Chile (Olavarria, Bravo-Ureta and Cocchi, 2004), in Colombia (Romano, 1993), in Mexico (Fernandez-Cornejo and Shumway, 1997), in Uruguay (Arancet and Calvete, 2003), other work in the Andean Region (Pfeiffer, 2003), and in South American countries (Bharati and Fulginiti, 2007). Ludeña (2010) and Diaz Avila, Romano and Garagorry (2010) have more recent studies in the region. The first author performed an extensive study on the agricultural productivity growth in LAC and other regions, between 1960 and 2007, and found that LAC regions had high productivity growth rates in the last two decades, more due to technological change rather than improvements in efficiency.

Some studies about agricultural TFP in Argentina show heterogeneity in their estimates: while some authors have found a negative TFP growth rate, others found positive rates. For example, TFP growth rates of -2.70% were estimated by Coelli and Rao (2005) between 1980-

2000, -1.85% by Arnade (1998) between 1961-1993, -2.63% by Trueblood and Coggins (2003) between 1961-1991; and even higher (in absolute values) by Fulginiti and Perrin (1998), -4.8% between 1961-1985. On the other hand, positives growth rates for agricultural TFP were estimated by Nin and Yu (2008): 2.88% between 1964-2003, by Lanteri (1994): 1.94% between 1964-1992, and by Elias (1992): 0.49% and 1.09% for the 60s and 70s, respectively. A more closer inspection over those studies reveal additional heterogeneities. From the same data from FAO, Nin and Yu (2008) indicate that TFP grew slowly from 1984 to 2003 (with an annual average growth rate of 1.97% between 1963-1984 and 2.88% between 1964-2003); while Diaz Avila and Evenson (2004) found a higher TFP rate of 1.83% for 1961-1980 and 2.35% for 1981-2001. Others as Coelli and Rao (2005) show that using the Tornqvist index (instead of Malmquist index) the estimates changes from -2.7% to 0.4%. Fulginiti and Perrin (1998) found that the TFP fell at an average annual rate of -4.8% between 1961-1985; whereas using stochastic frontier the TFP growth rate was 3.47% per year between 1972-1981, and 1.38% between1982-1991 (Fulginiti and Bharati, 2007).

Others studies have identified several sources of agricultural growth and TFP evolution through the argentine history, especially regarding to the use of inputs (land, labor and capital), government policies or institutional change, technological change, as well as other sources. For example, Ballesteros (1957) found that after the World War II policies adopted by the argentine government negatively affected the relative prices of the major grains (wheat, corn and flax), the rural labor, and therefore the agricultural production growth rate. Diaz Alejandro (1975) states that these policies made that only a small part of new technological developments were incorporated in the country. Estimates from Cavallo and Mundlak (1982) shows that agriculture grew 1.4% between 1940-1972, (slower than the 1.8% observed between 1908-1920) as a consequence in price controls and government taxes imposed to the rural sector. Fulginiti and Perrin (1990) estimates suggest that interventions in agriculture significantly reduced the rate of growth between 1940-1980, and could have reduced the aggregate agricultural production in around 25% to 30%. However, the trends seems to reverse during the 60s, since then important technological changes were observed especially in agriculture by the use of fertilizers, herbicides, machinery, seed, and new agricultural practices and farm management.

Some others authors focused their analysis on the use of inputs and sources of TFP change. Elias (1992) found a rise in the use of land and capital between 1950-1980, but an

opposite trend in labor due to an important migration to the cities (induced by wage differentials) and also that TFP explains 21% of total agricultural growth. Lema (2010) found that between 1968-2008, TFP can explain 68% of the total agricultural growth. Gallacher (1999) made an estimate of TFP growth for six regions and several agricultural activities, finding differences on TFP growth among them. The maximum TFP growth was in wheat (5% annually), followed by soybean (2.4-2.8%), sunflower (1-3%) and corn (1%). Improvement in production and productivity in the last two decades was largely due to the use of new agricultural inputs, increased storage capacity ("silo-bag" storage) , genetically modified seeds in soybean, maize, cotton (Trigo and Cap, 2006), improved machinery and "zero tillage" practices (Parellada and Ekboir, 2002). All those factors contributed to the expansion of the agricultural frontier and also to an increase in the intensive margin in the use of land.

The rest of this paper is organized as follows: first a conceptual framework and methodology for TFP estimates is presented. Second, we present estimates of the evolution of TFP in three levels of analysis: the aggregate agricultural sector from 1913 to 2010, and the crop and livestock sector from 1960 to 2010. The final section presents a discussion of possible sources of TFP growth and some policy implications.

2 METHODOLOGY

2.1 CONCEPTUAL FRAMEWORK

Coelli, Prasada Rao, O'Donnell, Battese (2005) highlight four methods to estimate the TFP: a) econometric models, b) index of total factor productivity (TFP) (Tornqvist / Fisher), c) data envelopment analysis (DEA); and d) stochastic frontier (SF). In this paper we use the Tornqvist index approach. This index number capture the influence in prices and quantities changes over time, and especially when there are structural changes due to activities substitution. This structural change effect, or different vectors of inputs and outputs, is common in agriculture as farmers decisions are linked to the prevailing relative prices of the year. TFP estimate from Tornqvist index of output and input follow this calculation[3]:

$$\ln PTFst = \ln \text{Output Index}_{st} - \ln \text{Input Index}_{st} \quad (1)$$

[3] Product, inputs and TFP Tornqvist indices were estimated using the "TFP INDEX PROGRAM" software from the Center Efficiency and Productivity Analysis, Department of Econometrics, University of New England.

