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Agricultural Productivity in Mercosur

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This thesis applies econometric methods to investigate reported decline in productivity in the countries of Mercosur in Latin America. While non-parametric methods in general claimed thus, more recent studies using parametric approach exhibited mixed results. We show that the results are contingent to the estimation method employed, the dataset used and the degree of diversity in socio-political and economic environment prevailing in the countries analysed. Our results indicate that the region is experiencing 2.24% productivity growth dominated by technical growth (1.97%) and marred by low efficiency (0.24%), the latter being explained primarily by the quality of human capital in agriculture, investments in research and the economic environment of the member country.

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Chapter 1

1.1 Introduction

In the economics literature, aggregate productivity refers to the amount of output obtained from a given level of inputs in an economy or a sector. It is an important topic of study because productivity is one of the two fundamental sources of larger income streams; the other being savings, which permit 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 aggregate 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 inter-country production functions which indicated that agricultural productivity in 22 LDC's declined at an annual rate of 2.1% between 1960n 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 if 1.5-2.0% per year between 1960 and 1970, and by another 1.0-1.5% between 1970-1980. Lau and Yotopolous used slightly different inter-country production function approach using much of the same data, and while production elasticity estimates differed, they estimated that productivity rose tat eh rate of 0.25% during the 1970s. 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 have expanded due to 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-fuelled the debate and motivated a number of recent studies. These studies examined cross-country differences in agricultural productivity for a large number of countries, 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 Fischer).

The analysis to follow will focus in 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 homogenous area of production, sharing some institutional characteristics. Mercosur is a custom union created in 1991 involving now ten countries with varying degree of membership. While the orginal

Treaty of Asuncion had four signatories: Argentina, Brazil, Paraguay and Urugauy, 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 a 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.

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)

While these countries individually have been the focus of a number of studies[1] 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.) 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.

1.2 Literature Review

The rapid deterioration in Argentina's agricultural growth has been the subject of a few studies. While Argentina was at par with the developed countries like the US and Canada till the 1930s, its per capita output fell gradually thereafter reaching an all time low in the 80s (Mundlak and Domenech,1995). Inconsistent economic policies, inward looking growth strategies, growing state intervention combined with external shocks like the debt

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[1] 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.

crisis were responsible to some extent for this. In fact, increasing government intervention reduced the rate of growth of output substantially between 1940-80 (Fulginiti and Perrin). Using World Development indicator data on per capita GDP growth (in constant local currency), we find that while the economy was growing at an annual rate of 1.2% during the 1970s, it deteriorated to -2.2% annually during the 80s.

While literature suggests declining agricultural productivity in Argentina on the one hand, on the other it also points to improvement in this sector in Brazil. Agricultural productivity in Brazil is increasingly coming into lime light also because it alone produces about 28% of the agricultural exports of Latin America (Helfand and Rezende, 2004) and has been showing a marked increase in productivity especially since the 1990s. A study on the region wise agricultural growth in Brazil for the period 1970-1996(Pereira et al,2002) concluded that the south, the south-east and in more recent times the central west regions have been showing astounding rates of technological advancement which in some regions is also compensating for the lack of natural resource advantage.

Compared to the above two countries, Paraguay's growth is a different story altogether given the fact that it was under military subordination till as late as 1989 and was mired in the resulting political, social and economic stability. However, its growth trajectory is gradually catching up. Not much work has been done on agricultural productivity in Paraguay despite the fact that agriculture is the mainstay of the economy. One study analyzing the efficiency of small landholders in Eastern Paraguay using non parametric methods found high levels of technical efficiency and low allocative and scale efficiency in this region (Fletschner and Lydia, 2002). Bravo-Ureta and Evenson (1993) also estimated high level of economic efficiency in cotton and cassava production in eastern Paraguay using a stochastic efficiency decomposition method. In contrast, the key finding of an older country study on Paraguay (Hanratty and Meditz, 1990) was that growth in agriculture was rapid in the period between early 1970s to early 1980s and declined thereafter. Although it's becoming widely accepted today that R&D activity is a predominant factor in agricultural growth, yet Paraguay's agricultural R&D investments and institutions are still not predominant and are heavily dependent on government and donor support (Beintema, Zambrano, Nunez, and Pardey, 2000).

Uruguay is the smallest in the group in terms of its land area and its population (Paiva and Gazel, 2004). Albeit the Uruguayan economy is largely dependent on agriculture (Baethgen and Giménez, 2004), yet its production levels were stagnant over several decades with production increasing at an average rate of less than 1% annually during the period 1950s-1980s which continued well into the 80s. This stagnation was attributable to: slow adoption of new technology, more so in the livestock sector, as also to the inconsistency of state policy vis-à-vis this sector (Rex and Meditz, 1992). However, the trend is reversing gradually as evidenced by the increasing focus on R & D in agriculture in the country. The national Agricultural Research institute (INIA), set up in 1989, accounts for 47% of Uruguay's R & D, is comparatively free from state control and is growing remarkably fast (Bientema, Hareau, Bianco and Pardey, 2000).

Chile, which joined this group as an associate member in 1995, has been generating a lot of research interest in the very recent past primarily because of the surge in growth, especially the growth in exports of ag products like fruit and wine. While land reforms like elimination of cap on land ownership and privatization of land held previously in the land reform sector (Janvry, Key, Sadoulet, 1997) helped, the big stimulant was the market oriented government policies that brought about key shifts in the agricultural sector (Sparks, Bravo-Ureta, 1992; Janvry, Key,Sadoulet, 1997).

The only study we can find on agricultural productivity in Bolivia, Colombia, Ecuador, Peru and Venezuela is by Pfeiffer (2003) who uses a translog frontier production function as well as a non parametric DEA method and finds positive growth in all these countries, with both methods suggesting that this growth is based mainly on technical progress. The results further indicate that behavioral differences among these countries vis-à-vis their productivity growth rates are explained partly by the level of social unrest prevailing therein.

Now we briefly review some studies that have included these countries as a part of a larger group of countries. There has been a surge in the past two decades in the literature analyzing agricultural productivity using a meta-frontier production function starting with the work of Hayami and Ruttan (1970) and later Kawagoe and Hayami (1983,1985). Hayami and Ruttan (1971) studied productivity differences across countries using cross sectional data for the period 1960 and found that the nature of technology development should be compatible with the resource endowment of the country to provide conducive environment for agricultural productivity growth. Years later Kawagoe and Hayami (1983) attempted to examine if technological advancement had reduced the productivity gap between the developed and the developing world in 1980 as compared to 1960 using two measures: land and labor productivities. The results were an eye opener which would lead to several more studies on this subject. Their results indicate that the gap in labor productivity had widened primarily due to increasing land-labor ratio in DCs and adoption of labor saving technologies in the developed countries. At the same time the growth rate of land productivities were comparable in the DCs and the LDCs. Inefficiency in production and lack of scientific research in pursuit of better technology lowered agricultural productivity growth in the LDCs. Lau and Yotopolous (1989) applied a translog meta production function to Hayami and Ruttan data set adding first differences to separate the country-specific effects and reached similar conclusions of declining productivity in the developing countries.

Fulginiti and Perrin (1997) used a non parametric Malmquist index method to examine productivity change in a set of 18 less developed countries, including Argentina and Brazil, for the period 1961-1985.They estimated a fall in agricultural productivity in both, Argentina (-4.8) and Brazil (-0.5) and productivity gain for Chile (1.1%) for the entire period of study, although they estimated a productivity gain for Brazil (3%) during 1974-1985. In their analysis, technological regression was largely responsible for the productivity regression. They reported same results for these two countries in a previous study (1993) using an expanded Cobb Douglas technology.

