Is there a Slowdown in Agricultural Productivity Growth in South America?

Federico J. Trindade - University of Nebraska Lincoln

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Abstract

This article uses parametric and nonparametric methods to update estimates of agricultural productivity growth in 10 South American countries in 1969-2009 with the objective of checking if the slowdown being measured in other countries is present in the region. Results show that the increase in agricultural output during the period analyzed is explained by factor accumulation, but also by higher Total Factor Productivity (TFP) and that the slowdown present in the U.S. and some European economies does not seem to be present in South America. The region yearly average TFP growth went from 1.23 percent during the 1970s to 1.79 percent in the 1980s, 2.04 percent in the 1990s and 2.59 during the 2000s. This growth is not uniform across countries; the different performances can be associated to different environmental and institutional conditions.

Introduction

Productivity growth accounts for growth in output not attributable to growth in inputs. This growth is usually measured by changes in total factor productivity (TFP), where the TFP is defined as the ratio of total output to total inputs. The increase in TFP may be due technological change, improvement in the efficiency of inputs usage or both.

During the last two decades many studies investigated agricultural productivity in South America and the rest of the world. Using different models and econometric instruments their results were also different depending in the method employed. For the rest of the world, Alston, Babcock and Pardey (2010) found decreasing global yield growth rates for corn, wheat, rice and soybeans when comparing the period 1960-1990 with 1990-2007; this result was observed for high income countries but also for middle income countries. Following this trend, The World Bank Report (2008) found a 50 percent decrease in yields growth rate from the high values observed during the 1960s and late 1970s. Fuglies (2010) found similar results when studying yield growth rates and, when analyzing TFP growth rates per decade for the same period, he also found an increasing TFP trend from the 1960s to the 1990s followed by a decreasing trend during the period 2000-2006. This decrease was very significant for developed economies, where from a 2.13 percent growth during the 1990s, the growth rate fell to a 0.86 percent during the 2000s. This slowdown was observed in the major developed producing countries, including United States & Canada, Western Europe and Australia. For developing countries, he also found a slowdown in TFP growth rates but with a smaller intensity and not so homogenous between countries. In average, developing economies decreased its TFP growth rate from 2.30 percent during the 1990s to 1.90 percent during 2000s.

Focusing now on South America, following an increasing trend from the 1960s Fuglies (2010) found a small slowdown (<10 percent) in Brazil and the South Cone and a bigger deceleration on the Andean countries (≈ 45 percent) when comparing the 1990s with the 2000s. In a different study that uses a Malmquist index method, a non homogeneous trend was found by Ludena (2010) for the region when comparing TFP growth rate of the period 2000-2007 with that of 1990-1999; Argentina, Bolivia, Brazil, Ecuador, Paraguay and Uruguay had an increase in the growth rate, while Chile, Colombia, Peru and Venezuela a decrease. Using a translog frontier production function analysis Bharati and Fulginiti (2007) found no sign of a slowdown in the region when analyzing data from 1972 to 2002; the region TFP growth rate increased from 1.96 percent in 1972-1981 to 2.33 percent in 1982-1991 and to 2.36 percent for the period 1992-2002. From the sample of 10 countries comparing the last two periods only Colombia, Paraguay and Peru had an important decrease in the TFP growth rates. Finally, with a different level of year's aggregation, Avila et al. (2007) found no sign of a slowdown for the region in average when comparing the period 1961-1980 with 1981-2001, with Ecuador, Brazil and Chile having the higher level of acceleration and only Paraguay and Venezuela with strong decreases in their growth rates.

An important problem in estimating agricultural TFP growth rates is related with the bad or scarce information on input prices, information used to estimate the cost shares needed for the index number methods. To circumvent this problem there are different options that the mentioned authors have used. An increasingly more common tool used in these cases is the use of distance function measures like the Malmquist index used by Ludena (2010); this method does not require cost shares but given that it is constructed by comparing the observations with the best practice frontier that is determined by the set of countries included in the sample it is very

sensitive to set of countries included and to the number of variables considered. Avila et al. (2007) and Fuglies (2010) approached the problem of lack of information by estimating input shares for some important economies that have enough data on prices and use those share for related smaller economies. Another option that was also used by Fuglies is the estimation by econometric methods of the input production elasticities as weighting factors for input growth aggregation. Assuming profit maximization and long run competitive equilibrium, theoretically these production elasticities should match with the corresponding cost shares.

In this study I examine agricultural productivity by econometrically estimating the production elasticities of a translog frontier production function of a set of 10 South American countries during the period 1969-2009. To give more support to my results I also estimate TFP growth rates by using a Malmquist index method. This study also uses a set of environmental, institutional and socio-economical variables to account for differences among the countries in the set that may help to explain different technical efficiency levels across countries.

The model

For the development of the model I follow Bharati et al. (2007), I use some different variables, make some adjustments on others and update their results. On this study I focus on a potential decrease on rates of productivity growth in the latter years of the series as observed by other authors. Initially I approximate the agricultural technology with a translog production function and use two econometric methods: I estimate the agricultural productivity growth rate first using ordinary least squares (OLS) and then using a maximum likelihood stochastic frontier (ML). Finally I use a nonparametric Malmquist index as an alternative estimation method that helps in identifying unexpected changes in the data as this method is very sensitive to outliers.

The standard neoclassical production function is defined as:

$$\ln Y_{it} = f(x_{it}, t; \beta) + \varepsilon_{it} \qquad i = 1, \dots, I \quad t = 1, \dots, T \qquad (1)$$

Where Y_{it} is the output of the i-th country during the time period t, x_{it} is an Nx1 vector of the logarithm of inputs for the i-th country in time period t, β is a vector of unknown parameters, and ε_{it} are random variables with distribution characteristics that depend on the econometric approach utilized. For the OLS approach the ε_{it}s are assumed to be iid $N(0, \sigma_\varepsilon^2)$. For the stochastic frontier approach, following Battese and Coelli (1995), the error term is decomposed into two random variables: $\varepsilon_{it} = v_{it} - u_{it}$. Where v_{it} are random errors which are assumed to be iid $N(0, \sigma_v^2)$, and independently distributed from u_{it}, and u_{it} is a non-negative random variable assumed to be iid $N(\eta, \sigma_u^2)$, where η is associated with technical inefficiency of countries over time. The production function in (1) is used to decompose output growth into three parts, growth in the use of inputs, changes in efficiency in the use of inputs and technological change, the last two are referred to as total factor productivity (TFP) change

$$\dot{Y}_{it} = \sum_n \frac{\partial f(x, t, \beta)}{\partial x_n} \dot{x}_{itn} + T\dot{F}P_{it} \qquad i = 1, \dots, I \quad t = 1, \dots, T \qquad (2)$$

The growth in the TFP is decomposed into:

$$T\dot{F}P = \frac{\partial f(x, t, \beta)}{\partial t} + \frac{\partial TE_{it}}{\partial t} \qquad (3)$$

The first term on the right hand side of (3) represents technical change (TC) or that growth due to innovations and it is the shift of the production frontier, and the second term represents the technical efficiency change (EC) or growth due to catching-up to the most efficient countries; it is the rate at which a country moves toward or away from the production frontier. The technical efficiency of the i-th country in period t accounts for the ratio of observed output for the i-th

country relative to its potential output when the individual country effects are zero, this is

$TE_{it} = \frac{Y_{it}}{\exp[f(x_{it},\beta)+v]}$. The potential output, $\exp[f(x_{it},\beta)+v]$, is represented by the output of a

fully efficient country using the same input vector. . This measure takes values from zero to one;

a value of one indicates that the country is fully efficient.