$$= \frac{1}{2}\sum_{i=1}^{n}[w_{is} + w_{it}][\ln y_{it} - \ln y_{is}] - \frac{1}{2}\sum_{j=1}^{k}[v_{js} + v_{jt}][\ln x_{jt} - \ln x_{js}] \quad (2)$$

s y t two periods of time

y output vector

w weight of products in each period

x input vector

v weights of inputs

2.2 DATA

Data of prices and quantities of inputs and outputs were collected from several sources. For the total agricultural sector we compile information of over nearly 100 years for each variable and it is important to note some limitations: (i) the data and its source can not be the same along the series, and hence connections between sets require additional estimates, and they may involve restrictive assumptions; (ii) outputs and inputs are not homogeneous over time, and may require quality adjustments. Thus, there may be potential omitted variables; (iii) there may be environmental issues (climate change, natural resources changes) affecting TFP that are not necessarily represented in a quantitative indicator of inputs and outputs.

Output

The total agricultural output is approached by the agricultural value added (crops and livestock sector only) in constant pesos of 1993 from national accounts[4]. The series is from 1913 to 2010, and is constructed as follows: i) 1913-2008 is based on the series from Ferreres (2010), and ii) 2009-2010 it based on unpublished series of national accounts from MECON[5]. To connect both series, the growth rates of MECON were imputed in the series from INDEC.

The output for the crop sector is calculated from quantities and prices of the four major grains (wheat, corn, sunflower and soybean), published by MINAGRI[6].

[4] INDEC: Instituto Nacional de Estadisticas y Censos (http://www.indec.mecon.ar)
[5] MECON: Ministerio de Economia y Finanzas Publicas (http://www.mecon.gov.ar)
[6] SIIA: Sistema Integrado de Información agropecuaria (http://www.siia.gov.ar)

The output for the livestock sector is approached by the livestock value added from the national account published by Ferreres (2010) from 1960-2008, years 2009-2010 were estimated from unpublished series of national accounts from MECON.

Land

The total agricultural land series in hectares for 1913-2010 was constructed as follows: i) 1913-1984 from the time series published by the journal Estudios Fundación Mediterranea (1986); and ii) 1985-2010 period was estimated applying to the time series in *i)*, the grow rates of the cultivated area from the database published by Frank[7].

The crop area in hectares for wheat, corn, soybean and sunflower was obtained from SIIA-MINAGRI, for the period 1961-2010. The area for livestock was taken from the statistics published by FAO (2015) on permanent meadows and pastures (in hectares).

Labor

The labor series for total agricultural sector for 1913-2010 was constructed by splicing the series of labor from the journal Estudios Fundación Mediterranea (1986) with the data of rural labor from ECLAC for 1980-2010, and then adjusted by the unemployment level. For crop sector, labor series from 1960 to 2010 are expressed as number of people employed. This was estimated adding the man hour per hectare for the four main crops (wheat, soybean, sunflower, and corn) by decades taken from the Frank's database, multiplied by the total sown area for each crop published by Ferreres (2010). This total of man hour per year was used to estimate the total number of people working in agriculture, assuming an average of 45 hours/week of work. For livestock sector, the labor variable was estimated assuming one full time worker every 600 cows (data provided by personal reference in the industry and MINAGRI[8], 2015).

Capital Stock

Capital stock for 1913-2010 is expressed in constant pesos of 1993. The complete series was constructed by splicing different sources of data, as follows: i) 1913-1984 the data of agricultural capital deflated and expressed in millions pesos of 1993, from the journal of Estudios Fundación

[7] The Rodolfo Frank database (http://www.anav.org.ar/sites_personales/5/)
[8] http://www.minagri.gob.ar/dimeagro/indicadores/metodologia.php

Mediterranea (1986); ii) 1984-1990 it was performed a regression with capital from the journal Estudios Fundación Mediterranea (1986) as dependent variable, and independent variables machinery and constructions from Goldberg (1988), and cattle stock from Ferreres (2010) for 1970-1984. Then, the predicted values for the regression were estimated for the period 1985-1990; and iii) 1990-2010 it was spliced by using the values of agricultural capital stock without land, published by Coremberg (2009, 2011).

For crop sector, capital stock was weighted by the share of the crop sector in the agricultural value added, for the period 1961-2010. For livestock sector, the animal stock was taken as an estimate of the capital stock.

Others inputs

Fertilizers were considered as consumption of equivalent tonnes of nutrients (nitrogen "N", Potassium "K", and Phosphorus "P"), for 1961-2010 and published by FAOSTAT and Fundación Fertilizar (2014).

Prices

All prices used in the estimates are in constant pesos of 1993, deflated by the General Wholesale Price Index.

a. Land Price

Estimates for the aggregate agricultural sector and crop sector:

The land price series for 1913-2010 was built from: i) 1913-1915, Mundlak and Cavallo (1986), ii) 1916-1977 is the average price of land for wheat, corn, and livestock from Ras and Levis (1979); and iii) 1978-2010 from AACREA (2014) for crop and livestock land prices.

Since 2000 it was observed an important upward trend in the land value, describing a exponential rising pattern probably related to the increase in agricultural prices and also to the behavior of financial markets after the "convertibility" crisis in 2001. In order to avoid that bias in the real price of land, it was performed a regression with the land price as dependent variable and a trend, a dummy variable for the structural break in 2001, and the interaction between the last both as independent variables. From the errors estimated from this regression and the trend coefficient until 2001, a new variable was created as the sum of the long-term trend (1913-2001) and the errors from the whole regression. Therefore, the structural break (the shift in price

growth) was eliminated, and it was projected the structural trend by removing the breakdown effect, and then the errors were added to build the adjusted price of the land.