Arnade (1998) also used programming methods to measure agricultural productivity in 70 countries and reached similar conclusions of declining productivity in Argentina (-1.9), Brazil (-2.1), Ecuador (-0.99) and Uruguay (-1.3) and productivity growth for the other countries included here. Trueblood and Coggins (2000) used data for 115 countries for the period 1961-1991 to test if the findings of declining agricultural productivity in the developing countries by previous studies were indeed true using non parametric data envelopment analysis. For the countries in our set their results reflect that except for Chile which shows productivity growth, Argentina and Paraguay are efficient yet show declining productivity because of technological regression while Brazil and Peru owe their negative productivity mainly to increasing inefficiency in production.

Weibe et al (2000) studied the impact of resource quality on agricultural productivity using panel data for 110 countries for the period 1961-1997. With respect to Latin America, a significant finding of this study was that even when the quality of land in this region is comparable to global standards, only the best quality of soil and climate would generate further increases in output per worker.

Coelli and Rao (2003) calculated Malmquist indexes in 93 countries for the period 1980-2000. In contrast to the results of the previous studies, they reported productivity gains for many developing countries including the countries in this study. However, Argentina and Paraguay reported declining productivity primarily due to technological regression as was also the finding in Fulginiti and Perrin (1997) for an earlier period. But an interesting implication of their study was that not only did the sample as whole record productivity gains, but also there was evidence of catch up in efficiency with the more developed countries. More recently, Bravo-Ortega and Lederman (2004) applied a translog production function to a panel of 86 countries for the period 1960-2000 and reported positive agricultural productivity for all the countries in this study with Brazil being the best performer (1.93%) amongst the Latin American countries.

Alauddin, Headey and Rao (2004) and Ludena and Hertel (IAMA paper, 2006) use translog production and DEA methods respectively in a panel of 111 and 116 countries respectively covering the period 1961-2001 and find positive TFP gains for all the countries included herein.

We notice in the above review some significant and systematic differences between those studies that generated negative productivity growth and those that did not. First the set of studies indicating growth cover the 90s and some do not include the 60s (Coelli and Rao, 2003). Fulginiti and Perrin (1997) found that the 60s were the period of least growth while the 70s and the 80s saw a rise in the growth trend. Second, the recent studies have incorporated more variables to control for the behavioral differences across borders. However, the results do not seen to be an artifact of the analytical method used. Recent research has used both parametric (for example Bavo-Ortega and Lederman, 2004) and non parametric approach (Allaudin, Headey and Rao, 2004; Ludena and Hertel, 2006) to arrive at the same result of positive growth.

Chapter 2

2.1 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.[2] 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.

The standard neoclassical production function is written:

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

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 $\mathrm{N}(0, \sigma_{\varepsilon}^{2})$. 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,

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

the error term is composite, $\varepsilon_{it} = v_{it} - u_{it}$ where v_{it} are random variables which are assumed to be iid $N(0, \sigma_v^2)$ and independent of u_{it}, and u_{it} is a non-negative random variable distributed iid $N(\eta, \sigma_u^2)$ 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:

(2) $$\dot{Y}_{it} = \sum_n \xi_{itn} \dot{x}_{itn} + \dot{TFP}_{it}$$

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

(3) $$\dot{TFP} = TC + EC$$

where $TC = \frac{\partial f(x,t;\beta)}{\partial t}$ 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*, $TE_{it} = \frac{Y_{it}}{\exp[f(x_{it};\beta)+v]} = \exp(-u_{it})$.

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 effect 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

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

in which h_{it} is a (1x*p)* vector of variables that influence the efficiency of the country, and δ is a (*p*x1) 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 $\gamma = \frac{\sigma_u^2}{\sigma_u^2 + \sigma_v^2}$, 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.[3]

2.2 Data[4]

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 (table 2a, 2b).**

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[3] 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.

[4] Input-Output data is presented in appendix A – Figure 1a

The dependent variable is the aggregate value of agricultural output in millions of 1979-81 US dollars computed using FAO data. The data source and the definition of the traditional inputs are the ones used in the original Hayami and Ruttan studies and in most other papers mentioned before. 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 (figures 1a, 1b)** shows the evolution of these variables during the period under consideration. We note the rapid growth of commercial inputs, with the erratic trajectory 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 been 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.

2.3 Estimation[5]

We estimate the translog flexible functional form using both OLS and ML frontier approach. We estimate separately for the two datasets – group of original four members and for the larger group of 10 members – for the period 1972-2001. Denote with i = 1, … ,10 the countries, and with j and k = 1,…, 5 the inputs x_{ijt} and x_{ikt} at each time period t = 1, …, 30. Imposing symmetry, the translog production function we estimate is:

(5)

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

where Y is agricultural output; x 's are logarithms of 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

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[5] Program used in estimation is attached in appendix B

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

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):

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

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:

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

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, γ.

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.[6] In the second we test the null of no technical inefficiency (or the

[6] 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.

appropriateness of the one-sided error specification) and reject it.[7] 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.[8] 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 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 tables 3a, 3b.

With the ML frontier approach we obtain estimates of the δ 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.

Chapter 3

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[7] The estimates of the inefficiency variance parameter (γ) are, for the group of 4 and 10, 0.842 and 0.877 and are highly significant (t-ratio 19.64 and 32.91%), respectively. 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.

[8] This is done by setting the parameter γ (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.

3.1 Results for the original four member countries

We now examine the results obtained applying the two methods. Both methods corroborate a positive growth in agricultural productivity thorough the 1970s to 2000 (**figure-3**). The corresponding TFP levels for both the methods as depicted in **figure 4** show steady rise thorough the period.

We estimated TFP growth rates for the three decades under study (**Figures 5,6**) and found it to be steadily rising through out, with a sharper curve for OLS because here the time trend represents the TFP growth rate unlike the frontier method.

Given below in **table 4a** are the results for the OLS and MLE regressions. The average productivity growth for the region is 2.31% (OLS) and 2.57% (Frontier). Brazil is the best performer in the peer group closely followed by Argentina. Paraguay is an exception showing negative average productivity growth for the period, which as indicated by the frontier run, may be primarily due to regressive technological growth. Technical change contributes positively (2.68%) to TFP growth in the region while efficiency change retracts from it (-0.44%). Coelli and Rao (2003) used non parametric Data Envelopment analysis of 93[9] 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[10].

To explain the wide discrepancy in the production inefficiency (**figure-8**) amongst the countries, we specified the inefficiency effects as a function of the six categories of

[9]Argentina, Brazil, Uruguay and Paraguay were a part of this study.
[10] A comparison of our results with those of other studies is given in appendix A- table 9

variables as described in the section on data. The results of the inefficiency effects model are given in **table-4b**. **Table 4b** highlights that land quality and telephone lines per person do not explain the variation in production efficiency amongst these countries. Weibe et al (2000) who got negative and insignificant effects for land quality variables found that the countries in Latin America usually lie above the global median. Pfeiffer (2003) also found that accounting for land quality in the Andean community did not explain the heterogeneity in efficiency levels of the countries. In their analysis of determinants of agricultural productivity Bravo-Ortega and Lederman (2004) found that while telephone lines was a good control variable for infrastructure, its effect in Latin America declined significantly post 1990 which may explain our result on this variable. The estimates on full time equivalent (FTE), life expectancy, freedom and trade intensity ratio are not significant in explaining the production efficiency variation across the countries in the sample.

Figure 9 traces the evolution in technical change for each country obtained using the stochastic frontier method. All the countries depict fairly consistent trends with Brazil being the most innovative and Paraguay the least. The trends in technical change for each country closely resemble those obtained using the ordinary least squares method. Post 1996, Argentina and Uruguay show a downward trend while Paraguay shows gradual improvement during the 1990s.

