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INSTITUTIONS AND AGRICULTURAL PRODUCTIVITY IN MERCOSUR[1]

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Abstract: We revisit earlier estimates of agricultural productivity in original Mercosur member countries and later associates: Argentina, Brazil, Paraguay, Uruguay, Chile, Bolivia, Colombia, Ecuador, Peru and Venezuela, for 1972-2002. We estimate a translog frontier production function and revise our earlier estimates as well as those of others that indicated declining agricultural productivity. We find that the average rate for the region was a strong 2.25 percent. All the member countries experienced positive agricultural productivity growth for the sample period with Brazil being the fastest gainer. Institutions such as investments in public health and in public agricultural R&D, as well as an economic environment conducive to trade with the rest of the world are associated to differential performance across countries.

JEL classification: O4, O1

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1. Introduction

In the economics literature, aggregate productivity refers to the amount of output obtained from given levels of inputs in an economy or a sector. It is an important topic of study because productivity is one of two fundamental sources of larger income streams; the other being savings, which permit

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more inputs to be employed. Moreover, productivity rather than additional inputs has been the real engine driving growth in agricultural output in the developed world, inasmuch as changes in output from decade to decade in this century have borne little or no relationship to changes in inputs. Schultz first noted this phenomenon in the 1950s, and it has been even more pronounced since then.

Agricultural productivity in developing countries has been measured as a shift in the aggregate agricultural production function, because the absence of price data has made conventional indexing techniques infeasible. The first such study relevant to the green revolution period was that by Hayami and Ruttan. They estimated intercountry production functions which indicated that agricultural productivity in 22 LDC's declined at an annual rate of 2.1 percent between 1960 and 1965, on the eve of the green revolution. That study was updated by Kawagoe, Hayami and Ruttan who found that productivity continued to decline, but at the rate of 1.5-2.0% per year between 1960 and 1970, and by another 1.0-1.5% between 1970 and 1980. Lau and Yotopolous used a slightly different intercountry production function approach using much of the same data, and while production elasticity estimates differed, they estimated that productivity rose at the rate of 0.4% during the 1960s and declined at the rate of 0.25% during the 1970s.[3] It is interesting to note in contrast that similar studies of developed country agricultural sectors, by some of the same authors, have without exception shown increases in agricultural productivity.

In the past decades the number of studies has expanded due to the availability of the FAO data set, new methods of estimation, an interest in evaluating the impact of the Green Revolution technologies, and a desire to capture long run effects of institutional factors that affected the sector. Using new techniques and this data set, a result of declining productivity in developing country agriculture by Fulginiti and Perrin (1993) re-fueled the debate and motivated a number of recent studies. These studies examined cross-country differences in agricultural productivity for a large number of countries,

[3] Except for Lau and Yotopolou's results, most estimates show more decline in the 60's than later. Our own results, econometric or nonparametric, support this evidence.

spanning all continents, and using diverse techniques. These techniques range from econometric estimation of production functions (mainly Cobb-Douglas and translog), to non-parametric indexes (Malmquist as well as Fisher indexes).

The analysis to follow will focus on productivity performance in the countries of Mercosur. By narrowing the focus of analysis from the whole world to the south cone of Latin America, we are isolating a relatively more homogeneous area of production, sharing some institutional characteristics. Mercosur is a customs union created in 1991 involving now ten countries with varying degrees of membership. While the original treaty of Asuncion had four signatories: Argentina, Brazil, Paraguay and Uruguay, it grew to include Chile and Bolivia as associate members. The present decade saw the addition of Peru, Colombia and Ecuador as associate members, and recently Venezuela as full member. Agriculture in this region accounts on average for 12% of GDP, for 40% of exports and it occupies approximately 20% of the labor force (Table 1). Productivity performance in the agricultural sector is important to improvement in overall economic growth as the sector serves as a source of revenues and foreign exchange for the rest of the economy. If indeed the deterioration in productivity is true then it is cause for concern.

While these countries individually have been the focus of a number of studies[4] there is no comparative study in the literature aiming at identifying key institutional factors that might have influenced the difference in performance across countries. Some of these countries have been included in recent worldwide multicountry studies by Fulginiti and Perrin (1993, 1997), Arnade, Trueblood and Coggins, Coelli and Rao, Pfeiffer, Bravo Ortega and Lederman, Allaudin, Heady and Rao, and Ludena and Hertel and only Pfeiffer's study narrows the analysis to five of them (the Andean group.)

[4] The following is a list of country studies which does not intend to be exhaustive. For Argentina: Fulginiti and Perrin (1993), and Mundlak and Domenech . For Brazil: Pereira et al., Helfland and Rezende For Paraguay: Hanratty and Meditz, Bravo Ureta and Evenson , Beintema et al., and Fletschener and Zepeda. For Uruguay: Hudson and Meditz, Beintema et al., De Brun , Paiva and Gazel , and Baethgen and Gimenez. For Chile: Olavarria, et al., Sparks and Bravo Ureta, de Janvry et al.

These studies, though they covered different time periods and different sets of countries, seem to indicate a recovery. The present study aims at providing a comprehensive understanding of agricultural productivity growth in this region, and on the role of key public inputs such as investments in agricultural R&D, investments on improvement in the quality of inputs, as well as some other institutional factors that might give additional insights on the differences in performance of these countries during the last thirty years.

2. Analytical Approach

Productivity growth refers to growth in output which is not attributable to growth in the inputs but due to other factors like technological advancement or improvement in the efficiency of input usage. We address two questions about agricultural productivity in Mercosur. First, what have been the rates of productivity growth? Second, what institutional and socio-political factors may have affected agricultural productivity performance in the last three decades?

Among the many alternatives available to estimate productivity growth, the one we adopt is the production function approach pioneered by Solow and Griliches and used by many others in the multi-country context.[5] We approximate the agricultural technology with a translog production function and use two econometric methods: ordinary least squares (OLS) and a maximum likelihood stochastic frontier (ML). OLS has been used in most other cross-country studies, and we use it here as reference. The ML frontier approach has been used by Pfeiffer and by Bharati and Fulginiti in Latin America and by Fulginiti et al. in Sub-Saharan Africa and gives a way of incorporating institutional variables to capture the intercountry differences in performance in addition to the within country rates of growth of productivity.