Livestock sector:

The price of land for the livestock sector was built adjusting the price of land for the aggregate agriculture and crop sector with a coefficient that represents the ratio between price of land for corn to the price of land for livestock. This ratio was estimated from the land price series from Ras and Levis (1979).

b. Rental Rate for Capital and land

The rental rate for land and capital was estimated following the methodology presented by Fulginiti and Perrin (1990). The rental rate was used as the rental price for the value of capital stock and the value of land stock.

c. Wages

Wages from 1913-2010 was spliced as follows: 1) 1913-1976 from the journal of Estudios Fundación Mediterranea (1986); and ii) 1977-2010 from AACREA.

d. Fertilizer prices

Prices of fertilizers in tonnes (nitrogen and phosphorus) were taken from AACREA database This prices were also adjusted in terms of nutrients (N, P, K) equivalent.

e. Crops prices

Crops prices at a farm level were taken from Ferreres (2010) and Ministry of Agriculture database[9].

f. Livestock prices

The livestock price series was calculated as a weighted average of different type of animals in the stock: steers, calves, cows, heifers and bulls. Prices were estimated from AACREA database, Márgenes Agropecuarios and Ferreres (2010)

3 RESULTS

Results are presented for the aggregate agricultural sector from 1913 to 2010, and for the crop and livestock sector from 1960 to 2010. Indexes of output, inputs and TFP are presented, by

[9] SIIA: Sistema Integrado de Información agropecuaria (http://www.siia.gov.ar)

decades, and also, for comparison purposes, by the same periods used by Diaz Avila and Evenson (2010): 1961-1980 and 1981-2000[10].

3.1 TRENDS IN OUTPUT, INPUTS AND TFP

The estimates show that during 1913-2010, the TFP of the aggregate agricultural sector grew at an annual average rate of 1.5%[11], explaining around 86% of the output growth, while inputs (land, capital and labor) the 14%.

[Table 7-1, able 7-2, Table 7-3, Table 7-4,

[10] A comparison of results is presented in [Table 7-6]

[11] All growth rates of output and inputs were obtained as a result of estimating the parameter β log-linear regression (log y = α + β * time - trend). Three-year moving averages are then estimated.

Table 7-5]

[Figure 7-1, Figure 7-2, Figure 7-3, Figure 7-4, Figure 7-5, Figure 7-6, Figure 7-7]

At the beginning of 1900 and during the first decades (1910 to 1940), Argentina had an important agricultural export profile. The output was growing at an annual rate of 2% and 3.4% by the end of 40s. At that time, productivity grew from 1.5% to 2.9% (between in 1913-1920 and 1930-1940). Agriculture was based on wheat, maize, flax and livestock. Labor represented on average almost 68% of the total inputs. The country has achieved political stability, that together with decreasing costs of overseas transport and the increment of the food global demand; fostered agricultural exports. It is important to note that between 1930-1940, the growth rate in input use was 0.4% per year while productivity raised 2.9% per year. However, during the 40s (1940-1950) the policy environment affected the economic model, and therefore its productivity trend. It was a decade where it was imposed a "import substitution" policy, which was based on import restrictions on capital goods and a strong promotion of the national industry. Also, differentials in wages induced a strong rural migration to the cities. As a result of the decline in input use (whose growth rate went from 0.4% to 0.1% per year), the agricultural output declined from 3.4% to -0.2% per year, and consequently the annual productivity decreased at an annual rate of -0.3%.

There were other policies affecting the performance of the agricultural sector. During the 40s and 50s, started new regulations on land lease, transport, and rural wages. In 1947 the Rural Worker Commission established minimum wages and conditions for seasonal workers. Farmers could only recruit new labor through the district union, and they were no able to use family labor. For example, if a farmer had a harvester, he could only use it on his farm and not in another property, except he hires an employee from the union. This regulation contributed to increased harvesting costs, which probably impacted the efficiency levels of the decade. By the 50s, the aggregate agricultural output recovered to an annual rate of 1.9%, and productivity grew at a 1.4% per year, explaining 78% of the output increase, while 22% was explained by inputs use (annual rates for labor, capital and land were -2.4%, 1.6%, 6.8% respectively).

The following decades (1960 and 1980) presented a rebound in output which grew at a rate of 2.4% per year, explained by productivity gains in 66% (which grew at 1.6% per year), and the remaining 33% due to input use (land 3.2% and capital 1.3% per year). Labor force

continued to fall at -0.6% per year. The crop output grew at an annual rate of 1% and the livestock output at 2%, while its TFPs evolved at -1.7% and 0.2% per year, respectively. In both cases, output was based in land expansion, capital (animal stock and machinery) and fertilizers. Also, the livestock sector increased its labor use (at 1.8% annual rate) probably linked to the expansion of the cattle stock.

From 1981-2001 the crop sector grew at 3.2% and livestock at 1% per year; and the annual TFP growth rates were 1.3% for crop sector, and 0.8% for the livestock sector. This 20-year period comprises two phases based on different macroeconomic policies: the first phase from 1980-1990, and the second form 1990-2000.

During the first phase (1980-1990) the aggregate agricultural output grew at 0.7% per year, a lower rate than the previous period, and this decline is strongly linked to a lower use of land (which decreased at -3.7% per year), capital (-1.1% per year) and labor (-0.6% per year). The same trend is reflected in the crop and livestock sector, and thus resulting in positive productivity growth rates in each case. In the crop sector, productivity increased at 1.6% per year and this is related to the increased use of fertilizers (that grew at 5% per year), even though the rest of the inputs declined. Similar trend is depicted by the livestock sector, whose output annual growth rate was 0.1% due to a sharp fall in land use (-4.5%), capital and labor (-0.4%), and therefore showing a productivity growth rate of 3.1% per year.