Figure 11 captures the evolution graphs of TFP growth for each of these four members. Brazil leads the group, as mentioned before, and exhibits most consistent and stable growth. The trends for both Argentina and Uruguay show sharp decline towards the end.

This curve approximately corresponds to the efficiency change growth rate (**figure-10**) for the two countries towards the end of the period under study. Both these countries also experience a marginal decline in technical change growth rate during this period.

3.2 Results for the group of 10 members

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 13** 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 14** we see the evolution of the 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 δ from equation (6) and presented in t**able 6**. 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.

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 t**able 7** 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 contradicts 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 f**igure 15** rates are high in all three decades, with rapid growth in the first twenty years

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[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.

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 8** 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 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 16** 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 17**. 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 for 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 7 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 18** we see the evolution of the catching up rates per country. Finally **figure 19** 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, 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 9**.[15]

3.3 Conclusion

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

[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.

We started out to investigate if there was a genuine cause for concern at the reported declining agricultural productivity across many countries around the globe. We set out with two premises (a) that the studies were multi country involving diverse countries with many disparate characteristics that influenced productivity and (b) that the results were dictated by data quality and the empirical method used for estimation.

For reasons explained by the first premise mentioned above, we used two sets of countries in the Mercosur, the original group of four members and the larger group with ten members. Three major results of the analysis are worth noting. (a) Agricultural productivity has been rising thorough the three decades under study; technological innovation has been consistently happening; however, production efficiency has been steadily declining across the three decades. A reasonable conclusion hence is that while resources are being employed to move towards the technological frontier, more efforts need to be directed to regenerate efficiency in input usage thorough, as the inefficiency model in section B highlights, greater investment in improving quality of human life and greater impetus to international trade. (b) Although the average productivity for the region is positive and increasing through the decades; except Brazil, Bolivia and Ecuador, the rest of the countries in the ten member group experience deteriorating productivity growth. A closer look reveals that this can partly be explained by large variations in efficiency through the decades. (c) Brazil is the best performer led largely by high rate of innovation rather than efficiency. With respect to productive efficiency it is better only to Argentina and Uruguay.

Hence, contrary to the evidence found in literature on productivity growth, this study allays fears of falling agricultural productivity and simultaneously points to the urgent need for more concerted effort for improved productive efficiency.

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APPENDIX A

SECTION A: Tables and graphs for the four original Mercosur members

Table-2a: Summary statistics of the data set used in the analysis, original members, 1972-2002

	Unit	Mean	Max	Min	SD
Output	millions of 1979-81 US dollars	18354.02	80386.72	950.61	21212.6
Land	1000 hectares	22687.46	66465	917	23119.29
Labor	1000 persons	4496.53	17480	190	6594.09
Livestock	cow equivalent	54611931	1.95E+08	4168247	60487433
Fertilizer	metric tons	1040495	6838000	1000	1735741

Machinery	no. of tractors	223209.3	806000	5000	261842.3

Table 2b: Summary statistics of the data set used in the analysis, All Ten members, 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
Machineryy	no. of tractors	1,036,658.58	1,313,011.00	507,451.00	265,459.70

Table 3a: Estimated Production Elasticities – OLS and frontier – For Four Original members (evaluated at the mean)

Production Elasticity	OLS	SFA
Land	0.06	0.14
Labor	0.58	0.35
Livestock	0.75	0.60
Fertilizer	-0.02	0.00
Agricultural Machinery (Tractors)	-0.26	-0.13
Constant	-25.84	-15.3

Table 3b: Estimated Production Elasticities – OLS and frontier – For All Ten members (evaluated at the mean)

Production Elasticity	OLS	SFA
Land	0.44	0.15
Labor	0.19	0.30
Livestock	0.31	0.25
Fertilizer	0.01	0.02
Agricultural Machinery (Tractors)	-0.02	0.07
Constant	2.13	8.05

Table 4a: Estimated TC, EC, TFP Change, Output Growth Rate, Original Members, Mercosur

	OLS	Stochastic frontier	Output

	TFP change	Technical Change	Efficiency Change	TFP change	Growth Rate
Argentina	3.49	3.50	0.016	3.516	2.37
Brazil	**4.044**	4.97	-0.021	**4.956**	**4.07**
Paraguay	**-0.694**	-0.34	-0.018	**-0.357**	**3.74**
Uruguay	2.399	2.58	-0.438	2.156	1.66
Average	***2.31***	**2.68**	**-0.115**	***2.57***	***2.96***

Table-4b: Parameter estimates, Efficiency variables – Stochastic frontier[16], Four Original Members, Mercosur

Variable	**Coefficient**	**T statistic**
Land quality	0.0007	0.04
SSER	0.0014	0.07
Life expectancy	-0.004	-0.02
FTE	-0.0001	-0.13
Freedom	-0.04	-0.05

[16] SSER– Secondary school enrolment ratio, FTE– Full time research personnel employed in agricultural research, TI– Trade Intensity Ratio, TEL– Telephone lines per 1000 persons

TI	-0.0003	-0.04
TEL	0.012	0.03

Table 5: Output Growth and Estimated Technical Change, Efficiency Change and Total Factor Productivity Change by Decade, Four Original Members, 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	3.35	3.42	3.73	0.77	-0.19	-0.45	4.05	3.22	3.28	3.47	1.38	2.39
Brazil	4.58	5.12	5.23	0.02	-0.01	-0.07	4.60	5.11	5.16	4.64	3.32	4.27
Paraguay	-1.02	-0.19	0.19	-0.31	0.24	-0.01	-1.30	0.04	0.18	5.10	5.17	1.32
Uruguay	2.83	2.54	2.37	-0.15	-0.68	-0.46	2.70	1.85	1.92	3.02	0.16	1.74
Weighted Average	***4.01***	***4.46***	***4.66***	***0.25***	***-0.07***	***-0.17***	***4.23***	***4.39***	***4.49***	***4.06***	***2.51***	***2.43***

Figure 1a: Growth of Agricultural Output and Inputs, Mercosur, Original members, 1972-2002

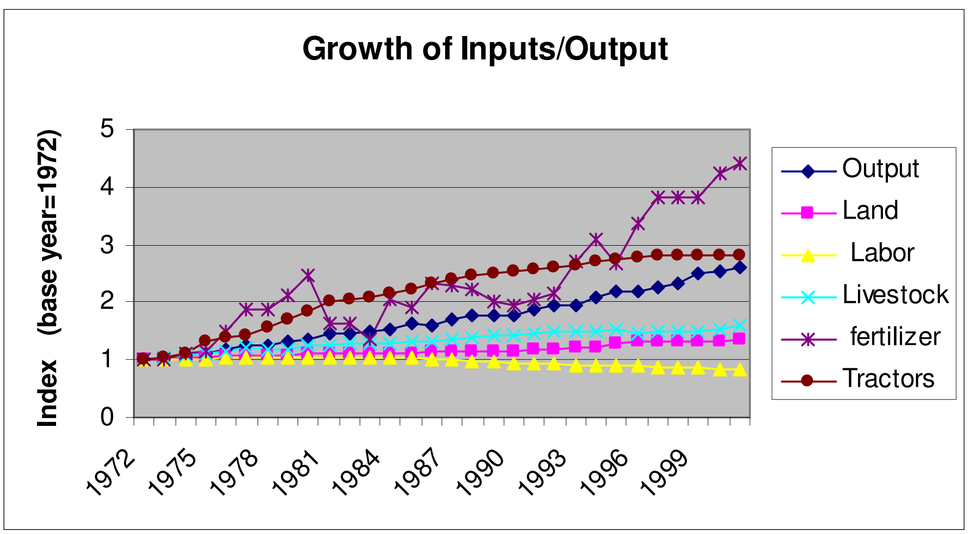


Figure 1b: Growth of Agricultural Output and Inputs, Mercosur, All Ten members, 1972-2002