[5] Also refer to as a meta-production function.

The standard neoclassical production function is written:

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

where Y_{it} is output of the i-th country in 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. When OLS is used ε_{it} are random variables which are assumed to be iid N(0, σ^2_ε). Aigner, Lovell and Schmidt, and Meeusen and Van den Broeck, modified the production function to allow for the presence of technical inefficiencies captured by a one-sided error term. This standard neoclassical production function is re-labeled a stochastic production frontier and following Battese and Coelli, the error term is composite, $\varepsilon_{it} = v_{it} - u_{it}$ where v_{it} are random variables which are assumed to be iid N(0,σ^2_v) and independent of u_{it}, and u_{it} is a non-negative random variable distributed iid N(0, σ^2_u) associated with technical inefficiency across production units (or individual production units effects.) In our case, it accounts for heterogeneity across countries that can cause departures from maximum potential output and it will be the conduit for the inclusion of institutional variables in the analysis.

We use the production technology in (1) to break down the growth rate of aggregate output into contribution from the growth of inputs versus productivity change:

$$\dot{Y}_{it} = \sum_n \xi_{itn} \dot{x}_{itn} + T\dot{F}P_{it} \tag{2}$$

where a dot over a variable indicates its rate of change, and $\hat{\imath}_{itn}$ is the production elasticity of input n, for country i in year t, $\xi_n = \dfrac{\partial f(x,t,\beta)}{\partial x_n}$ In turn, TFP growth can be decomposed as (dropping the *it* subscripts for simplicity):

$$TFP = TC + EC \tag{3}$$

where $TC = \dfrac{\partial f(x,t;\beta)}{\partial t}$ is a shift of the production frontier representing technical change, and technical efficiency change, EC, is the rate at which a country moves toward or away from the production frontier, which itself shifts through time as measured by TC.

The technical efficiency change component requires a little more explanation given that it will also be the basis for information that will lead us to answer the second question, the identification of institutional factors that underlie differential productivity growth performance across countries in Mercosur. Technical inefficiency is captured in equation (1) only when the frontier approach is used and the error term is a composite of two random variables. It is captured by the non-negative random variable u. The ratio of observed output for the i-th country relative to its potential output when the individual country effects are zero, is used to define the technical efficiency of the i-th country in period t, $TE_{it} = \dfrac{Y_{it}}{\exp[f(x_{it};\beta)+v]} = \exp(-u_{it})$. This measure of technical efficiency takes on values of zero to one, with a value of one indicating full technical efficiency. It represents the observed output of the i-th country at time t relative to the output produced by a fully efficient country using the same input vector. The change in *TE* between two periods is *EC*. Notice that when OLS is used, there is no one-sided error term and no opportunity to capture technical efficiency which is then considered equal to zero by assumption. So, under OLS all countries are considered equally efficient and *TFP* change is *TC*.

Given that the *TE* term indicates discrepancies in the productivity performance across countries, the frontier methodology lends itself to the inclusion of potential determinants of country heterogeneity which we refer to as 'efficiency changing variables'. We follow Battese and Coelli, and specify a frontier model where the technical inefficiency effects are defined to be an explicit function of country-specific institutional and socio-political variables. The technical inefficiency eeffect u_{it} for the i-th country in the t-th period has a truncated iid $N(\eta_{it}, \sigma_u^{\,2})$ distribution, where the mean is

$$\eta_{it} = h_{it}\delta, \tag{4}$$

in which hit is a ($1xp$) vector of variables that influence the efficiency of the country, and *ä* is a (px1) vector of unknown parameters to be estimated. This model provides a way of testing if inefficiency effects are indeed present in the error term. The measure, gamma, where $\gamma = \dfrac{\sigma_u^2}{\sigma_u^2 + \sigma_v^2}$, reflects the proportion of the error term which is due to inefficiency effects. It lies in the range of 0-1, where a value of 0 indicates that the error is solely due to white noise and a value of 1 reflects the fact that inefficiency effects are largely contributing to the error term.

For implementation, the production function in (1) is approximated with a specific functional form that imposes minimal a *priori* assumptions, a flexible form.[6]

[6] Two algebraic flexible approximations to the production function (1) have been used in the literature, Taylor series and Fourier series, with the first being more common than the last. Although it would be preferable to use the Fourier series because it approximates the function and its derivatives, this exercise is left for the future. In practice the Fourier flexible form, a semi-nonparametric form that combines a standard translog function with a non-parametric Fourier series has been used. This form has been used by Fulginiti et al. (2005) for Sub-Saharan Africa.

Data

Panel data on output and conventional agricultural inputs (land, labor, fertilizer, tractors and animals) for the ten Mercosur countries for 1972-2001, are available from the FAOSTAT website. These data have been used in nearly every recent cross-country study of agricultural productivity. Summary statistics and other details of the data set may be found in Table 2.

Agricultural output is expressed as the quantity of agricultural production in millions of 1979-1981 "international dollars". We refer to land, labor, livestock, machinery and fertilizer as traditional inputs. Agricultural land is measured as the sum of arable land and permanent crops in thousand hectares. Agricultural labor is measured as the number of persons who are economically actively engaged in agriculture, in thousands. The livestock variable is a weighted average of the number of animals on farms in thousands. The farm machinery variable is the number of agricultural tractors. Fertilizer is quantity of fertilizer plant nutrient consumed (N plus P_2O_5 plus K_2O), in metric tons. Figure 1 shows the evolution of these variables during the period under consideration. We note the rapid growth of commercial inputs, with the erratic trayectory of fertilizers and the plateau in tractors starting in 1996. Figure 2 shows the average output and input allocations across countries.

Two types of efficiency changing variables are considered in this analysis, those that allow for *qualitative* input differences and those that may capture differences in the *institutional and socio-political* environment across countries.

Data availability restricts us to two input quality measures: (a) land quality; and (b) labor quality. Land quality is proxied by the land quality index and the percentage of irrigated land. The land quality index is from Wiebe et al. and refers to the percentage of International Geosphere-Biosphere Program class 12 cropland that qualifies in land quality category 1, 2 or 3 (the National Resource Conservation Service classifies land in various categories primarily on the basis of the type of soil.) The percentage of irrigated land is from FAOSTAT. Life expectancy data, from the United Nations Development Programme (UNDP) website and World Bank's World

Development Indicators (WDI) website, is used to proxy labor quality. In fact this variable more than an indicator of labor quality is an indicator of quality of life as a result of investments in public health. As such then one can equivalently consider this variable a proxy for the institutional and socio-economic environment.