In the second phase (1990-2000), the macro policy turns towards a more open and deregulated economy. The output of the aggregate agriculture recovered and the annual growth rate was 2.7% (90s) and 2.8% (2000s), but based on different source of growth: in the 90's it was mostly due to greater use of inputs, while in 2000-10 the growth was explained by productivity gains. Analyzing by sector, crops were more dynamic than livestock, growing at 5.8% per year. This was derived from increments in capital (2.7%), introduction of inputs such as fertilizers (which grew at 17.2% per year) and land expansion. This trend is observed both in agriculture and livestock.

It is important to highlight the land expansion process. During this period (1990-2000), the agricultural area expanded annually at 10.4% in the aggregate agricultural level, 11.5% in the crop sector, and 8.7% in the livestock sector. The more important expansion was in crops, which new land came mostly from grazing areas. The expansion for cattle area was mostly related to new developments in marginal areas, out of the Pampa region. Together with this process,

appeared a new agent called “the contractor” which offers several farming services (planting, harvesting and others) with its own machinery to others farmers. This agent, gave more flexibility for agricultural management, decreasing its production costs. Therefore, farmers increased its productivity levels, by accessing to new equipment and more efficient organizational arrangements. Since 1990 the real prices of capital an intermediate inputs fell due to the more open economy policy environment. Gallacher (2000) notes that trade liberalization favored the imports of agricultural inputs (agrochemicals and farm machinery) and thus the government had a role of facilitating and promoting technological change. The adoption of genetically modified seeds (GMOs) was one of the major technological changes. Along with the use of GMO’s seeds, it came the massive adoption of "zero tillage" technology. By 2001, there were around 7.3 million hectares with this technology, and by 2007 zero-tillage accounted for approximately 80% of the planted area with soybeans. This technology was further developed to other crops such as corn, wheat and sunflower.

During the 90s, Argentina implemented policies that had great impact on the agricultural sector, such as: reduction of import tariffs for fertilizers, herbicides, machinery and irrigation equipment; and also the removal of export taxes, marketing boards, and distortions in fuel taxes. These institutional changes improved relative prices, encouraging the use of inputs, and therefore the expansion of the production. Coremberg (2007) cites that the pattern of growth of Argentina's economy was based more on factor accumulation rather than a shift in the production function, which coincides with the findings in this investigation. The growth of agriculture was based not only on technological advances generated in previous decades, which increased the intensification of the land use, partial productivity (yields) and total factor productivity itself; but also due to the new policy environment. However, in the last decade (2000 to 2010), the new government reversed some agricultural policies, reintroducing export taxes and distortions in relative prices. After 2004, international agricultural prices started to grow and the government took new measures to avoid an increase in domestic food prices, by applying a new schemes on export taxes in crops, meat and milk. Exports of meat and milk were initially subject to 15% tax, either by outright bans or other restrictions (Nogués and Porto, 2007). Export of soybeans, were taxed from 13% to 23.5%, and later from 27.5% to 35% in 2007, and up to 45% in 2008 variable according to the international price of this crop. Gallacher and Lema (2014) estimated that as a

result of this tax policy applied between 2007 and 2012, the agricultural sector transferred about 10 billion dollars per year to the national treasury and the consumers.

The aggregate agricultural output grew at 2.8% annually in the period 2000-2010, and this performance was explained in 27% by improvements in productivity and 73% by inputs use (land, capital and labor, in order of importance). The use of inputs grew at 2.1% per year (less than previous decade), which made the productivity increase to 0.8%. However, there were differences by sector. For example, the output of crop sector grew annually at 4.5%, with an input rate of 2.3% (less than the previous decade). The output of the livestock sector increased at 2.6% per year, the input use annual growth rate was 1.5% and the TFP annual growth rate was 1.1%.

4 PRODUCTIVITY, SOURCES OF GROWTH AND POLICY IMPLICATIONS

The analysis on long term series helped this study in identifying different sources of growth: factorial and non-factorial sources. Factorial sources are related to land, labor, capital and fertilizers. Non-Factorial sources are those related with the change in TFP: technological change and efficiency change. This includes organizational, and institutional changes, as well as other factors such as the international environment and climate events.

- **Technological change**

Throughout the analyzed 97-year, it was found that periods where there was some technological stagnation, as in the 40s and 80s when the rate of output growth was negative or near zero (regardless of any climate effect). Diaz Alejandro (1975) and Ballesteros (1957) highlight this scenario. However, an important technological change started in the 90s. There was a modernization in both hard and soft technologies, new varieties and hybrids seeds, agrochemicals, fertilizers, new machinery, irrigation systems, information and communication systems, new land use management, cattle and dairy herd management, among others. This new technologies, fostered the expansion of the agricultural frontier, the intensification of agricultural production system, and the scale of the operations (Lence, 2010).

- **Investment in research and development (R&D)**

There are numerous authors that describe the positive impact of sustained investment in research and development (R&D) and education, on agricultural productivity in developing countries (Hayami and Ruttan, 1985; Evenson and Fuglie, 2010 ; Fuglie and Rada, 2013; Aheran, 1998; Stads, Ruiz, De Greef, 2010). In the early twentieth century, agricultural research in Argentina

was carried out through experimental stations part of the Ministry of Agriculture. During the "import substitution period" (1930-1950) the agricultural research was not a priority for the government. It was just after the 50's when most of the R&D national agencies emerged until today. For example, INTA (National Institute for Agricultural Technology) was created in 1956, promoting the national agricultural research and extension system, and in 1958 started the National Council of Scientific and Technical Research (CONICET) with the role of promoting science and technology.