Technical efficiency is only captured by equation (1) when a frontier approach is used. Given the

definition of u_{it} , the mean of the technical efficiency η is defined as

$$\eta_{it} = z_{it}\delta, \qquad\qquad\qquad\qquad (4)$$

the first variable on the right hand side z_{it} is a (1xp) vector of explanatory variables that are

associated with the efficiency of the countries over time (institutional, environmental and quality

variables) and the second variable δ is a (px1) vector of unknown parameters to be estimated.

The random variable u_{it} is obtained by truncation (at zero) of the normal distribution at mean $z_{it}\delta$

and variance σ_u^2; this error term is associated with technical inefficiency of production. In this

model u_{it} will account for differences across countries that cause departures from the maximum

potential output, also refer to as the catch-up growth component.

When a non-frontier method is used, like OLS, there is only one error that accounts for all the

differences between countries, so technical efficiency is assumed away with all countries equally

efficient.

The Malmquist index estimation follows Fulginiti and Perrin (1997); this index is based on an

output distance function that is defined as

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$$D^T(x^t, y^t) \equiv \inf\left\{\theta : \left(x^t, \frac{1}{\theta}y^t\right) \epsilon\, S^T\right\} \tag{4}$$

Where the distance θ is the ratio of the current output basket to the maximum achievable multiple of that basket given the current level of inputs. The Malmquist productivity change can be expressed as

(5)

$$m^{t+1} = \frac{D^{t+1}(x^{t+1}, y^{t+1})}{D^{t+1}(x^t, y^t)}$$

This expression can be factored into the product of the technical change and the efficiency change.

$$m^{t+1} = \frac{D^{t+1}(x^{t+1}, y^{t+1})}{D^t(x^t, y^t)}\left[\frac{D^t(x^{t+1}, y^{t+1})}{D^{t+1}(x^{t+1}, y^{t+1})}\frac{D^t(x^t, y^t)}{D^{t+1}(x^t, y^t)}\right]^{\frac{1}{2}} \tag{6}$$

The first term on the left is the change in relative efficiency between years t and t+1, the term in brackets is the change in technology between those years. Values greater than one in any of them reflect gains and values smaller than one reflects losses; a Malmquist index value greater than one also reflects increases in productivity.

For the Malmquist indexes, Coelli's DEAP program, version 2.1 was used.

Data

The countries included in the analysis are Argentina, Bolivia, Brazil, Chile, Colombia, Ecuador, Paraguay, Peru, Uruguay and Venezuela. These countries represent more than 99 percent of South America agricultural output and population.

Data on most conventional agricultural inputs (land, labor, livestock and machinery) and output was obtained from FAOSTAT website. Agricultural output accounts for agricultural gross production measured by a production index that uses a common set of commodity prices from 2004-2006 period and expresses them in constant US dollars of this period. Following Fuglies, to minimize the effect of short run shocks that are not accounted by the variables considered (like weather or other sudden disturbances) I smooth the output series for each country using the Hodrick-Prescott filter, where the smoothing parameter λ was set equal to 6.25 as suggested by Ravn and Uhlig (2002).

Figure 1 - Agricultural Gross Production index -
3 main producers - Original and smoothed variables
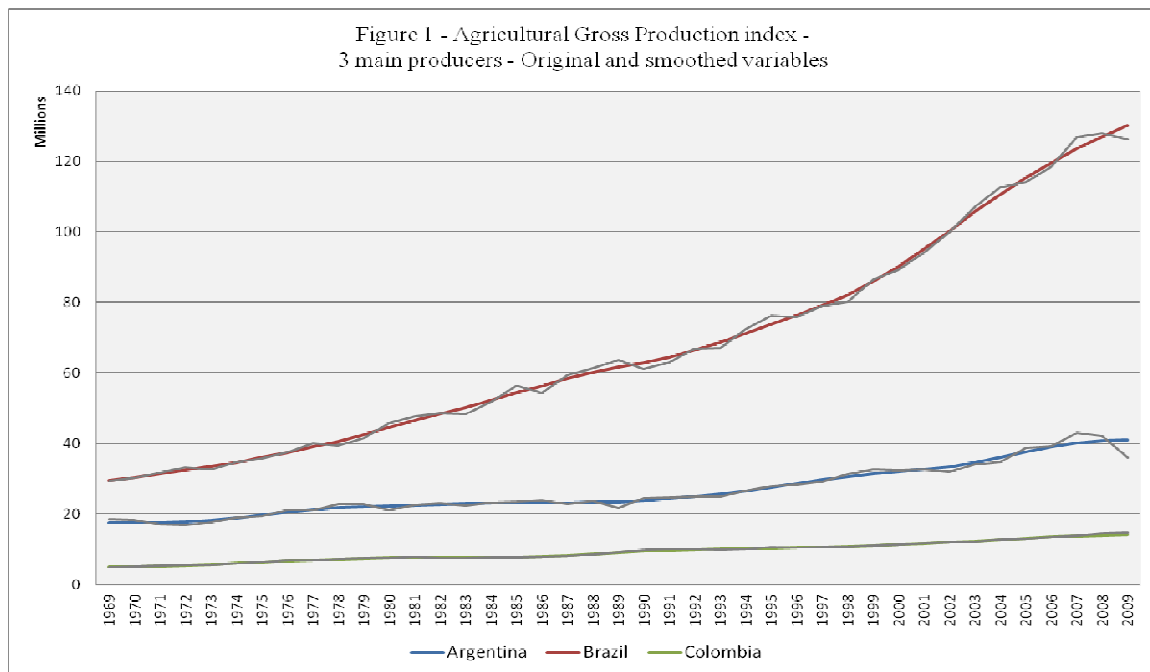
Land is agricultural land used in permanent crops, annual crops and pastures in thousands of hectares. Labor is number of thousands persons (males and females) who are economically active in agriculture. Livestock is number of animals in farms expressed in cattle equivalent converted using Hayami and Ruttan (1985) weights. Machinery is the number of agricultural

tractors used; for this item FAO data was updated using estimates from the respective national institutes of statistics. Fertilizers is total fertilizer consumed in metric tons of N, P_2O_2 and K_2O; this input data was obtained from Fuglies database as he used a mixed of FAO data and International Fertilizer Association data that is supposed to be more accurate and recent.

Table 1 has summary statistics of the output and inputs data set. Summary statistics per country are included in the appendix.

Table 1 - Summary statistics

Variable	Unit	Mean	Max	Min	SD
Output	Thousands of constant 2004-2006 US dollars	12,700,000	128,000,000	816,421	21,900,000
Fertilizer	Metric tonns	667,828	11,300,000	1,000	1,592,902
Machinery	No. of tractors	103,454	867,815	2,100	198,956
Livestock	Thousands cattle equivalent	34,100,000	245,000,000	3,770,163	51,000,000
Labor	Thousands persons	2,673	16,342	184	4,057
Land	Thousands hectares	54,296	264,700	4,795	70,576

Figure 1 shows the evolution of the variables in index form from 1969 to 2009, for all the countries in the study. We note that there are no big fluctuations in the variables with the exception of Fertilizers that has increased rapidly since the 1990s and stabilized during the 2000s. Tractors show increases in the 1970s and 1980s while output shows an almost monotonic increase during the whole period. We note the decrease in the use of labor since 1980 and the stability of land indicating no major land expansion until the decade of analysis.