The institutional and socio-political variables are as follows. (a) The variable freedom, is a political freedom and civil liberties index developed by Freedom House that is used to capture the political and social climate of the countries. Each country is measured on a one-to-seven scale, with one representing the highest degree of freedom and seven the lowest. Countries whose index fall between 1 and 2.5 are designated free, between 3 and 5.5 as partly free and between 5.5 and 7 as not free. (b) To control for differences in the economic environment across these countries, in particular to give a sense of how important has international trade been, we used the trade intensity (TI) ratio which is defined as the ratio of the sum of exports and imports to real GDP from the World Penn Tables. (c) To proxy infrastructure, data on telephone lines obtained from the World Development Indicators is used. This variable has shown to be relevant in Bravo-Ortega and Lederman's study of agricultural growth in Latin America. (d) To proxy public investments in agricultural R&D, personnel employed full time in agricultural research (FTEs) from Cremers and Roseboom was used.

3. Estimation

We estimate the translog flexible functional form using both OLS and ML frontier approach. Data for ten countries during the 1972-2001 period is used. Denote with $i = 1, \ldots, 10$ the countries, and with j and $k = 1, \ldots, 5$ the inputs x_{ijt} and x_{ikt} at each time period $t = 1, \ldots, 30$. Imposing symmetry, the translog production function we estimate is:

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

where Y is agricultural output; x 's are logarithms of inputs (land, labor, livestock, machinery, and fertilizer); t is time from 1 to 30 (a proxy for technical change); *a, b, c,* are parameters to be estimated, and ε is an error term. When a frontier function is estimated this error term is composed of two random variables

$$\varepsilon_{it} = -u_{it} + v_{it}$$

where u is the one-sided technical inefficiency term assumed truncated at zero and distributed iid $N(\eta, \sigma_U^2)$ that captures heterogeneity across countries and is the basis for differences in technical efficiency while v allows for measurement error and other random factors and is distributed iid $N(0, \sigma_v{}^2)$ and independent of u. When an average production function is estimated with OLS then

$$\varepsilon_{it} = v_{it}$$

and only a two sided random error is allowed implying that all countries are efficient.

When a ML frontier function is estimated, the technical inefficiency term is specified as the following function of efficiency-changing variables (h), estimated simultaneously with equation (5):

$$u_{it} = h_{it}\delta + \xi_{it} \tag{6}$$

with random variable ξ_{it} sharing the distributional characteristics of random variable u_{it}.

The first derivative of (5) with respect to t allows us to evaluate the rate of technical change, TC:

$$\mathrm{TC}_{it} = b_t + b_{tt}t + \sum_{j=1}^{5} b_{jt}x_{ijt}t \qquad (7)$$

The simultaneous maximum likelihood procedure of Coelli's FRONTIER 4.1 was used to estimate simultaneously the 28 parameters in equation (5), the 9 parameters in equation (6) and the ratio of variance, y. 19 out of 37 parameters are significantly different from zero at the 99% confidence level and 7 at the 95% confidence level. SHAZAM version 9.0 was used to estimate 28 OLS parameters. 13 out of 28 parameters are significantly different from zero at the 99% confidence level and 3 at the 95% confidence level.[7]

Three specification tests were performed. In the first the Wald test is used to compare the translog with the nested Cobb-Douglas specification leading us to reject this more parsimonious form.[8] In the second we test the null of no technical inefficiency (or the appropriateness of the one-sided error specification) and reject it.[9] A third test is a Wald test of the null hypothesis that inefficiency effects are absent from the model and that they are nonstochastic. This hypothesis is also rejected indicating that the full frontier model with all the country-specific variables in the efficiency term is appropriate.[10] These results imply that the full 37-parameter translog model of equations (5) and (6) produces estimates of the production function with the least amount of approximation error. It is at this point that we introduced the second criterion for model evaluation, consistency of the estimated function with the properties implied by production theory. We

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[7] Parameter estimates can be obtained from the authors.

[8] Restricting all the second order coefficients to zero gives the Cobb Douglas functional form. The Wald test results rejected this form. Wald test result - chi-square test statistic: 1233.67, p-value: 0.0000.

[9] The estimate of the inefficiency variance parameter (ã) is 0.877 and is highly significant (t-ratio 32.91%). A value of zero would indicate that the error variance in the model is solely random in nature. The estimate of gamma shows that indeed a significant portion of the error variance is due to inefficiency effects.

[10] This is done by setting the parameter g . (a ratio of standard errors) and all parameters in equation (7) to zero. Wald test result - chi-square test statistic: 167.94 exceeding the 5% critical value of 15.51 with 8 degrees of freedom.

calculate production elasticities for each of the models estimated above to evaluate monotonicity (non-negative production elasticities). The frontier translog production elasticities are, on average, consistent with theory while the OLS are not as can be seen in Table 3.

With the ML frontier approach we obtain estimates of the *ä* parameters in equation (6) that allow prediction of the efficiency levels per country from where we obtain the efficiency change (EC) estimates. Having TC and EC we use equation (3) to obtain the ML estimates of productivity (TFP) growth rates for each country.

It is not very informative to discuss the average rate of technical change for all countries and years, because grand averages "hide" information. We find it more informative to look at the evolution of the annual average TFP for both models evaluated using equation (3). From the evolution of average TFP shown in Figure 3 there are four obvious conclusions. First, the OLS estimation, by structurally approximating TFP with a trend, smoothes out and shapes technical change. Second, the TFP rate in the region has been positive and high during the whole period under analysis. Third, the OLS productivity growth rate is an upper limit to the ML stochastic frontier rate. Fourth, there seems to be more volatility in the estimates before 1990. In Figure 4 we see the evolution of the a productivity index for the region derived from both estimations.