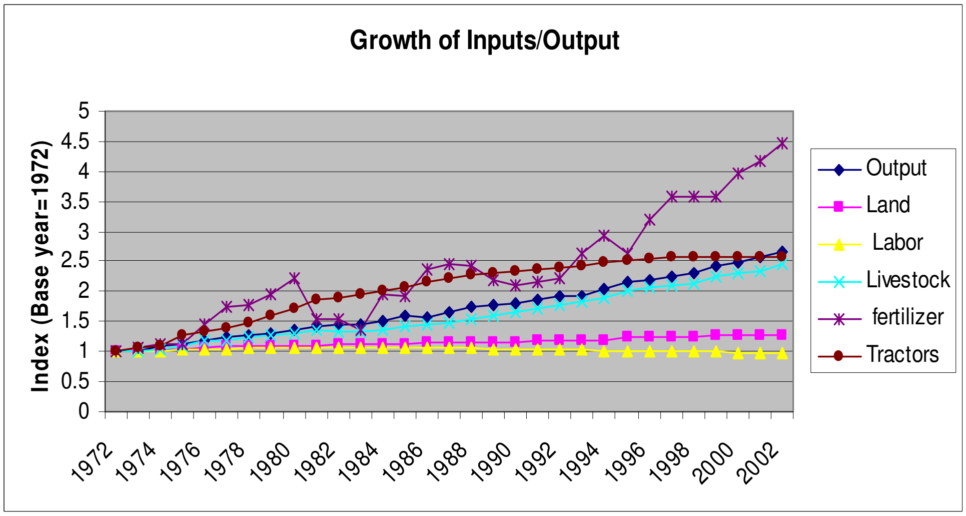


Figure 2. Average Share of Agricultural Output and Inputs per Country.

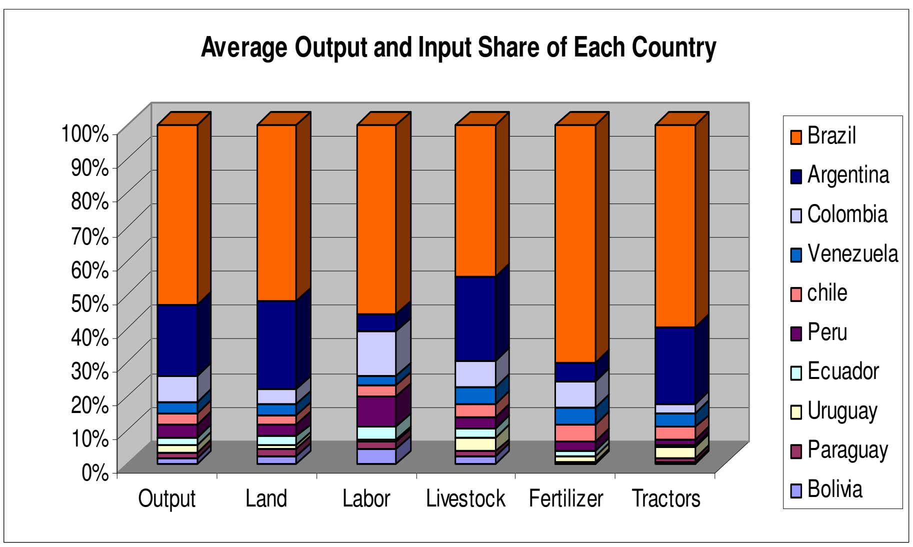


Figure 3: Comparing Evolution of TFP Growth Rate, Original Members

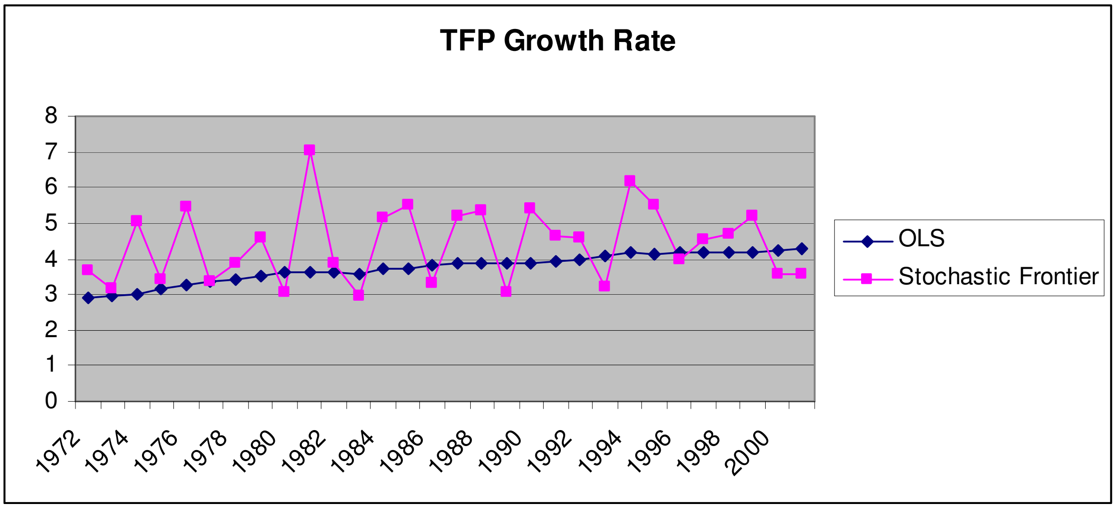


Figure 4: Evolution of Estimated Productivity Indices, Mercosur, Original Members, 1972-2002