Figure 2 - Evolution of output and inputs (index 1969=1)
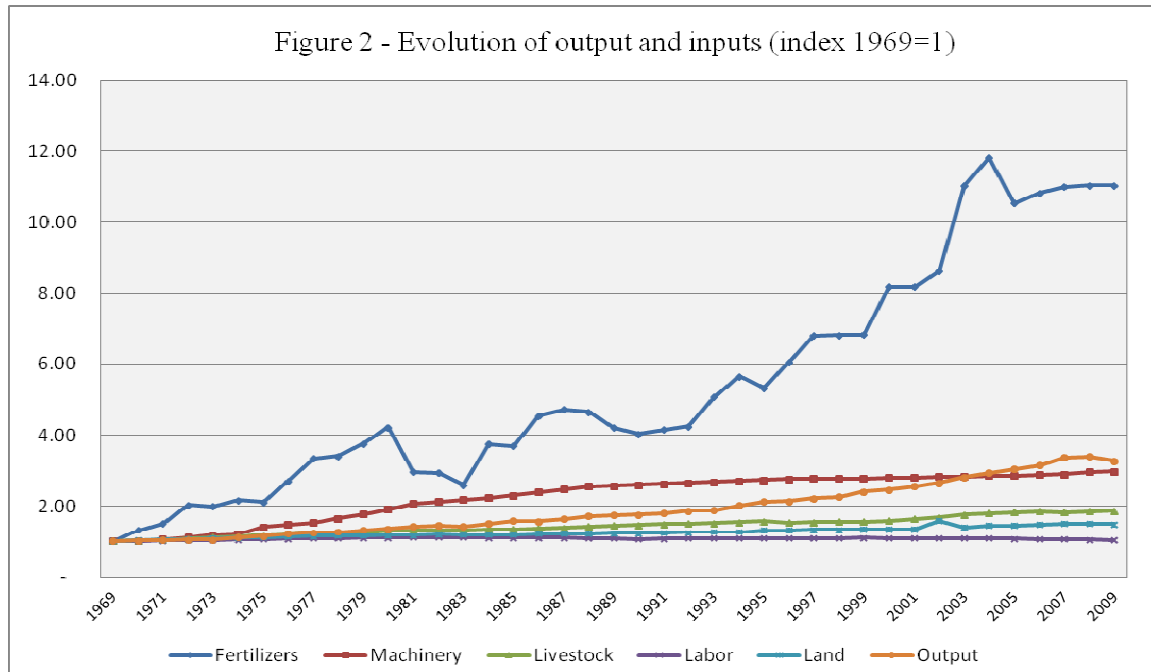
In terms of scale of production, Brazil greatly dominates. It accounts for about 50% of the total output of the region, uses 44% of land and is relatively fertilizer and labor intensive. Argentina contributes 20% of the region's output and it is relatively land and machinery intensive. The next biggest contributor is Colombia with close to 8% of production and a labor intensive system. Figure 3 shows the average output and input allocations across countries.

Figure 3 - Average Output and Input shares by country
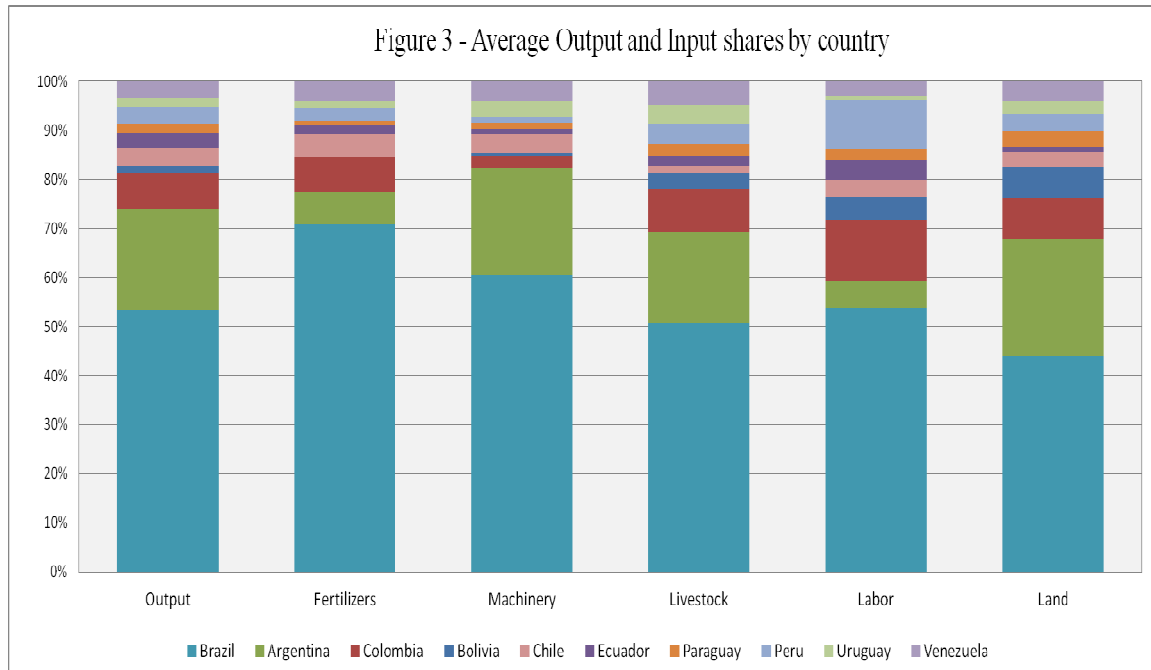
In addition to traditional input variables included by other studies, environmental, institutional, and socio-economic variables are also considered. These variables are treated differently than inputs and are associated to the mean of the one-sided error term, hypothesizing that they might help to understand the catch-up process of countries relative to best performers. The variables included are:

- Gross Domestic Product per capita: included as a proxy for overall economic development that includes economic aspects such as better financial instruments to farmers and better infrastructure for inputs and output transportation.

- Openness in constant prices: this ratio is defined as the ratio of the sum of exports and imports to real GDP and is obtained from the Penn World Table. This variable also reflects economic aspects that may produce differences in trade environment across the countries.

- Freedom: it is a political freedom and civil liberties index developed by the Freedom House. The index will have a value of one if the country is considered to be free and a value of zero if the country is not considered to be free. It is included to control for differences in the political environment and in civil rights across the countries.

- Labor quality: this variable is proxied by the life expectancy of each country published by the United Nations development Program (UNDP) website and the World Bank Development Indicators. This variable tries to control for differences in sociological characteristics across countries.

- Land quality: this variable was obtained from Fuglies (2010) database. It reflects the proportion of agricultural area that is in permanent pasture and in rain-fed cropland and their relative productivity.

- Irrigation ratio: this variable is the percentage of agricultural land equipped for irrigation obtained from FAOSTAT/AQUASTAT. This variable also proxies land quality.