Regarding to education, the first school for agriculture was established in 1883 (School of Agronomy and Veterinary Haras Santa Catalina, Buenos Aires). Later in 1905, this institution became the School of Science in Agriculture and Veterinary of University of La Plata. From that time and up to now, several universities with schools in agriculture appeared, and actually most of them have centers for basic and applied agricultural research

After the 90's, both the private and public sector started to increase its funding for research and development in agriculture. The private sector had an important role in promoting new technological innovations. Many multinational and national companies made direct investments in seeds, agrochemicals and other inputs, fertilizers, machinery, vaccines, storage, irrigation, information systems, among others. But also the government allocated funds to promote R&D by increasing national and international allocations to the national institutions. There are others programs that support public and private institutions such FONTAR, PROCISUR, FONTAGRO, IICA, CGIAR, among others.

- **Organizational changes**

The industrialization of agriculture started in the 90s may have fostered a change in the organizational and social structure of the agricultural production. For example, changes in farm size and increased scale of operations generated productivity and efficiency gains in both crop and livestock sector. The use of "contracts" facilitated that expansion or the agriculture without necessarily owning the land, while diversifying climate risk through different regions. This organizational arrangements improved the risk management while promoted technological change and agricultural intensification. Reca, Lema and Flood (2010) mention the importance of land reallocation in recent decades. The authors explain that the expansion of the agricultural frontier is generated in two directions: first, expansion to new areas beyond the Pampas region;

and second, the replacement of pastures with crops in the Pampa region. This resulted in an important land reallocation with important productivity gains.

- **Infrastructure**

  The improvement in infrastructure generates positive effects on development and productivity gains (Ahearn, 1998). In the early decades of the last century, Argentina obtained foreign investments which were allocated in railroads, facilitating the movement of primary products from the countryside to the main ports. By 1930, there were 38,000 km of railway line, since routes and motor transport were still not developed. However, after the global crisis in 1930, the foreign investment fell, and thus it was the government who began to finance the transport infrastructure, with several difficulties due to the macroeconomic policies applied until the 90s. From the 90's, a new period of national and international investment positively affected the infrastructure as well as the storage capacity, increasing the competitiveness of the agricultural sector.

- **Macroeconomic and sectorial policy**

  Several authors analyzed the impact of macroeconomic and sectoral policies on agricultural productivity in Argentina (Cavallo and Mundlak, Fulginity and Perrin, Diaz Alejandro). The main policy that affected the agricultural sector was the "import substitution strategy" during the 40s, and the exports duties on agricultural products. Later, the trade liberalization in the 90s changed the relative prices and favored the import of new capital and technology. However, this trend were not followed after the year 2002, when restrictions on the import of capital goods and the export taxes discouraged investment in agriculture. Similar situation is observed in the livestock sector, where during the same period there was a greater interest and investments in improving competitiveness through genetics, health, feeding systems, herd management, new slaughter plants, market development, among others. But later in 2006, beef exports were restricted by bans and quotas, affecting the entire value chain.

- **External environment**

  Production was also affected for several factor related to the external environment such as the global demand for raw materials and food, international prices, trade regulations and technological advances in other countries. The increase of commodity prices since 2004 had a positive impact on production encouraging farmers to invest and adopt new technology and therefore promoting productivity gains.

5 CONCLUSIONS

This paper presents TFP estimates for the aggregate agricultural sector in Argentina from 1913 to 2010, and also for the crop and livestock sector, for the period 1960-2010. The study also presents a compilation of the major political, economic and sectoral events occurred in the last century in Argentina. It was noted that the aggregate agricultural output grew at 1.55% annually from 1913 to 2010 but with two stages of stagnation (1940-1950 and 1980-1990). However, the series of 97 years, describes that the agricultural growth model was very related to factorial endowment of land, labor and capital and to productivity gains. This trend was similar for the crop and livestock sector. The review of policies show that institutional and organizational environment directly affect agricultural production and potential gains in productivity. The deregulation and market oriented policies during the 90s had an important impact in modernization and technology adoption. Policies during the 2000 allowed a better financing of national agricultural R&D. However trade and fiscal policies directed to the agricultural sector acted oppositely: restricting the market, modifying relative prices, and affecting the use of inputs, and the potential levels of output and productivity gains.

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7 ANNEX I. TABLES AND FIGURES

Table 7-1. Tornquist index for output, inputs and TFP for aggregate agriculture, 1913-2010.

Year	Output	Input	TFP
1914	100	100	100
1915	103	102	101
1916	101	102	99
1917	104	104	99
1918	109	109	100
1919	118	115	103
1920	120	124	97
1921	124	133	93
1922	128	145	89
1923	137	154	89
1924	139	163	85
1925	146	170	86
1926	149	173	86
1927	156	174	90
1928	158	172	92
1929	154	169	91
1930	149	165	91
1931	148	160	92
1932	151	155	98
1933	157	149	106
1934	167	142	117
1935	173	139	124
1936	179	139	129
1937	176	141	125
1938	181	143	127
1939	182	144	127
1940	194	143	136
1941	201	139	145
1942	207	136	152
1943	214	133	161
1944	210	133	158
1945	211	133	159
1946	207	134	155
1947	212	136	156
1948	209	137	153
1949	202	139	146
1950	200	137	146
1951	194	135	144
1952	205	131	157
1953	213	128	166