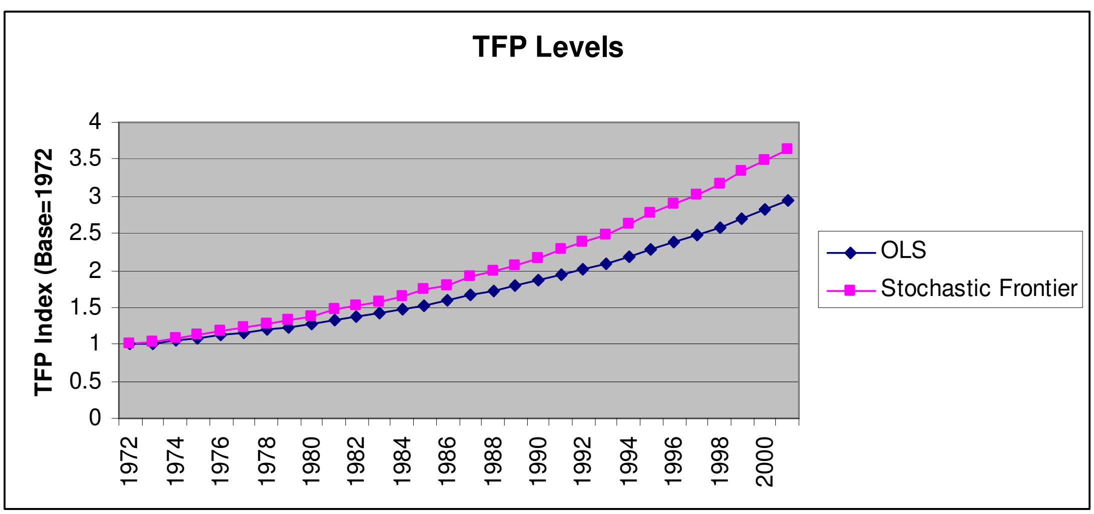


Figure-5 :Comparing Decade Average of TFP Growth Rate, SFA and OLS

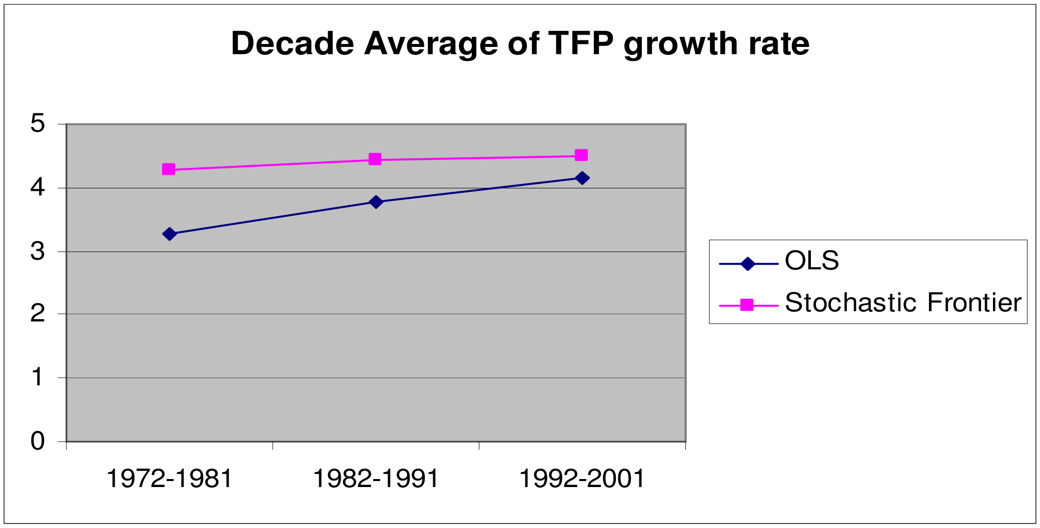


Figure-6 :Comparing Decade Average of TFP Indices, SFA and OLS

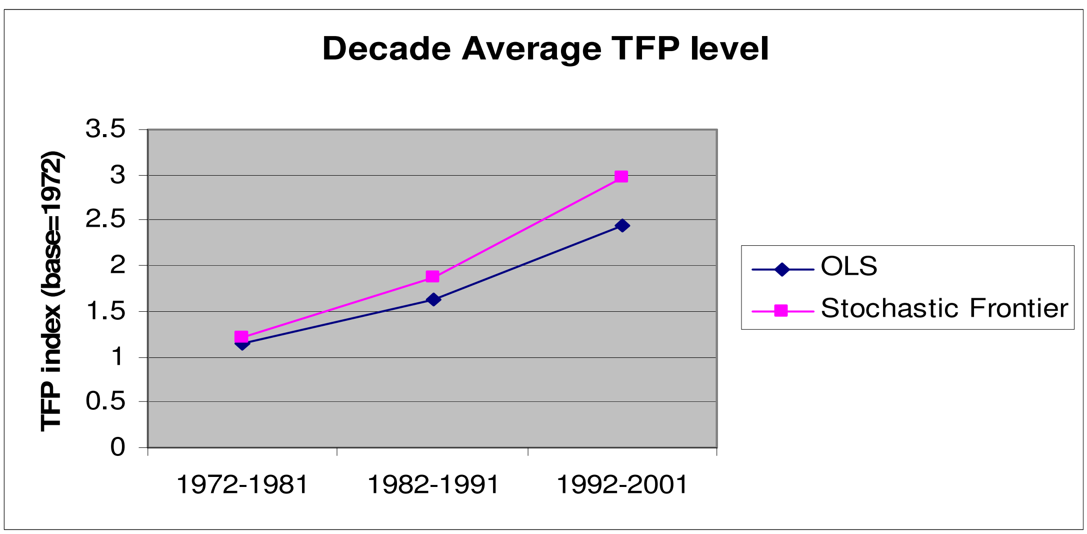


Figure 7: Estimated Total Factor Productivity Growth Rate and Technical Change (%), Mercosur, 1972-2002.

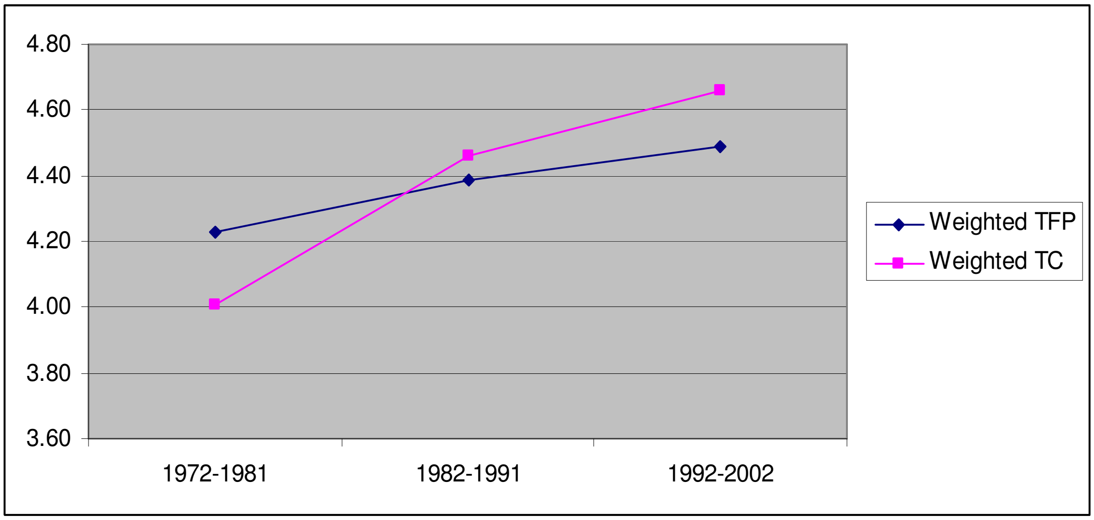


Figure 8: Estimated Annual Efficiency Levels by Country, Four Original Members, Mercosur, 1972-2002.

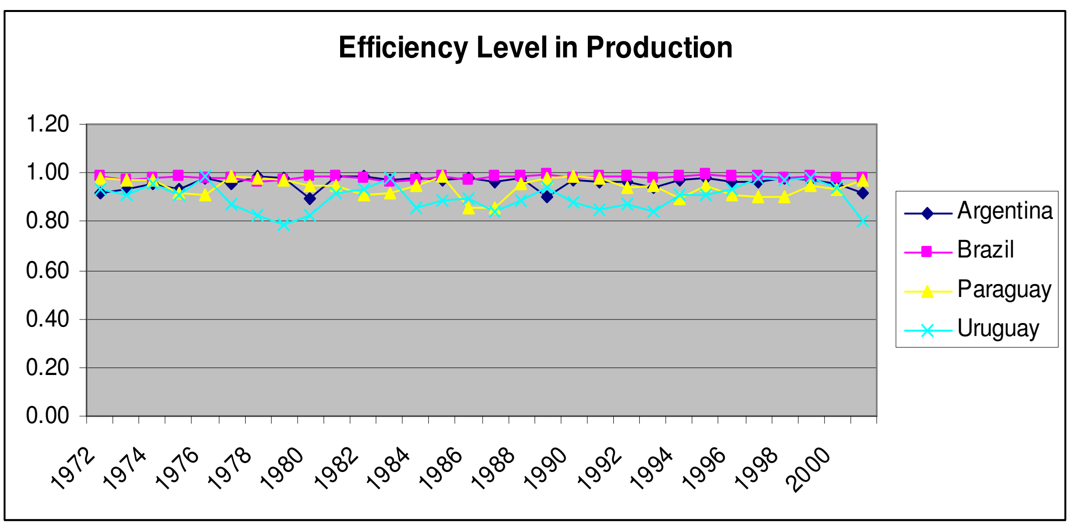


Figure 9: Estimated Annual Rates of Technical Change by Country, Four Original Members, Mercosur, 1972-2002