- Personnel employed full time in agricultural research (FTEs): this variable is considered to account for public investment in agricultural R&D. Data was estimated from data obtained from Bharati and Fulginiti (2007), the Agricultural Science and Technology Indicators (ASTI) website and FAOSTAT. The estimation of these variables was made with the following procedure: - From 1972 to 1993 it was used Bharati et al. dataset. - For some countries from 1994 to 2006 it was extended the initial data of Bharati et al. by following the trend observed in ASTI data. – For countries where there was no data from ASTI the evolution of researchers per million people as given by the World Bank (WB) was used as a trend – For countries were any of the other two sources were not available a mixed of expenditure in research as percentage of GDP and the evolution of the GDP

(from the World Bank) was used as a trend. – Finally when there was no data available from any source, the same variation observed from the average of the last three years of available data with respect to the average three years starting one year earlier was used.

Ex: $FTE_{09} = \frac{Average\ (FTE_{08}, FTE_{07}, FTE_{06})}{Average\ (FTE_{07}, FTE_{06}, FTE_{05})} \cdot FTE_{08}$

- Average precipitation in depth: this is the long-term average (over space and time) of annual endogenous precipitation (produced in the country) in depth elaborated by AQUASTAT. This variable helps to explain inefficiencies given by environmental factors.

Table 2 - Summary statistics efficiency variables

Variable	Unit	Mean	Max	Min	SD
GDP per capita	Constant 2000 Nominal US$	3,324	9,936	759	2,166
Openness	2005 constant prices in percent	42	167	9	23
Freedom Index	1 for Free and 0 for Not Free	0.49	1.00	-	0.50
Labor Quality	Life Expectancy	68	79	45	6
Land Quality	Index	0.20	0.55	0.08	0.09
Irrigation	Percent of agricultural land equipped for irrigation	16	83	2	18
FTE	Amount of personnel employed full time in agricultural research	484	2,797	18	563
Average Precipitation	Milimeters per year	1,575	2,612	591	543

Estimation

A translog production function is estimated using both a nonfrontier OLS approach and a Maximum Likelihood (ML) frontier approach. Imposing symmetry, the function estimated is (7):

$$\ln Y_{it} = a_0 + \sum_{j=1}^{5} b_j x_{ijt} + \frac{1}{2}\sum_{j=1}^{5} c_{jj} x_{jj}^2 + \sum_{j=1}^{5}\sum_{k>j}^{5} c_{jk}\, x_{ijt} x_{ikt} + b_t t + \frac{1}{2} b_{tt} t^2 + \sum_{j=1}^{5} b_{jt} x_{ijt} t + \varepsilon_{it}$$

where Y is agricultural output; x's are logarithms of the inputs; t is time from 1 to 41 (it is a proxy for technical change); a, b and c are parameters to be estimated, and ε is an error term. As stated previously, for the case of the stochastic frontier method the error is decomposed into two random variables: $\varepsilon_{it} = v_{it} - u_{it}$.

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The first derivative of (7) with respect to t corresponds to the rate of technical change, TC:

$$TC_{it} = b_t + b_{tt}t + \sum_{j=1}^{5} b_{jt}x_{ijt} \, t \qquad\qquad (8)$$

Coelli's FRONTIER 4.1 maximum likelihood procedure was used to simultaneously estimate the 28 parameters of equation (7), the 8 efficiency specific parameters of equation (4) and the ratio of the variance of u to the variance of ε: $\gamma = \frac{\sigma_u^2}{\sigma_u^2 + \sigma_v^2}$. This ratio reflects the proportion of the error term which is due to inefficiency effects. 29 out of 37 parameters are significantly different from zero at the 99% confidence level. For the OLS regression, the STATA 10.0 package was used to estimate the 28 parameters. 25 parameters out of 28 were found significantly different from zero at the 99% confidence level and 27 at the 95% level.

A Wald test was conducted to compare the translog specification versus a simpler Cobb-Douglas specification. The result of restricting all the second order coefficients of the translog form gave a Chi-square test statistic of 341.50 with a p-value: 0.0000 rejecting the nested Cobb-Douglas specification as a better specification. In the translog frontier specification, the value obtained for the inefficiency variance parameter γ was 0.6479 with a t-stat of 17.62; this indicates that the effect of the inefficiencies is likely to be highly significant explaining the value of output of the countries.

Production elasticities for the OLS and ML stochastic frontier methods are obtained to check for regularity conditions of the technology. The value for each (evaluated at the mean) can be seen on table 2. (Std errors pending)

Table 3

Production elasticities	OLS	Frontier
Fertilizer	0.0479	0.0236
Machinery	0.1781	0.1128
Livestock	0.4033	0.3771
Labor	0.1820	0.1668
Land	0.1323	0.1999
Constant	47.0423	54.2206

At the mean, all of them are consistent with the theory. Livestock and Labor elasticities are very close to each other in the two approaches; Machinery is around 50 percent bigger in the OLS estimation and Land is 50 percent bigger in the Frontier estimation. Fertilizer value from the OLS estimation doubles the value of the Frontier estimation, although the difference is small in absolute terms.

For the ML frontier approach the parameter values of the institutional variables are also estimated. These values can be seen on table 4.

Table 4

| Variable	Coefficient	t-statistic
Efficiency change variables		
GDP	(0.00001)	(3.8218)
Openness	(0.0002)	(0.9739)
Freedom	0.0101	1.4364
Labor Quality	(0.0179)	(11.1543)
Land Quality	(0.0759)	(0.9398)
Irrigation ratio	(0.0384)	(1.0871)
FTE	(0.0001)	(14.3273)
Precipitation	(0.0001)	(6.4414)

These variables will help to explain the different levels of technical efficiency across countries. GDP per capita, Labor Quality, FTE and Precipitation are negative and significant at 99 percent confidence level; the negative coefficient on these variables implies that countries with greater values on these variables tend to be less inefficient. For Land Quality, Openness and Irrigation ratio the coefficient is also negative but the relationship is too weak because the coefficient is very small relative to its estimated standard error. Finally Openness has a positive coefficient but it is not significant. Most of these results follow the same conclusion found by Bharati et al: Labor quality and FTE are very important explaining differences in inefficiencies across countries.

Agricultural Productivity Growth

Agricultural output growth for the region was 3.04% per year. This value is explained by a 1.76% growth in productivity per year according to the OLS approach, 1.74% per year according

to the Stochastic Frontier approach and 1.84% per year according to the Malmquist approach. All the estimates are very similar to the 1.7% increase found by Ludena (2010) for the period 1961-2007 for land abundant countries (excludes Ecuador), they are higher than the 1.47% increase found by Fuglies (2010) for a similar period (includes Caribbean countries that have a .45% decrease) and lower than the 2.24% increase found by Bharati et al. (2007) for the period 1972-2002. Comparing with developed economies, the estimate is higher than the one found by Fuglies (2010) for USA/Canada (1.29%) and Western Europe (1.21%) for the period 1961-2007 and slightly higher than the 1.65% estimated by Ball et al. (2009) for the United States (1961-2006).

Figure 4a represents the TFP change for the three different approaches. We can see a positive trend for the TFP growth with the three different estimations. In the Appendix, Figure 4b shows a similar representation but with averages per decade.