Year	Output	Input	TFP
1970	293	159	185
1971	301	164	183
1972	314	165	190
1973	330	172	193
1974	341	174	196
1975	347	189	183
1976	351	194	181
1977	360	183	197
1978	368	158	233
1979	367	142	258
1980	369	139	265
1981	372	141	264
1982	385	149	259
1983	393	157	250
1984	393	158	249
1985	391	148	264
1986	384	140	273
1987	393	133	294
1988	389	134	289
1989	403	130	310
1990	409	131	311
1991	425	129	331
1992	431	128	337
1993	442	128	346
1994	463	129	359
1995	479	138	348
1996	483	149	324
1997	493	163	301
1998	512	171	300
1999	530	171	310
2000	534	167	320
2001	527	166	318
2002	535	168	319
2003	541	173	314
2004	571	172	332
2005	591	174	340
2006	634	181	351
2007	656	196	334
2008	645	200	322
2009	656	196	335

1954	233	127	184
1955	233	126	185
1956	232	127	183
1957	230	129	178
1958	232	133	174
1959	235	136	173
1960	235	137	172
1961	238	136	175
1962	243	140	174
1963	253	144	175
1964	266	153	173
1965	273	157	174
1966	278	157	177
1967	274	156	176
1968	278	156	178
1969	282	158	179

2010	648	188	345

able 7-2. Output, input and TFP index for the crop sector, 1962-2010.

Year	Output	Input	TFP
1962	100	100	100
1963	103	106	97
1964	96	117	82
1965	98	123	80
1966	101	124	81
1967	99	120	83
1968	102	122	84
1969	104	126	82
1970	101	129	78
1971	92	136	68
1972	89	139	64
1973	94	149	63
1974	89	156	57
1975	81	173	47
1976	96	184	52
1977	123	177	69
1978	136	161	84
1979	124	149	83
1980	130	149	87
1981	139	154	90
1982	166	168	99
1983	177	186	95

Table 7-3. Output, input and TFP index for the Livestock sector, 1961-2010.

Year	Output	Input	TFP
1961	100	100	100
1962	103	104	99
1963	108	120	90
1964	113	127	89
1965	116	125	93
1966	118	116	102
1967	118	111	106
1968	120	114	105
1969	121	121	100
1970	125	138	90
1971	128	147	87
1972	134	165	81
1973	139	172	80
1974	141	193	73
1975	144	195	74
1976	144	176	82
1977	144	145	99
1978	144	126	115
1979	142	121	118
1980	140	121	116
1981	137	130	105
1982	138	145	95

1984	191	190	100
1985	181	181	100
1986	173	168	103
1987	187	160	117
1988	179	157	114
1989	173	154	112
1990	149	158	94
1991	165	158	104
1992	185	158	117
1993	205	158	129
1994	227	164	138
1995	249	180	138
1996	269	206	131
1997	287	235	122
1998	280	255	110
1999	273	258	106
2000	270	255	106
2001	354	260	136
2002	426	269	158
2003	476	281	169
2004	455	281	162
2005	440	285	154
2006	495	302	164
2007	577	336	172
2008	571	337	169
2009	581	319	182
2010	527	293	180

1983	136	148	92
1984	136	134	102
1985	136	125	109
1986	138	121	114
1987	138	125	110
1988	137	116	118
1989	137	111	123
1990	138	107	129
1991	140	108	129
1992	143	108	132
1993	148	105	142
1994	154	108	143
1995	157	119	132
1996	157	138	114
1997	155	149	104
1998	160	150	107
1999	164	142	115
2000	165	138	120
2001	156	136	114
2002	150	141	107
2003	153	138	111
2004	162	141	115
2005	171	144	119
2006	176	160	110
2007	181	165	109
2008	187	159	117
2009	188	154	123
2010	191	152	125

Table 7-4. Cumulative annual growth rate index of output, inputs and TFP by decades, 1913-2010

Sector	Decades	Index			Inputs growth rate			
		Output	Inputs	TFP	Labor (L)	Capital (K)	Land (T)	Fertilizers (F)
Aggregate	1913-2010	1.8%	0.3%	1.5%	-0.5%	0.8%	1.4%	
	1913-1920	2.0%	0.5%	1.5%	0.0%	1.1%	1.5%	
	1921-1930	2.6%	2.1%	0.5%	1.8%	2.1%	4.6%	
	1931-1940	3.4%	0.4%	2.9%	0.3%	0.6%	0.9%	
	1941-1950	-0.2%	0.1%	-0.3%	0.1%	-0.2%	1.9%	
	1951-1960	1.9%	0.4%	1.4%	-2.4%	1.6%	6.8%	
	1961-1970	2.1%	1.6%	0.5%	1.1%	1.0%	3.4%	
	1971-1980	2.4%	-0.8%	3.2%	-1.8%	1.5%	-0.1%	
	1981-1990	0.7%	-1.8%	2.4%	-0.6%	-1.1%	-3.7%	
	1991-2000	2.7%	4.0%	-1.3%	-0.9%	2.2%	10.4%	
	2001-2010	2.8%	2.1%	0.8%	1.4%	1.8%	2.6%	
Crops	1961-2010	4.0%	2.1%	1.9%	-0.5%	1.4%	2.7%	8.6%
	1961-1970	0.3%	2.7%	-2.4%	2.9%	0.9%	5.0%	20.1%
	1971-1980	5.1%	1.3%	3.7%	-0.1%	2.4%	-0.5%	5.3%
	1981-1990	0.5%	-1.1%	1.6%	-0.2%	-0.7%	-2.0%	5.0%
	1991-2000	5.8%	6.9%	-1.1%	2.4%	2.7%	11.5%	17.2%
	2001-2010	4.5%	2.3%	2.3%	2.0%	1.0%	3.3%	3.9%
Livestock	1961-2010	0.9%	0.3%	0.7%	0.3%	0.6%	0.3%	
	1961-1970	0.9%	1.0%	-0.1%	0.6%	0.6%	1.3%	
	1971-1980	0.9%	-3.9%	4.9%	1.3%	-3.3%	-4.9%	
	1981-1990	0.1%	-3.1%	3.1%	-0.4%	-0.4%	-4.5%	
	1991-2000	2.2%	5.9%	-3.7%	-0.6%	2.3%	8.7%	
	2001-2010	2.6%	1.5%	1.1%	0.2%	3.8%	1.1%	