Another empirical result of interest is the nature of the efficiency change, as reflected in the estimates of from equation (6) and presented in Table 4. We find that the effects of land quality and irrigation, both variables included to account for quality differences in land, are insignificant individually but significant as a group when tested. With respect to the institutional variables, investments that result on improvements in life expectancy, investments in agricultural R&D reflected by increases in full time equivalents (FTEs), and access to international markets seem to be important. The coefficient associated with improvements in life expectancy indicates that the higher is this index, the more efficient is the country's agriculture. Improvements in life expectancy are directly related to investments in public health. FTEs devoted to agricultural research indicate also that this is a variable of importance in decreasing inefficiency or the cross country difference in agricultural performance. This variable is directly related to public investments in agricultural R&D. The trade index, used here as a rather crude proxy for the economic environment in these countries, appears as an important variable in explaining differences in performance. This is not surprising given the importance of exports in agricultural growth. Our proxy for infrastructure, telephone lines per person, also a rather crude attempt but used before in other studies, is significant but has an unexpected sign. A better proxy for this important variable in development would be investments in roads, railways and port installations but data limitations did not allow their inclusion. Differences in respect for political rights and civil liberties do not explain the heterogeneity in production efficiency among these countries. This index, important in the study in sub-Saharan African agriculture in Fulginiti et al., does not present in Mercosur the variability observed in Africa.

Weibe *et al.*, in their analysis of Latin America, estimated negative and insignificant coefficients for land quality variables and found that climatic factors like rainfall and irrigation were not significant. Bravo-Ortega and Lederman found that while telephone lines was a good control variable for infrastructure, its effect in Latin America declined significantly post 1990. The estimates and significance of full time equivalent (FTE), life expectancy and the trade intensity ratio suggest that public research and health investments as well as an economic environment that facilitates exports have been important enough to explain some of the heterogeneity in performance of the agricultural sector across Mercosur countries.

4. Agricultural Productivity Performance in Mercosur.

Our objectives have been to obtain comparative measures of agricultural productivity covering the ten countries in Mercosur with the most complete set of years to date, and to explore the potential role of institutional and socio-political variables in understanding differences in performance of individual countries. The pooled frontier production functions of the previous section provide the basis for addressing these objectives.

We find in Table 5 that agricultural output growth for the region was 3.16% and the area achieved average annual productivity gains of 2.84% using the OLS estimates or 2.24% using the ML estimates over the three decades. [11] All countries show positive average rates of output and of productivity growth regardless of the estimation method, driven mainly by high rates of innovation. This is consistent with estimates of the most recent cross country studies and contradict earlier results.[12] [13] Brazil has the highest rate of output growth and it is the best performer averaging 2.62% per year, followed closely by Argentina, Chile, and Venezuela. Uruguay and Paraguay come next with average rates of 1.8%, then Bolivia and Colombia and lastly Ecuador with TFP growth rate of 0.6%.

Average gains in total factor productivity were positive for each decade. As shown in Figure 5 rates are high in all three decades, with rapid growth in the first twenty years and a levelling in the last ten. Average productivity gains in Mercosur of 2-2.5% are higher than gains experienced by developed countries. Table 6 shows that in the 1970s the region had a productivity growth rate of 1.96%. During the 1980s and 1990s productivity rates are even higher, at around 2.3%. The main driver each decade seems to be technical change showing increasing rates throughout the period. Catching up to the frontier countries seems to be more relevant during the 1970s than later.

On a country by country basis we see no uniform trend except for a direct relationship between rates of output growth and productivity growth. Most of the countries exhibit positive rates of growth of agricultural productivity in all three decades except for Peru in the 1990s and an almost

[11] In the ML estimation, when Brazil and Argentina, representing 52% and 22% respectively of production and having an average 2.47% TFP growth are purged from the set, TFP change in the rest of the countries is 1.46% percent. All are weighted averages with output shares used as weights.

[12] We should note though that the earlier results include data for the 1960's while most of the recent studies do not.

[13] From here on we will only describe results from the ML frontier estimation as this model fits the data better, gives us more information, and is consistent with the regularity properties of the technology.

stagnant Bolivia in the 1970s. In the case of Peru this might be explained by a drop in the rate of output growth during the 1990s.

More detailed information on each country's performance is obtained from Figure 6 showing the evolution of efficiency levels per country. Brazil and Argentina are consistently defining the frontier, they are the most efficient countries of the group. Bolivia and Peru are the furthest away from the efficient frontier but their rate of catching up to the frontier countries is notable.

The evolution of growth rates of technical change for each country can be followed in Figure 7. Brazil is the most innovative country in the region starting in 1980, with a period of rapid growth in the 1970s. Uruguay has high rates of innovation overall the period. Chile shows remarkable technical growth especially in the 1990s and moves closer to the frontier towards the end of the period of study. Bolivia is the least innovative country.

Table 5 gives the average rates of efficiency change or catching up per country for the whole period. The fastest rate of catching up belongs to Bolivia, followed by Peru and Paraguay. Uruguay, on average shows a deterioration but its performance is affected by some fairly important changes in FTEs devoted to agricultural R&D in this country. In Figure 8 we see the evolution of the catching up rates per country. Finally Figure 9 shows the evolution of the TFP index per country once the growth rates estimated are accumulated. Uruguay has been the most productive country followed by Brazil and Argentina. At the other extreme are Bolivia and Ecuador showing stagnation.

Coelli and Rao used non parametric Data Envelopment analysis of 93[14] countries to show that there is evidence of large increase in mean technical efficiency thereby implying catch-up. However, an analysis of our stochastic frontier results does not confirm these results at least for the countries in our sample. Our results are closer to those found in the more recent literature, for example Bravo-Ortega and Lederman, Alauddin,

[14]All Mercosur countries were a part of this study.

Headey and Rao, and Ludena and Hertel, who also find positive productivity growth due to innovations for the countries in Mercosur. A comparison of our results with those of other studies is given in Table 7.[15]

5. Conclusions

In this study of agricultural productivity in ten Mercosur countries, we have found that agriculture in the region had rapid and increasing progress during the 1970s and 1980s leveling at an annual rate of around 2.3% in the 1990s. Agricultural productivity levels have been improving for most countries in the region and rates of growth have been impressive and on average higher than that for developed country agriculture. The over-all average rate of productivity growth for the three decades was estimated at 2.24% per year. Further, the study highlights the fact that technical change is the main contributor to agricultural productivity growth in this region. Brazil experienced maximum productivity growth and the highest rates of innovation. The general nature of these results is consistent with several recent studies of agricultural productivity that include these countries among others and contradicts earlier results that indicated regressive technical change for some of them. Although the data is quite similar, our analytical approach is quite different from any other study, and has a focused geographical scope. This provides some confidence in the robustness of the estimates. Robustness is particularly useful in comparative studies of agricultural productivity because of the limitations in the quantity and quality of data needed for the purpose.