Figure 4a - TFP Growth Rate
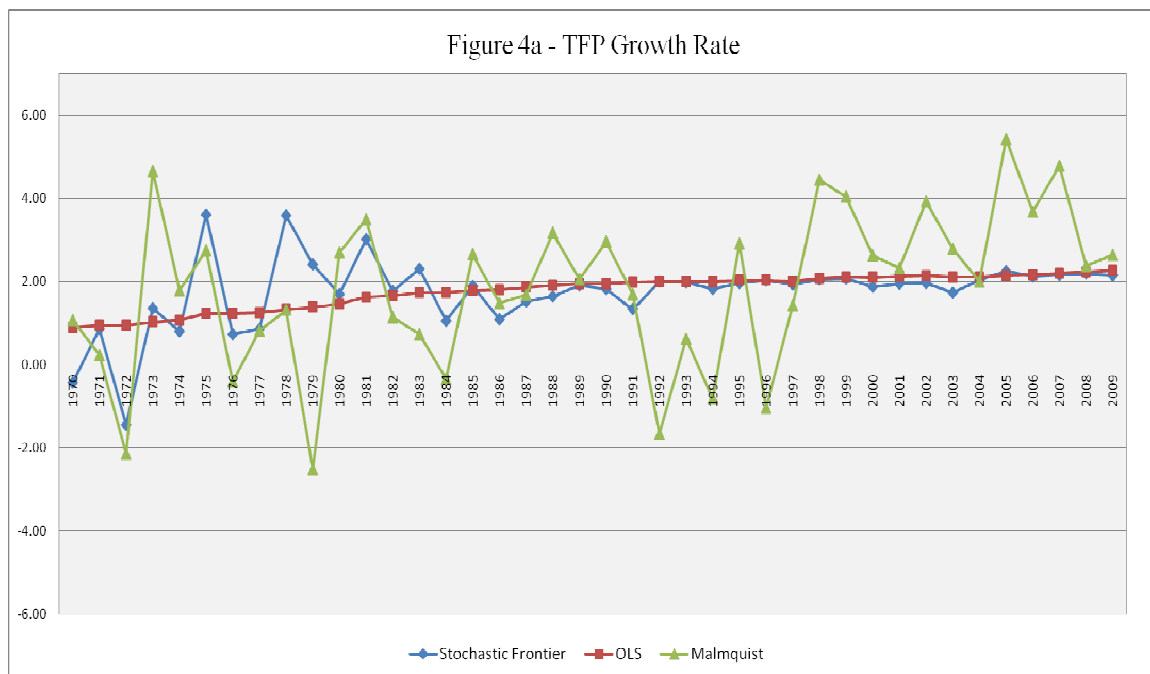
The OLS estimation is smoother because it approximates the TFP assuming no technical inefficiency and minimizing the sum of the square of the errors; thus in the OLS estimation TC is equal to TFP change. The Stochastic frontier approach allows more variability since it does not impose full technical efficiency, hence to the variability in the TC it adds the EC. The Malmquist index is more volatile because it is nonstochastic and it only uses information of two consecutive periods; hence if there is a slowdown in productivity growth with respect to the previous year it is going to show, by construction, a negative value.

Since the Malmquist index is very sensitive to extreme values, an average is not good indicator as it will be affected by extremes. A better representation is an accumulative index as represented in figure 5.

Figure 5 - TFP Level Index (1969=1)
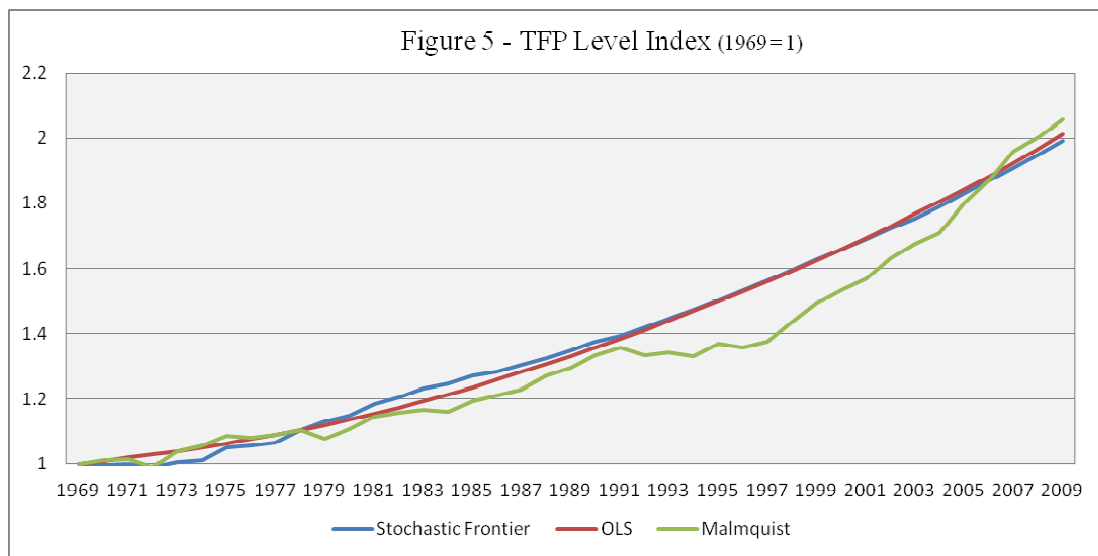
The evolution of an index of TFP growth for the region estimated by these three approaches represented in figure 5 is more representative than an average value for the period for the Malmquist index estimates. For the Malmquist index, it is interesting to note the slowdown during the 1990s and the posterior increase in the slope around 1997-1998, indicating accelerated

rates of TFP growth. This insight is lost in the econometric estimates as by construction, they impose a monotonic rate of technical change. In Table 5 TFP growth estimates per country for all three methods are presented.

Table 5

Econometric Estimates: Average TFP growth estimates (%), per country: 1969-2009

Country	OLS TFP	Stochastic Frontier			Malmquist			Output
		TC	EC	TFP	TC	EC	TFP	
Argentina	1.416	1.364	0.430	1.794	-0.955	0.000	-0.955	1.837
Bolivia	0.434	0.292	0.560	0.851	2.147	0.000	2.148	3.589
Brazil	2.044	1.338	0.453	1.791	2.078	1.003	3.063	3.765
Chile	2.394	2.088	0.529	2.618	1.837	0.000	1.838	3.056
Colombia	1.028	0.477	0.515	0.992	1.152	1.150	2.223	2.808
Ecuador	1.949	1.278	0.642	1.920	0.080	0.000	0.080	3.104
Paraguay	1.439	1.220	0.423	1.643	0.228	-0.877	-0.685	3.574
Peru	1.459	0.797	0.798	1.595	-0.085	1.900	1.358	2.997
Uruguay	1.304	1.314	0.429	1.743	1.353	0.090	1.348	2.006
Venezuela	1.652	1.334	0.486	1.821	1.895	0.185	2.075	2.677
South America	1.763	1.241	0.470	1.742	1.209	0.627	1.837	3.042

With the OLS and ML methods all the countries show positive average rates of productivity growth, but with the Malmquist index method some countries show negative average values. The negative estimate for Argentina given by a negative TC is driven by a sharp increase and posterior decrease in the use of Labor during the 1990s, while the estimate of Paraguay is related with negative values of EC and it seems to be driven by an sharp increase and posterior decrease in the amount of FTEs reported during the 1980s and 1990s. The stochastic frontier approach shows that the TFP growth is driven mainly by technical change (1.24% average per year versus only .47% efficiency change). Chile shows the highest TFP growth rate during the period, followed by Venezuela, Ecuador, Argentina and Brazil. Among the ten countries analyzed, Peru has the higher rates of efficiency change; for Bolivia, Colombia and Peru this change has been the most important force in determining the TFP growth rate. The gains in efficiency observed mainly by Peru (and Ecuador at a lesser extent) is given by a fast displacement of it towards a

slower expanding frontier that was mostly determined by Brazil (26 years) and Argentina (10 years), with Argentina dominating during the 1970s and Brazil since the 1980s. From a generally constant period with an expanding frontier, only 4 out of the 41 years the frontier contracted; the years 1971 and 1991 showed the bigger contractions, although these values were smaller than 0.5%. This dominance of Argentina and Brazil determining the frontier can be seen in Figure 6.