Table 7-5. Cumulative annual growth rate index of output, inputs and TFP, 1960-2010 (periods defined as Dias Avila and Evenson, 2010)

Sector	Decade	Index			Inputs growth rate			
		Output	Input	TFP	Labor (L)	Capital (K)	Land (T)	Fertilizers (F)
Aggregate	1960-2010	2.0%	0.3%	1.7%	-0.4%	0.7%	1.1%	
	1960-1980	2.4%	0.8%	1.6%	-0.6%	1.3%	3.2%	
	1981-2001	-0.5%	0.6%	1.3%	-0.8%	0.6%	1.8%	
	2002-2010	2.8%	2.1%	0.7%	1.2%	1.7%	2.9%	
Crops	1961-2010	4.0%	2.1%	1.9%	-0.5%	1.4%	2.7%	8.6%
	1961-1980	1.0%	2.7%	-1.7%	-0.5%	1.8%	4.0%	8.4%
	1981-2001	3.2%	2.0%	1.3%	0.0%	1.0%	2.5%	12.4%
	2002-2010	4.5%	2.3%	2.3%	2.0%	1.0%	3.3%	3.9%
Livestock	1961-2010	0.93%	0.27%	0.67%	0.3%	0.6%	0.3%	
	1961-1980	1.94%	1.81%	0.15%	1.8%	1.7%	2.0%	
	1981-2001	1.04%	0.22%	0.83%	-0.5%	0.1%	0.5%	
	2002-2010	3.21%	1.68%	1.46%	-0.1%	4.3%	1.3%	

Table 7-6. TFP growth rates comparison

Authors	Crops		Livestock		Aggregate	
	1961/80	1981/01	1961/80	1981/01	1961/80	1981/01
Dias Avila y Evenson (2010)	3.08%	3.93%	0.90%	0.43%	1.83%	2.35%
Saini y Lema (2015)	-1.7%	1.3%	0.15%	0.83%	1.6%	1.3%

Figure 7-1. Outputs, inputs and TFP for the aggregate agriculture, 1913-2010

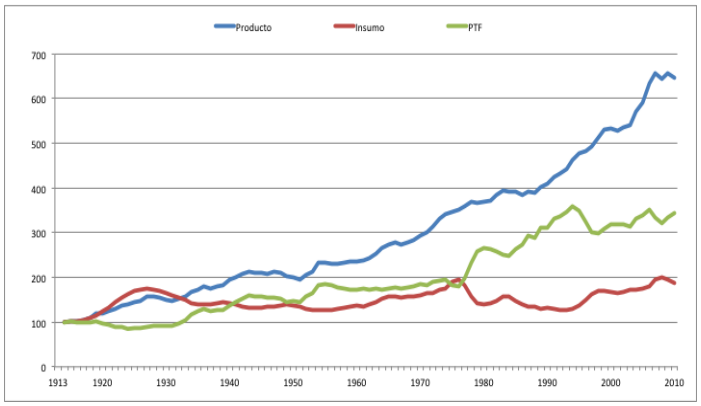


Figure 7-2. Shares of labor, capital and land in the total cost of the aggregate agriculture, 1913-2010

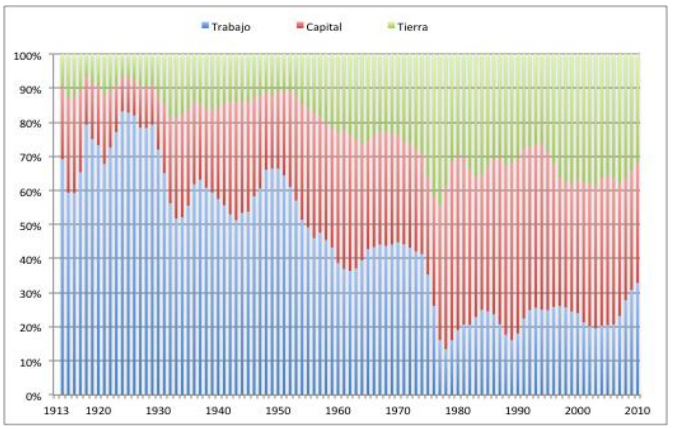


Figure 7-3. Outputs, inputs and TFP for the crop sector, 1962-2010

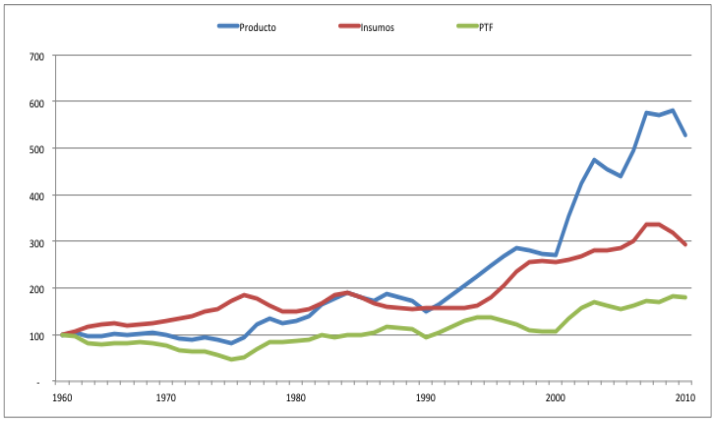


Figure 7-4. Shares of labor, capital, land and fertilizers in the total cost of the crop sector, 1962-2010