We estimated TFP gain or loss for each country in each year as the sum of predicted change in the production frontier in that vicinity plus predicted change in technical efficiency for that country and year. We used the Battese-Coelli approach to estimate the efficiency effects of institutional and other

[15] While the methods used are similar to those used in the earlier literature, i.e. translog production function and non parametric DEA method, the period covered in these studies includes the 1990s. We recall that some of the earlier studies which report negative productivity do not cover this decade.

efficiency-changing variables, with the production frontier specified as a translog flexible form. We found that the use of an average OLS meta-production function that included only the traditional inputs could not be justified by goodness-of-fit criteria, or by economic theory criteria as it posed violations of the required monotonicity property. We chose for the analysis the ML translog stochastic frontier function which allows the incorporation of variables that might explain the cross-country heterogeneity in performance.

A primary objective of the study was to examine the relationship between growth in productivity and institutional factors, following a number of recent studies showing that GDP growth rates are strongly affected by these factors. We found that difference in performance across countries is associated, in addition to differences in the natural environment, to differences in public investments in R&D and investments in public health, and by differential ability to access international markets. These results indicate that institutional factors, and in particular public inputs and regulations, are important determinants of agricultural productivity growth, as well as per capita GDP growth as established in other recent studies.

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Table 1. Share of Mercosur countries in labor force, exports, and GDP

	% workforce in Agriculture	% Ag share in total exports	% Ag share in GDP
Argentina	15	47.2	10.5
Bolivia	43.1	33.2	12.8
Brazil	20	33.1	10
Chile	13.6	35.5	6
Colombia	22.7	23.7	12.5
Ecuador	8	46.3	7
Paraguay	45	82.7	27.5
Peru	9	22.5	8
Uruguay	14	63.7	7.1
Venezuela	13	-	4

Source : CIA WORLD FACT BOOK, WTO

Argentina, Brazil, Paraguay, Uruguay (1991)

Chile (1996), Bolivia (1997), Peru (2003), Colombia , Ecuador (2004)

Venezuela (associate member-2004), Full member (2006)

Table 2 - Summary statistics of the data set used in the analysis (1972-2002)

	Unit	Mean	Max	Min	SD
Output	millions of 1979-81 US dollars	96168.21	149344.8	55860.52	27158.87
Land	1000 hectares	108,429.29	120,130.00	93,840.00	7,625.09
Labor	1000 persons	28,106.39	29,308.00	26,349.00	889.74
Livestock	sheep equivalent	34547.72	53967.06	20818.10	9901.75
Fertilizer	metric tons	5556165.42	10667393.00	2380680.00	2270422.96
Machinery	no. of tractors	1,036,658.58	1,313,011.00	507,451.00	265,459.70

Table 3 - Production Elasticities (evaluated at the mean.)

Production elasticity	**OLS**	**Frontier**
Land	0.437	0.153
Labor	0.192	0.303
Livestock	0.308	0.245
Fertilizer	0.012	0.023
Tractors	-0.015	0.065
Constant	2.13	8.048

Table 4 - Parameter Estimates, Efficiency Changing Variables

Variable	**Coefficient**	**T statistic**
Land quality	0.0002	0.19
Irrigation Ratio	0.1545	1.25
Life expectancy	***-0.0275***	***-10.15***
FTE	***-0.0004***	***-9.10***
Freedom	0.0362	1.38
TI	***-0.0047***	***-3.58***
TEL	0.0014	4.52

Table 5 - Estimated Total Factor Productivity Change in Mercosur, 1972-2002 (%)

	OLS	**Stochastic Frontier**			
	TFP Change	**Technical Change**	**Efficiency Change**	**TFP Change**	**Output Growth Rate**
Argentina	3.35	2.03	0.13	2.15	2.37
Bolivia	0.67	-0.16	1.31	1.11	3.64
Brazil	3.38	**2.42**	**0.2**	**2.62**	4.07
Chile	2.05	1.95	0.21	2.16	3.39
Colombia	0.99	0.79	0.28	1.07	2.57
Ecuador	0.84	0.11	0.48	0.57	2.98
Paraguay	1.65	1.19	0.71	1.87	3.74
Peru	0.88	0.27	0.89	1.12	3.74
Uruguay	1.93	2.47	-0.64	1.86	1.66
Venezuela	1.95	1.81	0.59	2.39	2.89
Weighted Average	*2.84*	***1.97***	***0.24***	*2.24*	***3.16****

*simple average

Table 6 - Output Growth and Estimated Technical Change, Efficiency Change and Total Factor Productivity Change by decades, Mercosur, 1972-2002 (%)

Table 6 - Output Growth and Estimated Technical Change, Efficiency Change and Total Factor Productivity Change by decades, Mercosur, 1972-2002 (%)

	TC			EC			TFP			Output Growth Rate		
	1972-1981	1982-1991	1992-2002	1972-1981	1982-1991	1992-2002	1972-1981	1982-1991	1992-2002	1972-1981	1982-1991	1992-2002
Argentina	1.45	2.10	2.50	0.71	-0.05	-0.20	2.16	2.05	2.31	3.47	1.38	2.39
Bolivia	-0.72	-0.01	0.21	0.78	1.24	1.80	0.06	1.23	2.01	3.40	3.46	4.01
Brazil	1.61	2.69	2.90	0.50	0.09	0.05	2.11	2.78	2.95	4.64	3.32	4.27
Chile	1.28	1.78	2.73	0.83	0.53	-0.58	2.11	2.31	2.15	3.58	3.24	3.38
Colombia	0.49	1.04	0.85	0.12	0.34	-0.03	0.61	1.38	0.82	3.22	2.66	1.33
Ecuador	-0.78	0.20	0.84	1.15	0.33	0.06	0.37	0.52	0.90	2.33	3.16	3.35
Paraguay	0.66	1.33	1.54	2.21	0.57	-0.39	2.87	1.90	1.14	5.10	5.17	1.32
Peru	0.00	0.29	0.49	2.10	2.21	-1.32	2.01	2.50	-0.83	5.10	5.17	1.32
Uruguay	2.12	2.60	2.68	0.55	-1.29	-1.03	2.67	1.31	1.65	3.02	0.16	1.74
Venezuela	1.11	1.82	2.45	1.69	-0.01	0.24	2.80	1.81	2.69	3.63	2.19	2.93
Weighted Average	***1.29***	***2.16***	***2.43***	***0.68***	***0.18***	***-0.07***	***1.96***	***2.33***	***2.36***	***3.75***	***2.99***	***2.60***

Table 7 - Estimates from recent studies.