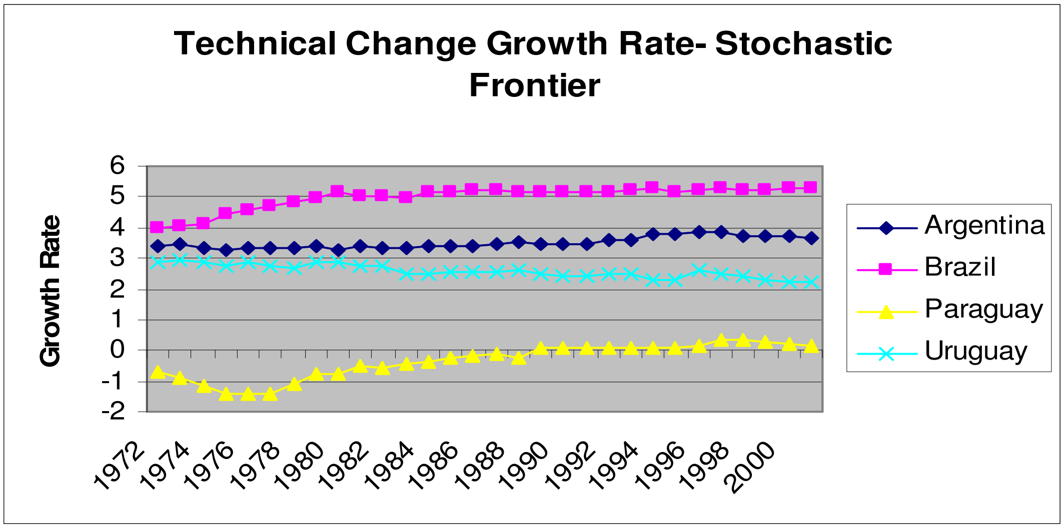


Figure 10: **Estimated Annual Rates of Efficiency Change by Country, Mercosur, 1972-2002.**

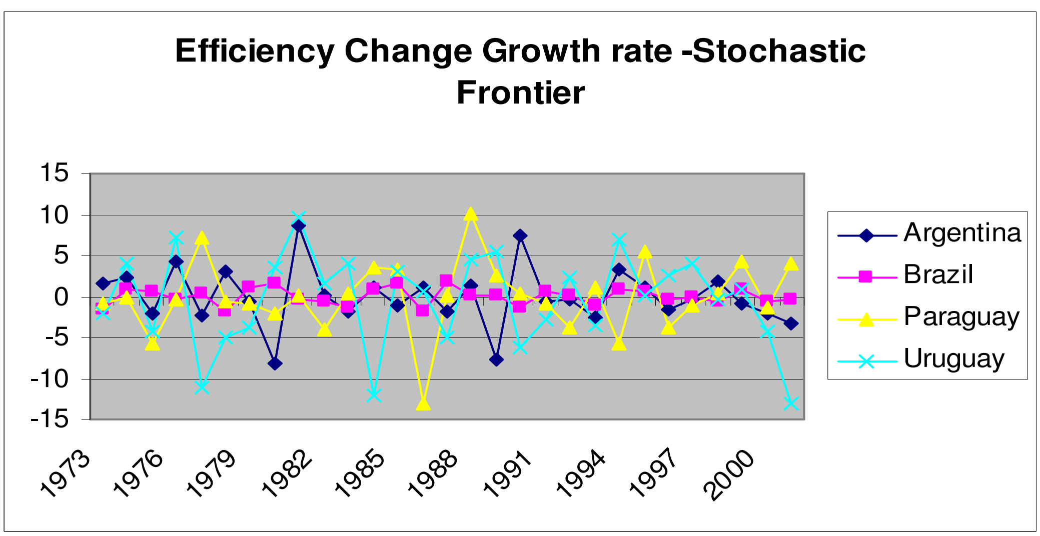


Figure 11: Estimated TFP Growth Rate by Country, Four Original Members, Mercosur, 1972-2002

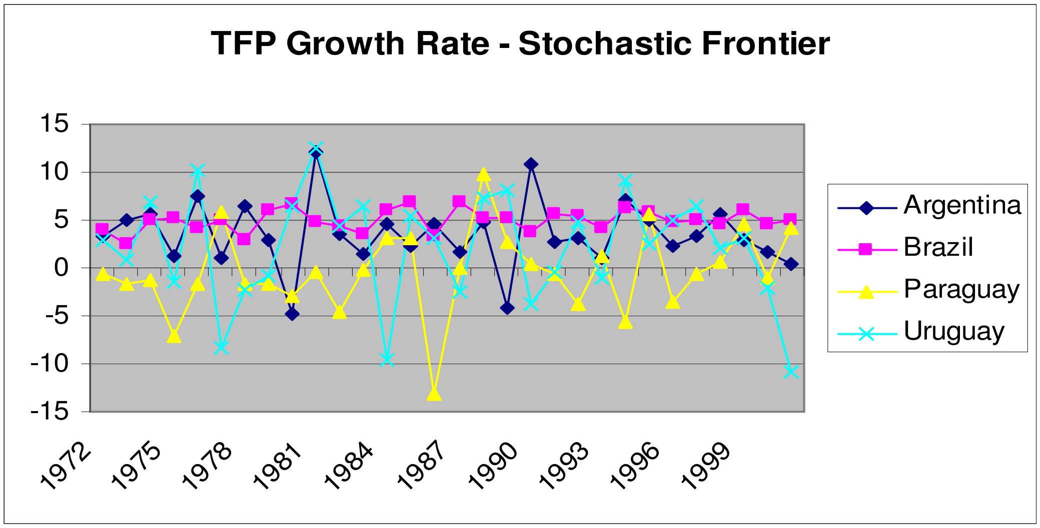
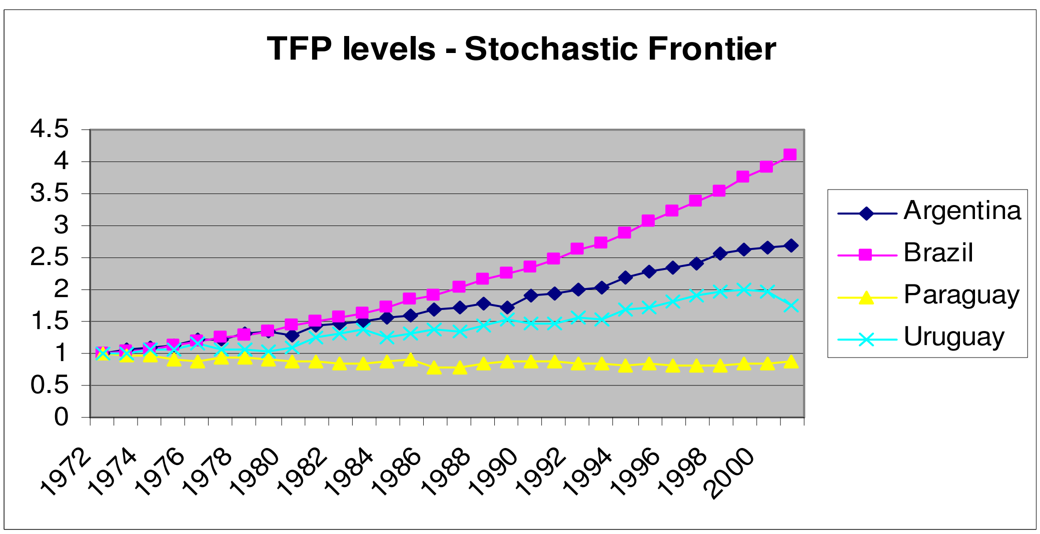


Figure 12: Estimated Annual Productivity Indices by Country, Mercosur, 1972-2002.