Figure 6 - Efficiency Estimators - Stochastic Frontier
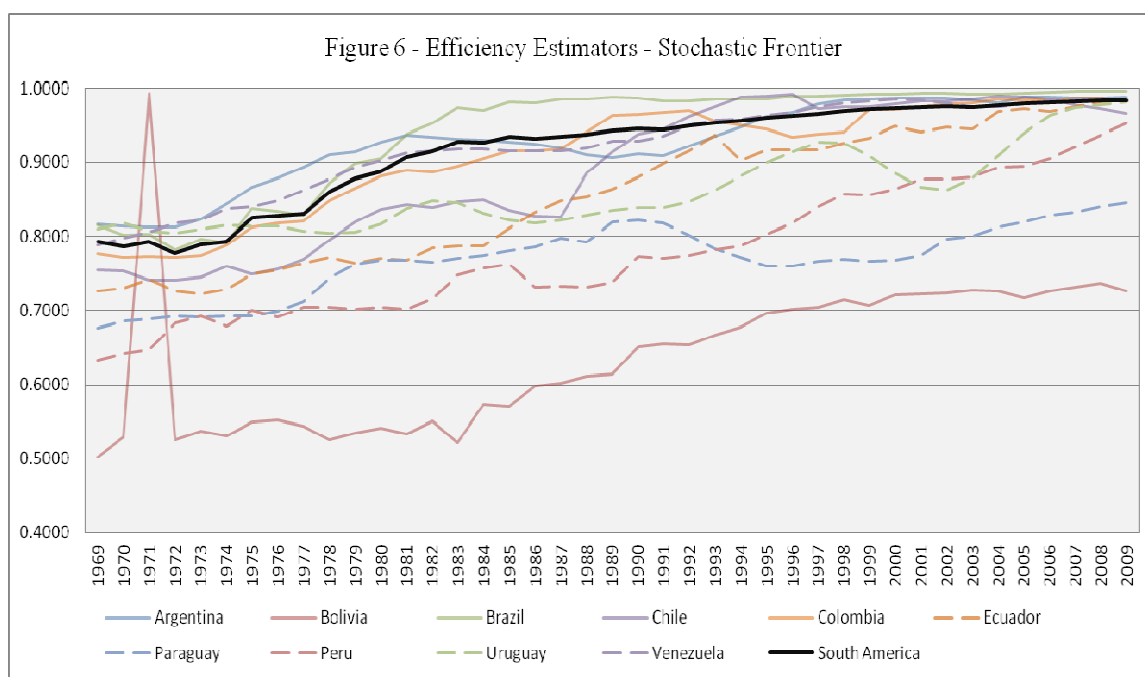
We can see how most countries tend to converge to the proximity of the frontier by the late 2000s with the exception of Paraguay and Bolivia. The kink in Bolivia's efficiency estimator during 1971 is due to the value of fertilizer reported for that year that is half of that reported for 1970 and near one third of that reported for 1972.

Table 6 opens the Frontier TFP growth rate estimations by decades.

Table 6 - Frontier Estimates

Country	TC				EC				TFP			
	1969-1979	1980-1989	1990-1999	2000-2009	1969-1979	1980-1989	1990-1999	2000-2009	1969-1979	1980-1989	1990-1999	2000-2009
Argentina	0.58	1.22	1.69	1.96	0.99	-0.09	0.80	0.02	1.57	1.13	2.49	1.99
Bolivia	-0.64	0.11	0.67	1.03	0.33	0.79	0.93	0.19	-0.32	0.90	1.60	1.22
Brazil	0.37	1.28	1.70	2.00	0.83	0.90	0.04	0.04	1.21	2.17	1.74	2.04
Chile	1.32	1.80	2.32	2.91	0.66	0.94	0.61	-0.09	1.98	2.74	2.93	2.82
Colombia	-0.16	0.46	0.64	0.96	0.89	0.97	0.09	0.11	0.73	1.44	0.73	1.07
Ecuador	0.40	0.97	1.59	2.15	0.37	1.00	0.69	0.50	0.77	1.97	2.29	2.66
Paraguay	0.39	1.00	1.56	1.93	0.86	0.57	-0.53	0.79	1.25	1.56	1.04	2.73
Peru	0.04	0.61	1.11	1.43	0.68	0.37	1.18	0.96	0.72	0.98	2.29	2.39
Uruguay	0.57	1.11	1.53	2.05	-0.04	0.29	0.74	0.73	0.52	1.40	2.28	2.77
Venezuela	0.58	1.12	1.63	2.01	1.04	0.37	0.54	-0.01	1.62	1.49	2.16	2.01
South America	0.37	1.16	1.60	1.93	0.83	0.63	0.30	0.11	1.23	1.79	1.90	2.04

For all the decades the average TFP growth rate is positive and increasing. We observe that the productivity growth rate rose steadily from a 1.23% increase during the 1970s to a 2.04% increase during the 2000s. This latter estimate is similar to that found by Ludena (2010) for the period 2001-2007, lower than that found by Fuglies (2010) for 2000-2007 (2.60%) and higher than that found for Fuglies for developed economies (0.86%), including weak 0.33% and 0.59% increases for United States/Canada and for Western Europe respectively (after a strong growth of 2.26% and 1.63% during the 1990s).

Table 6 also shows how the TFP growth rate is mainly due to technological change and how the average TC rate has been steadily increasing since the 1970s. This positive and increasing trend applies for every single country in the region. Opposing to this trend we also observe how the EC has steadily decrease its rate of growth; this decrease is mainly driven by the initially fast catching up of the more inefficient countries with respect to those that are in the frontier; once over the frontier, efficiency can only be gained by expanding the frontier.

Disaggregated by country, all the countries show a positive rate of TFP growth in the four decades with the sole exception of Bolivia during the 1960s. During the 2000s, for most of the countries the TFP grew at more than 2%. Chile (2.82%) followed by Uruguay (2.77%) and Paraguay (2.73%) have the faster growth rates. Colombia (1.07%) and Bolivia (1.22%) show the

slowest growth rates. For Brazil we observe a recovery with respect to the small slowdown observed during the last decade, from a 1.74% growth in the 1990s to a 2.04% in the 2000s. This estimate is slower than that found by Gasquez et al. (2008) for the period 2000-2007 (2.80%) and by Fuglies (3.26%) for the same period. We do observe a slowdown in the second economy of the region, Argentina; from a strong 2.49% increase during the 1990s to 1.99% increase during the 2000s. This estimate for the 1990s period is slightly higher to that found by Bharati et al. (2007) for the period 1992-2002 (2.31%) and much higher to that found by Ludena (2010) for 1991-2000 (0.8%), who also found a 3.8% increase for the period 2001-2007; observing the opposite trend for the last two decades. For the remaining countries, Colombia, Ecuador, Paraguay, Peru and Uruguay show an increase in the TFP growth rate during the 2000s with respect to the 1990s.