	Fulginiti and Perrin (1997)	Arnade (1998)	Trublood And Coggins (2000)	Coelli and Rao (2003)	Peiffer (2003)	Bravo-Ortega and Lederman (2004)	Alauddin, Headey, Rao (2004)	Ludena and Hertel (2006)	This Study
Method	DEA	DEA	DEA	DEA	Translog	Translog	DEA	DEA	Translog
Data	5	5 + 1	5	5 + 1	5 + 3	6	5	9	5 + 6
No. of countries	18	70	115	93	5	86	111	116	10
Time period	1961-85	1961-93	1961-91	1980-2000	1972-2000	1960-2000	1960-2000	1961-2001	1972-2001
Argentina	-4.80	-1.85	-2.63	-2.70		1.84	0.99	1.04	2.15
Bolivia		4.68		1.10	0.61	1.18	0.96	1.10	1.10
Brazil	**-0.50**	**-2.05**	**-0.60**	**2.00**		**1.93**	**1.13**	**1.01**	**2.61**
Chile	1.10	1.25	1.39	1.10		1.20	1.18	1.01	2.16
Colombia	0.00	1.82		1.40	0.64	1.43	1.21	1.02	1.07
Ecuador		-0.99	-0.60	0.30	3.26	1.28	0.92	1.01	0.57
Paraguay		0.24	-1.10	-1.60		0.74	1.19	1.02	1.87
Peru		0.62	-0.10	1.50	2.79	1.36	1.13	1.02	1.12
Uruguay		-1.30		0.00		1.35	0.93	1.05	1.86
Venezuela		0.19		0.60	1.37		0.99	1.01	2.38

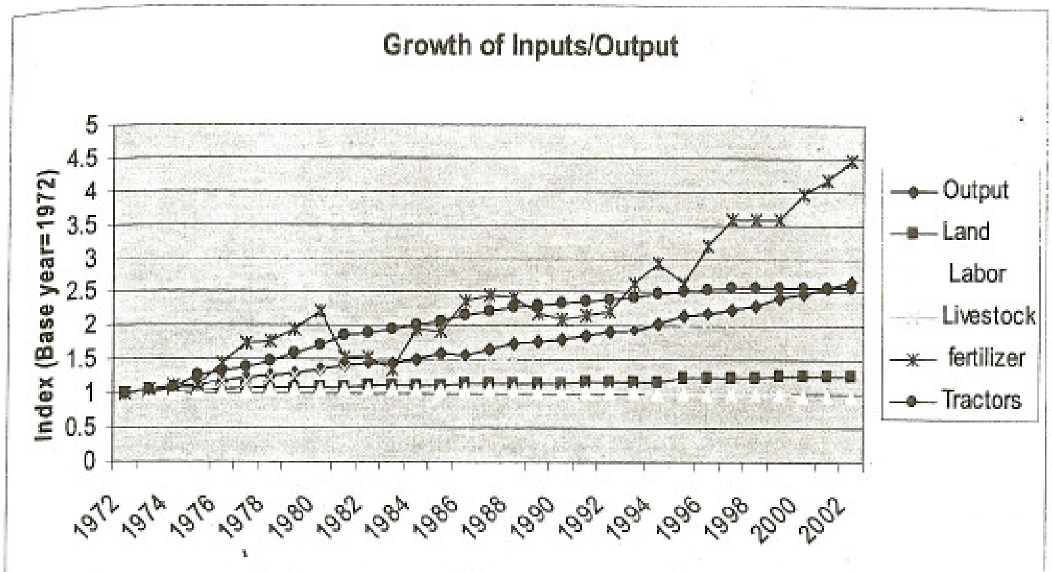

Figure 1 - Growth of Agricultural Output and Inputs, Mercosur, 1972-2002.