SECTION B: Tables and graphs for the group of 10 Mercosur Members

Table 6: Parameter Estimates, Efficiency Changing Variables, SFA, All Ten members, Mercosur, 1972-2002

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***

Table 7: Estimated TC, EC, TFP Change, Output Growth Rate, SFA, All Ten members, 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-8: Output Growth and Estimated Technical Change, Efficiency Change and Total Factor Productivity Change by decades, Mercosur, 1972-2002 (%)

	TC			EC			TFP			Output Growth Rate		
	1972-81	1982-91	1992-02	1972-81	1982-91	1992-02	1972-81	1982-91	1992-02	1972-81	1982-91	1992-2002
Argentina	1.45	2.1	2.5	0.71	-0.05	-0.2	2.16	2.05	2.31	3.47	1.38	2.39
Bolivia	-0.72	-0.01	0.21	0.78	1.24	1.8	0.06	1.23	2.01	3.4	3.46	4.01
Brazil	1.61	2.69	2.9	0.5	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	0.2	0.84	1.15	0.33	0.06	0.37	0.52	0.9	2.33	3.16	3.35

Paraguay	0.66	1.33	1.54	2.21	0.57	-0.39	2.87	1.9	1.14	5.1	5.17	1.32
Peru	0	0.29	0.49	2.1	2.21	-1.32	2.01	2.5	-0.83	5.1	5.17	1.32
Uruguay	2.12	2.6	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	2.8	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***	***2.6***

Table-9: 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	-4.8	-1.85	-2.63	-2.7		1.84	0.99	1.04	2.15
Bolivia		4.68		1.1	0.61	1.18	0.96	1.1	1.1
Brazil	**-0.5**	**-2.05**	**-0.6**	**2**		**1.93**	**1.13**	**1.01**	**2.6**
Chile	1.1	1.25	1.39	1.1		1.2	1.18	1.01	2.16
Colombia	0	1.82		1.4	0.64	1.43	1.21	1.02	1.07
Ecuador		-0.99	-0.6	0.3	3.26	1.28	0.92	1.01	0.57

Paraguay		0.24	-1.1	-1.6		0.74	1.19	1.02	1.87
Peru		0.62	-0.1	1.5	2.79	1.36	1.13	1.02	1.12
Uruguay		-1.3		0		1.35	0.93	1.05	1.86
Venezuela		0.19		0.6	1.37		0.99	1.01	2.38

Figure13: Comparing Evolution of TFP Growth Rate, All Ten Members, Mercosur, 1972-2002

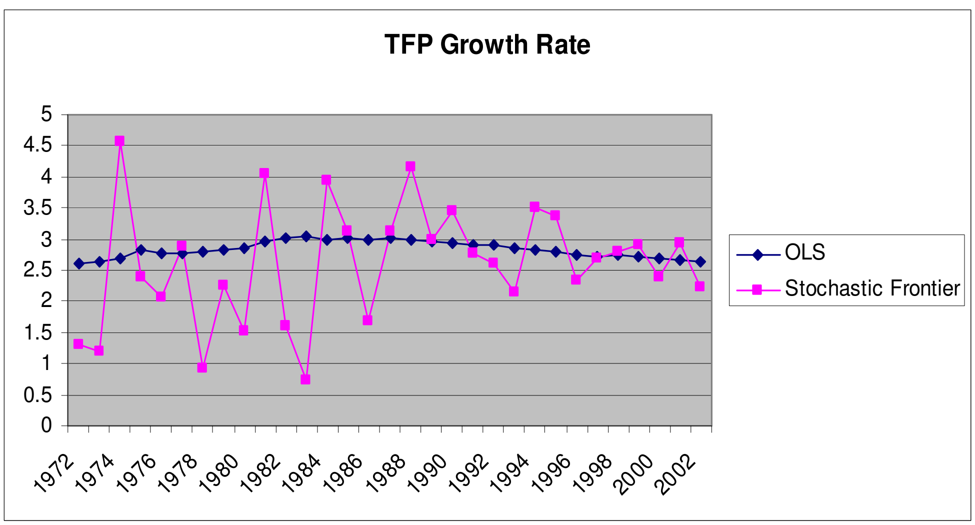


Figure 14: Evolution of Estimated Productivity Indices, Mercosur, 1972-2002

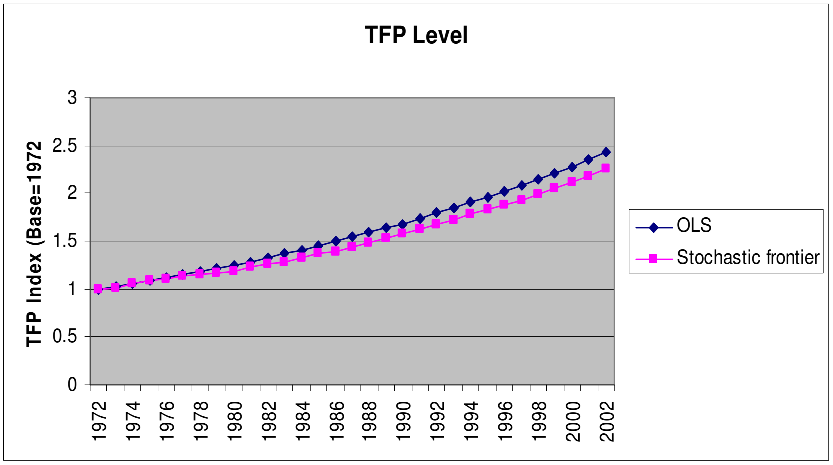


Figure 15: Estimated Total Factor Productivity Growth Rate and Technical Change (%), Mercosur, 1972-2002.