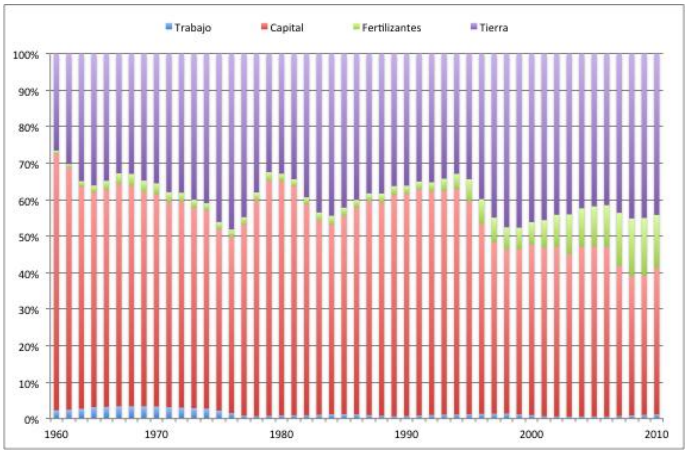


Figure 7-5. Outputs, inputs and TFP for the livestock sector, 1961-2010

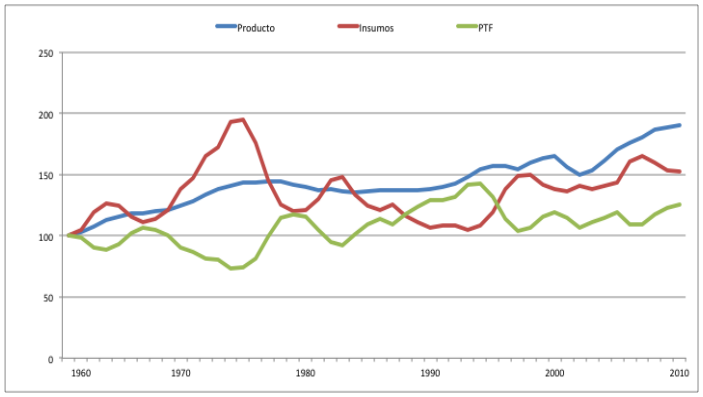
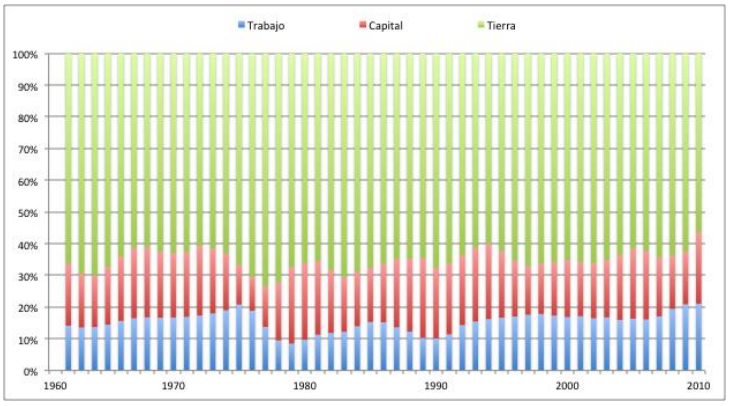
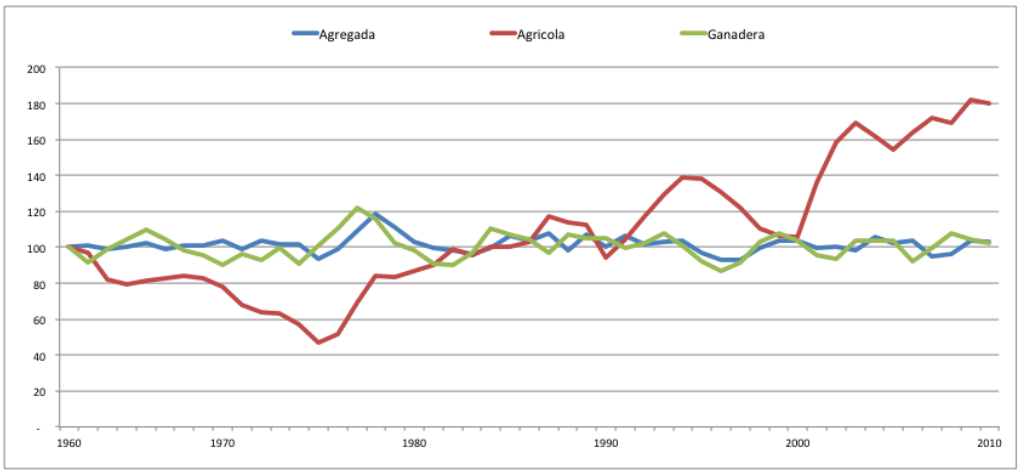


Figure 7-6. Shares of labor, capital, and land in the total cost of the livestock sector, 1962-2010



Source: Authors estimates.

Figure 7-7. TFP for the aggregate agriculture, crops and livestock sector, 1960-2010



Source: Authors estimates.