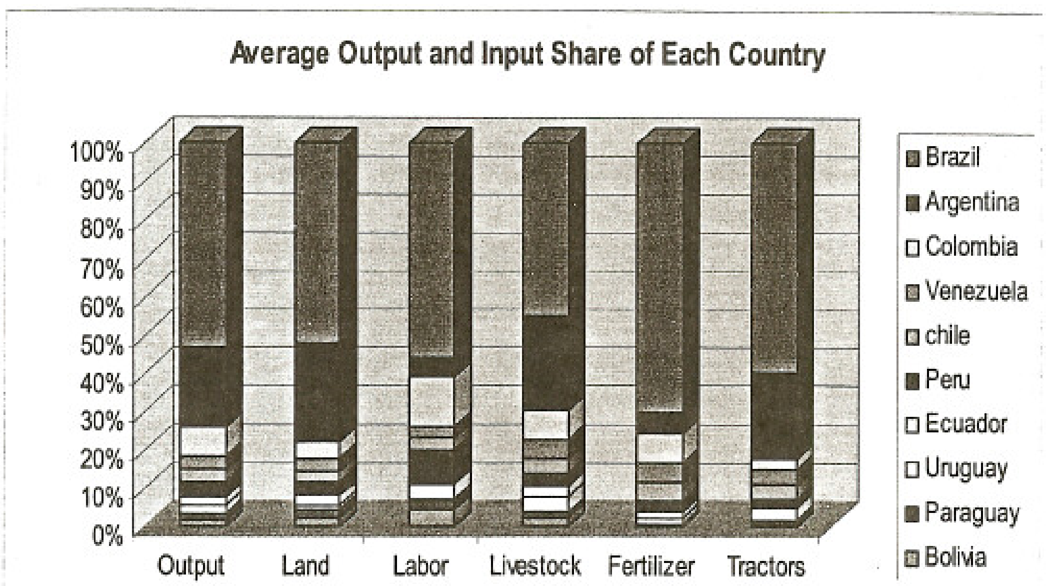

Figure 2 - Average Share of Agricultural Output and Inputs per Country

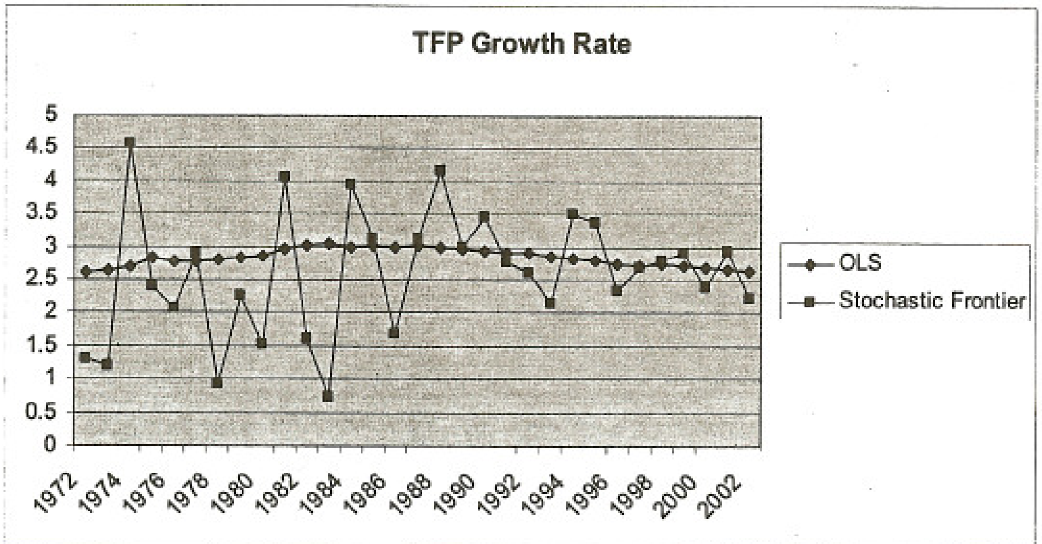

Figure 3 - Evolution of TFP Growth Rate

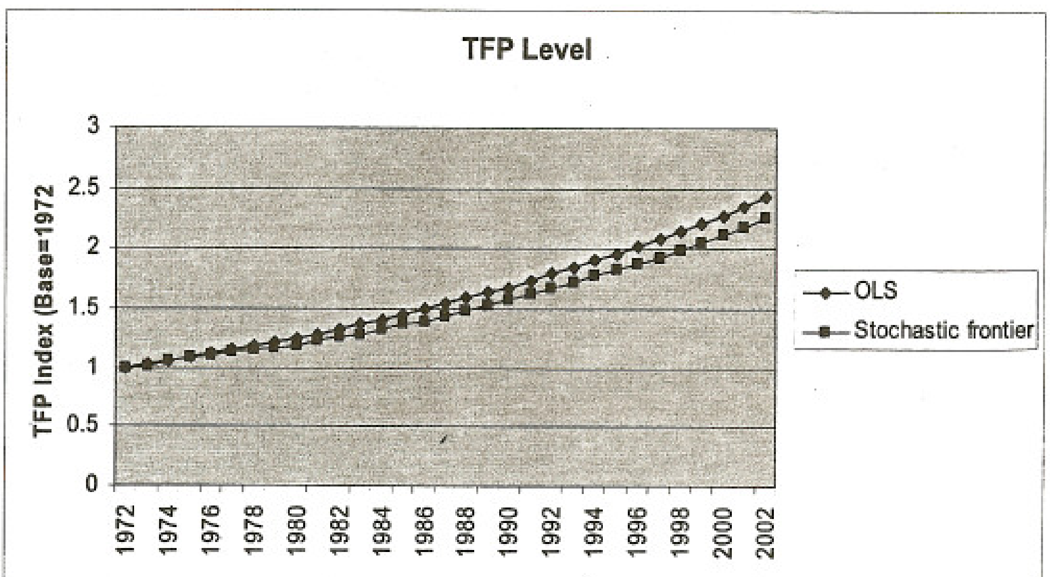

Figure 4 - Evolution of TFP levels

Figure 5 - Total Factor Productivity growth rates and Technical Change, Mercosur (%)