Figure 7 shows the indexed TFP growth for every country since 1969. It is noticeable the separation of Chile with respect to the other countries and how Bolivia (and in a lesser extent Colombia) seem to fall behind the rest of the countries. In this graph is also visible the sharp increase in efficiency estimated for Bolivia during 1971 that was due to the sudden drop in the amount of fertilizer used.

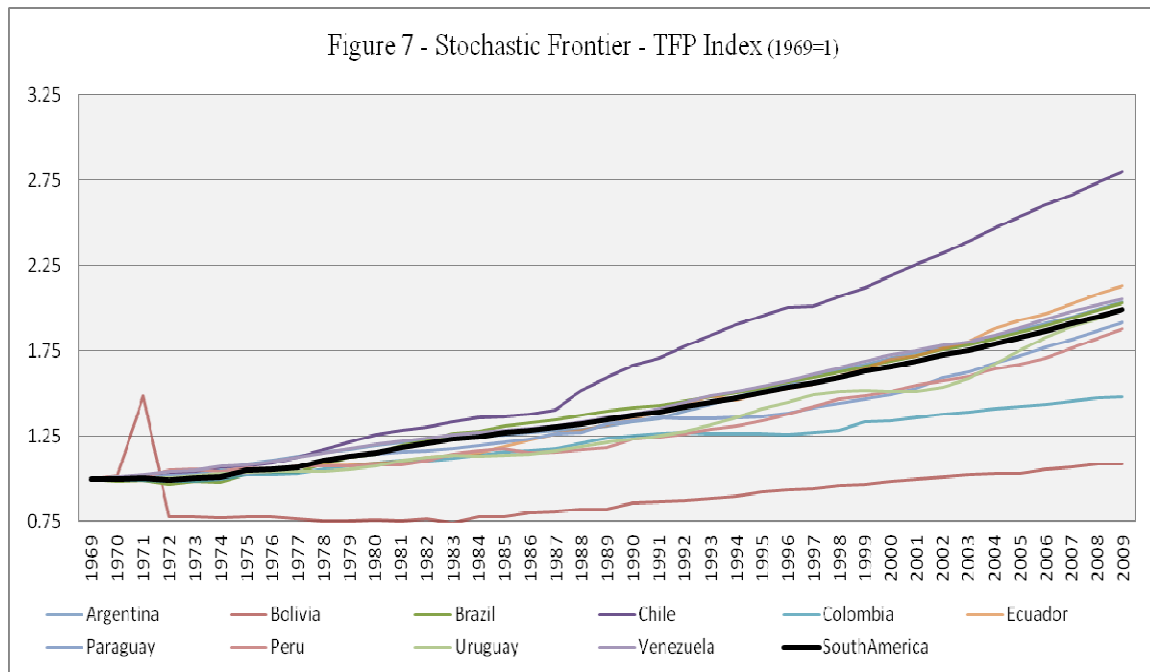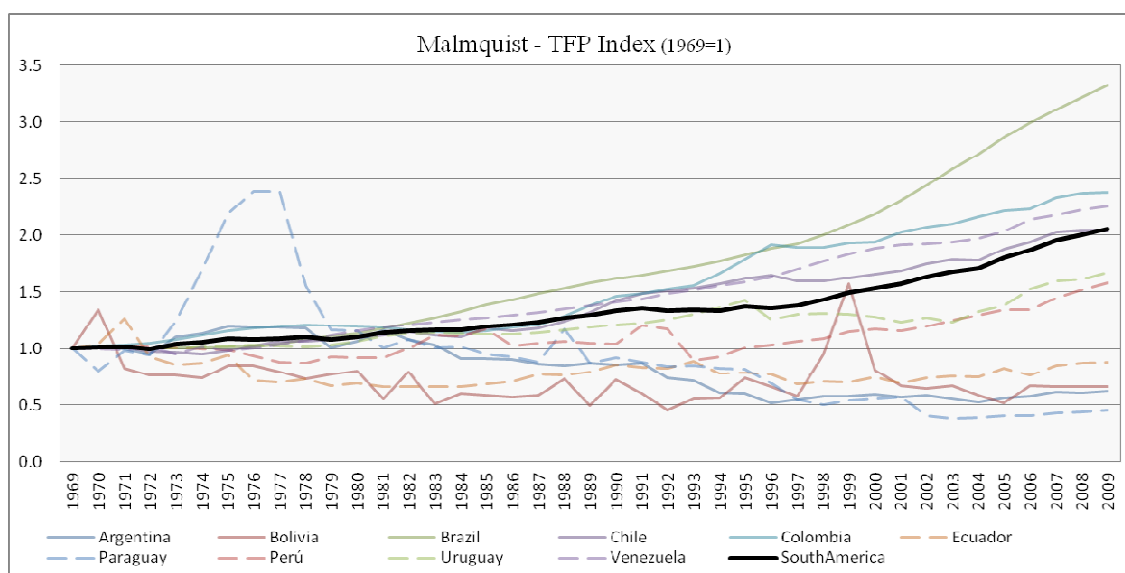Figure 7 - Stochastic Frontier - TFP Index (1969=1)

Figure 8 shows the indexed TFP growth estimates using the Malmquist index approach. The estimated average growth rate for the region is very similar to the one found using the Frontier approach, but there are some important changes with respect to the Frontier estimation: there is not a cluster of countries that are close to the region average and most seem to diverge. Also, in this estimation, the country that is leading the growth is Brazil, with 3.3 fold in the growth rate since 1969. Further away we observe Colombia, Venezuela and Chile with growing rates over the region average. In the other extreme, we have 4 countries falling behind: Ecuador, Bolivia, Paraguay and Argentina. We observe here an inconsistency between the two estimations; Colombia was the country we the second slowest growth rate for the Frontier estimation, but with the Malmquist index it is the second country with the highest growth rate. Similar, Ecuador was the second country with highest growth rate in the Frontier estimation but with the Malmquist Index it is well below the average growth of the region.

Malmquist - TFP Index (1969=1)

Legend: Argentina, Bolivia, Brazil, Chile, Colombia, Ecuador, Paraguay, Perú, Uruguay, Venezuela, SouthAmerica

Conclusions

This research finds that no slowdown in agricultural productivity growth is present in South America. We find that the yearly average productivity growth rate in the region during the period studied was a positive 1.742% for all the countries in average. The highest estimated rate is for Chile (2.62%) and the lowest for Bolivia (0.85%). This increase on average TFP growth in the region is related mainly to innovations. During the period considered, the decade with lower average TFP growth was 1969-1979 showing an increase of 1.23 percent; this estimate constantly grew each decade to a highest during the period 2000-2009 with a rate of 2.04 percent. This latter estimate can be decomposed into a 1.93 percent growth due to technological change and a 0.1 percent growth due to efficiency change.