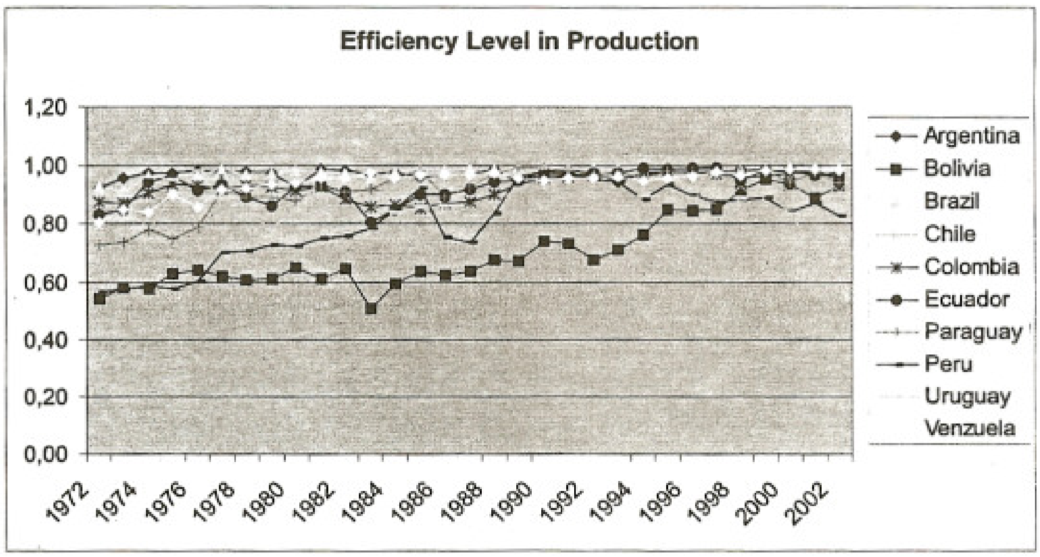

Figure 6 - Estimated Annual Efficiency Levels by Country

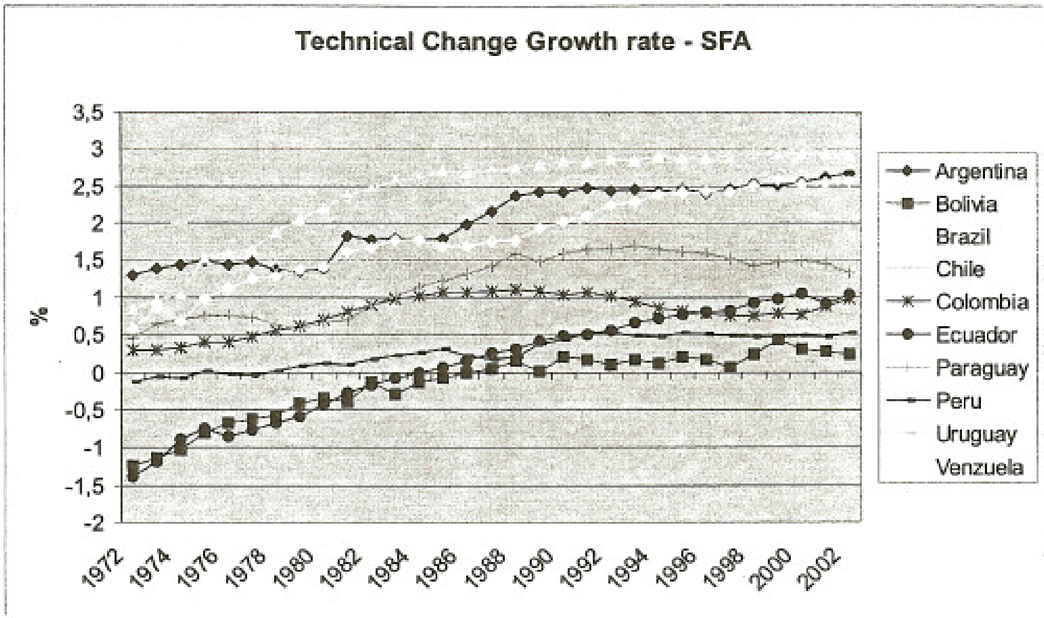

Figure 7 - Estimated Annual Rates of Technical Change by Country

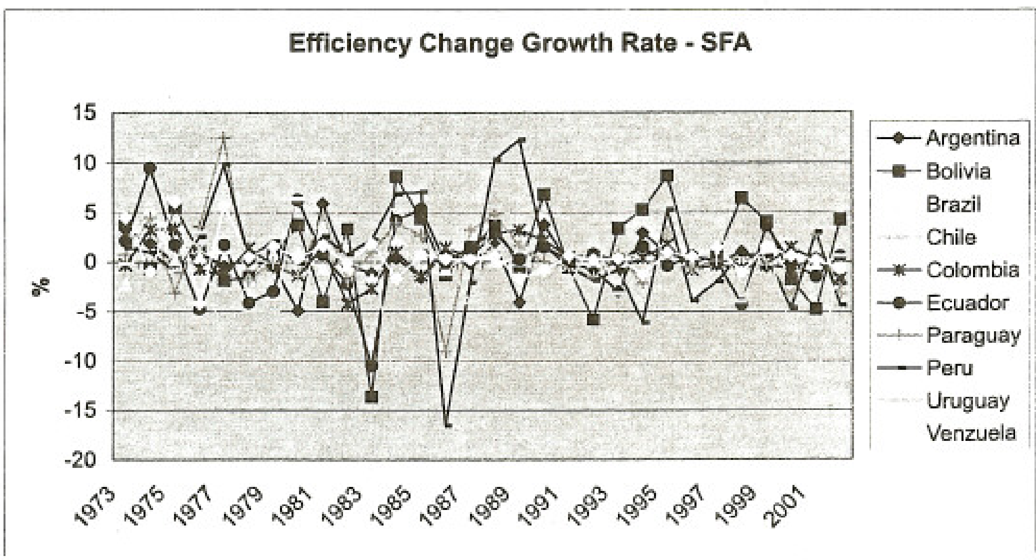

Figure 8 - Estimated Annual Rates of Efficiency Change by Country

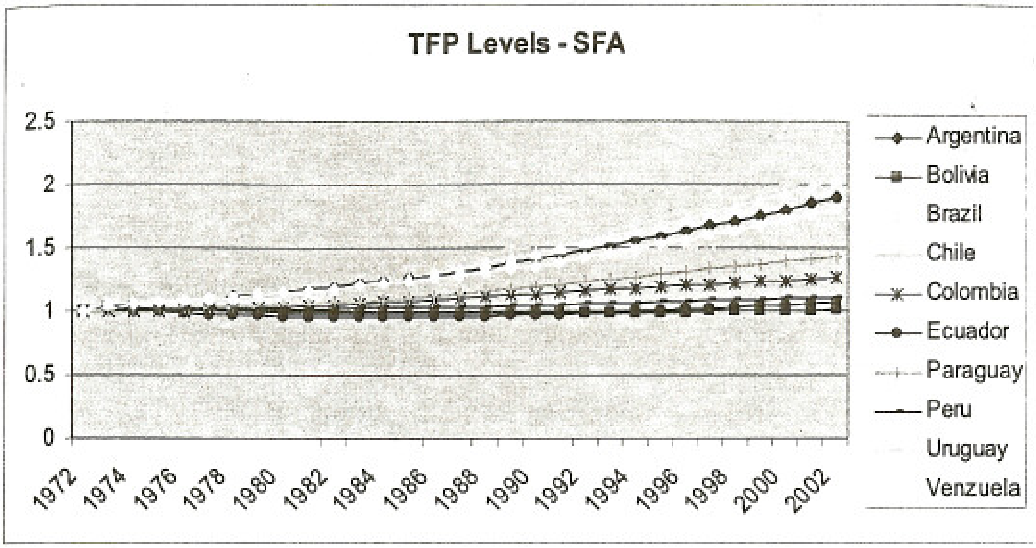

Figure 9 - Estimated Annual Productivity Indexes by Country