Given these results, the nonparametric Malmquist Productivity Index was used on the same data set with the purpose to check robustness of the econometric results. Here, we also found an increase in TFP growth rates for the region as a whole. The average TFP change for the period was 1.84 percent, with innovations contributing 1.21 percent and efficiency change with 0.63 percent. This consistency in the estimation for the average of the region is not present when analyzing countries individually. There is a

qualitative inconsistency: two countries with a positive average TFP growth estimated with the Frontier approach had negative average growth rates with the Malmquist Index approach (Argentina and Paraguay). And there is also an ordinal inconsistency: countries leading in the Malmquist Index approach are falling behind in the Frontier estimation.

With respect to the institutional variables, following results in previous studies, I found that differences in efficiency across the countries in the sample can be explained by institutional and socio-economical characteristics of each country. Among these, GDP per capita, Labor Quality (life expectancy), personnel employed in R&D in agriculture and average precipitation where found very important to decrease technical inefficiencies.

This analysis shows that there is no evidence of a slowdown in agricultural productivity in South American economies. For the last 41 years, total agricultural production in South American countries has increased steadily; from 1969 to 2009 it has increased more than 3 times. This raise in output is related, in part, to a higher factor accumulation, but also, as this article demonstrates to a higher Total Factor Productivity (TFP).

References:

- Aigner, D. J., C. A. K. Lovell and P. Schimdt. "Formulation and Estimation of Stochastic frontier Production Function Models." J. Econometrics 6 (1977): 21-37.

- Alauddin,M., Headey, D., Rao, D.S.P., " Explaining Agricultural Productivity Levels and Growth: An International Perspective." Centre for Efficiency and Productivity Analysis, Working paper series no.02, 2005.

- ANFAVEA. "Brazilian Automotive Industry Yearbook 2011". Associação Nacional dos Fabricantes de Veículos Automotores, Brazil. 2011.

- Arnade, Carlos, "Using a Programming Approach to Measure International Agricultural Efficiency and Productivity", Journal of Agricultural Economics, 1998, 49,67-84.

- Alston, J. M., Babcock, B. A. and Pardey, P. G. "The Shifting Patterns of Agricultural Production and Productivity Worldwide". The Midwest Agribusiness Trade Research and Information Center Iowa State University, Ames, Iowa. 2010.

- ASTI website: http://www.asti.cgiar.org/. Accessed May 2012.

- Battese, G.E. and Coelli, T.J., "A Model for Technical Inefficiency Effects in a Stochastic Frontier Production Function for Panel Data", Empirical Economics, 20, 325-332, 1995.

- Bharati, P., and Fulginiti, L. 2007. "Institutions and Agricultural Productivity in Mercosur." In: E.C. Teixeira and M.J. Braga, editors. Institutions and Economic Development. Vicosa, Brazil.

- Ball, E., Wang, S. L. and Nehring, R. "Agricultural Productivity in the United States". Economic Research Service (ERS). United States Department of Agriculture (USDA). 2009.

- Ball, V. E., J-P Butault, C. San Juan Mesonada, and R. Mora. "Productivity and International Competitiveness of European Union and United States Agriculture, 1973-2002," Agricultural Economics (September 2010): 611-627.

- Bravo-Ortega, C., Lederman, D. "Agricultural Productivity and Its Determinants: Revisiting International Experiences" Estudios de Economia, v. 31, iss. 2, pp. 133-63, December 2004.

- Coelli, T. J. "A Guide to DEAP version 2.1: A Data Envelopment Analysis (Computer) Program." working paper, Centre for Efficiency and Productivity Analysis (CEPA), Department of Econometrics, University of New England, Armidale, Australia, No. 8/96, 1996.

- Coelli, T. J. "A Guide to FRONTIER Version 4.1: A Computer Program for Stochastic Frontier Production and Cost Function Estimation." working paper, Centre for Efficiency and Productivity Analysis (CEPA), Department of Econometrics, University of New England, Armidale, Australia, No. 7/96, 1996.

- Coelli, T. J. and D.S. Prasada Rao, "Total Factor Productivity Growth in Agriculture: A Malmquist Index Analysis of 93 Countries, 1980-2000, CEPA working paper series no. WP02, 2003.

- FAOSTAT. 2011. http://faostat.fao.org/site/339/default.aspx Accessed May 2012.

- Fuglie, Keith O. "Total Factor Productivity in the Global Agricultural Economy: Evidence from FAO Data". Chapter 4: The Shifting Patterns of Agricultural Production and Productivity Worldwide. The Midwest Agribusiness Trade Research and Information Center Iowa State University, Ames, Iowa. 2010.

- Fulginiti, L. and Perrin, Richard K, "Prices and productivity in agriculture", Review of Economics and Statistics, 75, 471-482, 1993.

- Fulginiti, L. and Perrin, Richard K., "LDC Agriculture: Non parametric Malmquist Productivity Indexes", Journal of Development Economics, 58, 373-390, 1997.

- Gasquez, J. G., Bastos, E. T. and Bacchi, M. "Produtividade e Crescimento da Agricultura Brasileira". Assessoria de Gestão Estratégica. Brasilia, November 2008.

- INDEC. "Informe de coyuntura de la Industria de Maquinaria Agrícola - Cuarto Trimestre Año 2010". Instituto Nacional de Estadísticas y Censos, Argentina. 2011.

- Kawagoe, T.; Hayami, Y.; Ruttan, Vernon W., "The Intercountry Agricultural Production Function and Productivity Differences among Countries." Journal of Development Economics, v. 19, iss. 1-2, pp. 113-32, 1985.

- Lau, L. and P.Yotopolous, "The Meta Production Function Approach to Technological Change in World Agriculture", Journal of Development Economics, 31, 241-269, 1989.

- Ludena, Carlos E., "Agricultural Productivity Growth, Efficiency Change and Technical Progress in Latin America and the Caribbean", Inter-American Development Bank, 2010.

- Ludena, Carlos E. and Hertel, Thomas E., "Productivity Growth and Convergence in Agriculture and its effects on World Food Trade", contributed paper, IAMA 16th Annual World Food Forum and symposium, Buenos Aires, Argentina, June 10-13, 2006.

- Pfeiffer,Lisa M., "Agricultural Productivity Growth in the Andean Community" American Journal of Agricultural Economics, v. 85, iss. 5, pp. 1335-41, 2003.

- Ravn, Morten; Uhlig, Harald. "On adjusting the Hodrick–Prescott filter for the frequency of observations". The Review of Economics and Statistics 84 (2): 371–375. 2002.

- Trueblood, M.A. and Coggins, J.. "Intercountry agricultural efficiency and productivity". Economic Research Service, US Department of Agriculture, Washington, DC. Mimeo, (2000)

- United Nations. United Nations Development Programme web-site.
  http://hdr.undp.org/hdr2006/statistics/

- Weibe, K., M. Soule, C. Narrod, and V. Breneman. "Resource Quality and Agricultural Production: A Multicountry Comparison" Washington, D.C.: US Department of Agriculture, Economic Research Service, July 2000.

- World Bank. World Development Indicators on line.
  http://web.worldbank.org/WBSITE/EXTERNAL/DATASTATISTICS/

Appendix

Figure 4 - TTP Growth Rates by decade - South America %