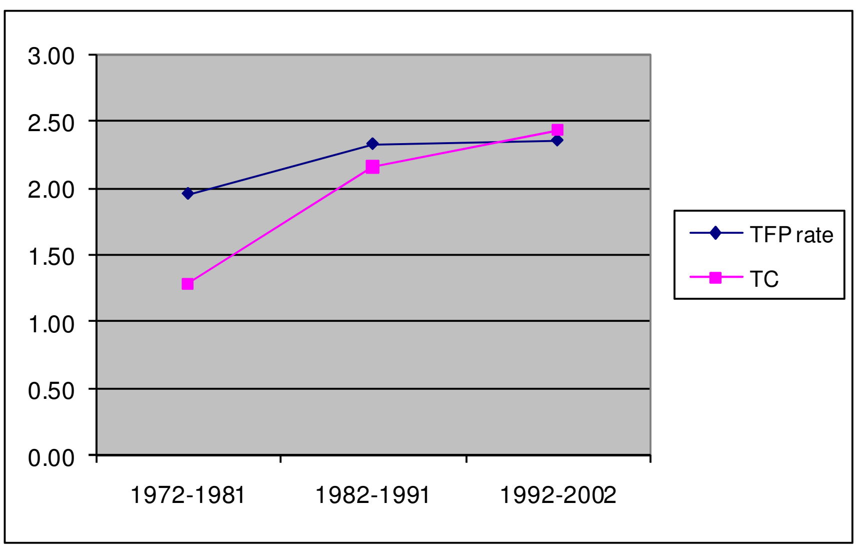


Figure 16: Estimated Annual Efficiency Levels by Country, Mercosur, 1972-2002

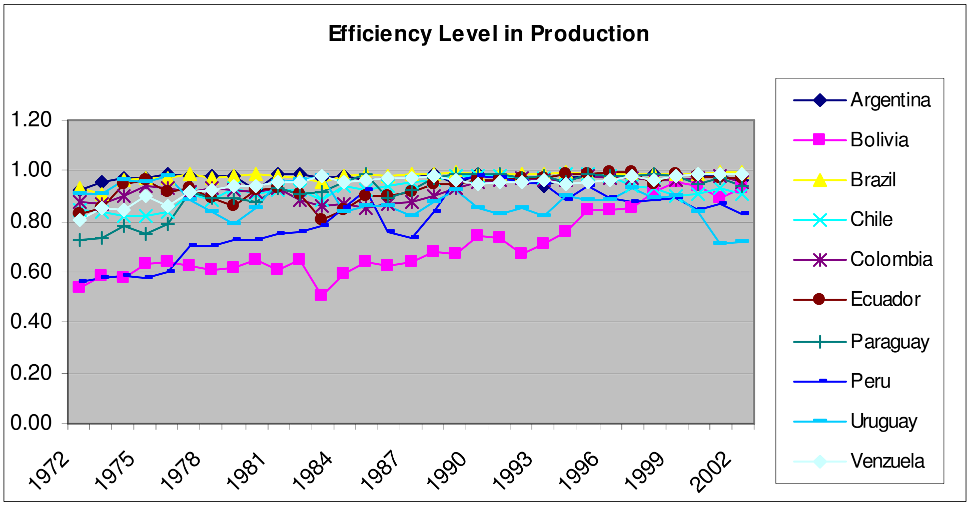


Figure 17: Estimated Annual Rates of Technical Change by Country, Mercosur, 1972-2002

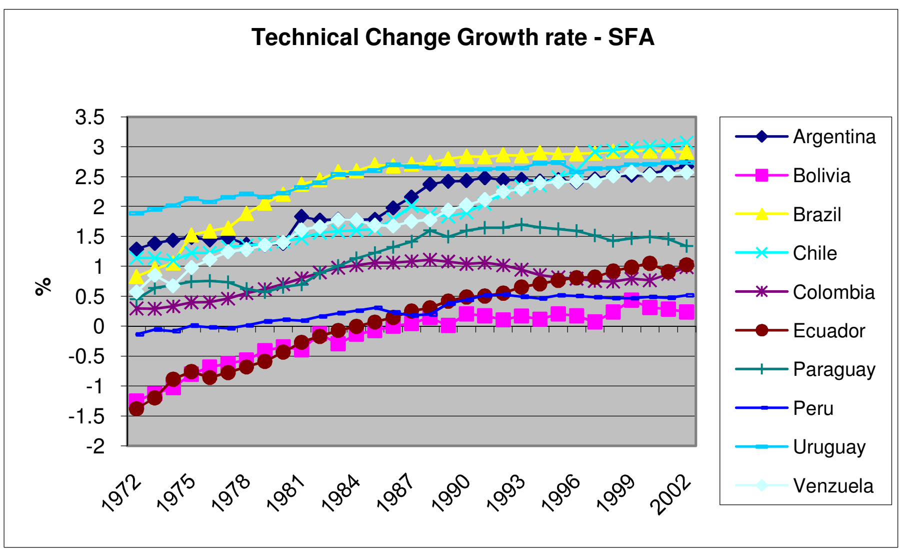


Figure 18: **Estimated Annual Rates of Efficiency Change by Country, Mercosur, 1972-2002.**

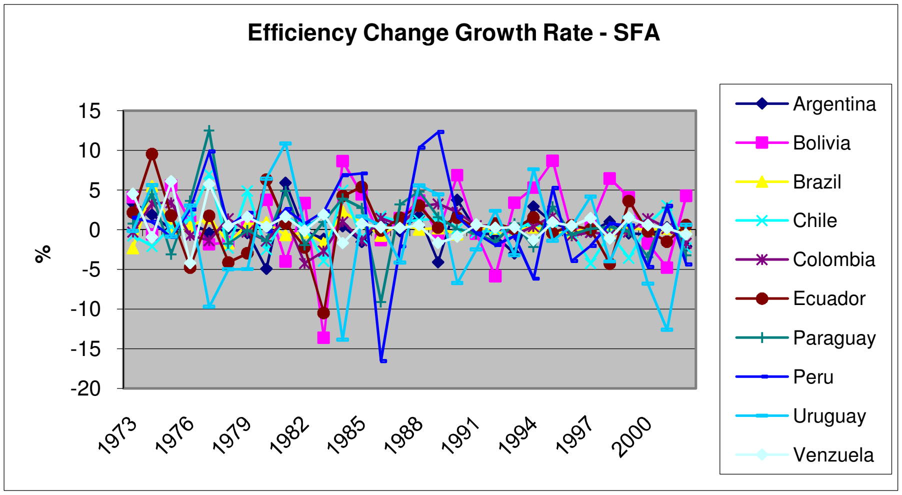
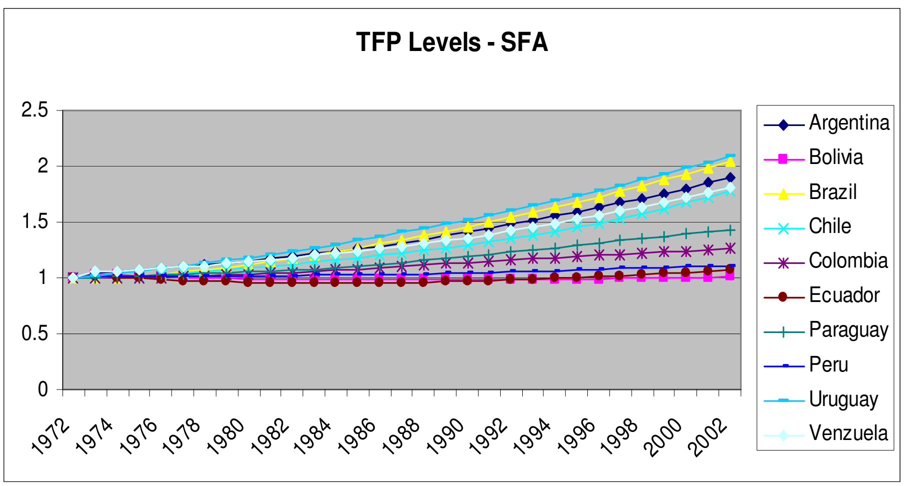


Figure 19: Estimated Annual Productivity Indices by Country, Mercosur, 1972-2002.



Appendix B

B.1 Output in millions of 1979-81 “international dollars”

	Argentina	Bolivia	Brazil	Chile	Colombia	Ecuador	Paraguay	Peru	Uruguay	Venezuela,
1972	13654	775	26966	1796	4924	1616	950	1803	1424	1953
1973	14175	855	26981	1630	4969	1655	969	1839	1438	2060
1974	15116	862	29103	1867	5251	1808	1029	1953	1585	2133
1975	15607	915	29842	1978	5713	1827	1010	1916	1598	2292
1976	17171	931	31334	1962	6033	1875	1090	2068	1781	2185
1977	17091	926	33472	2111	6176	1961	1299	2465	1533	2357
1978	18442	930	32835	2037	6430	1889	1296	2460	1466	2458
1979	18600	944	34825	2220	6678	1872	1315	2496	1406	2564
1980	17162	1031	38820	2249	6705	1963	1332	2528	1572	2648
1981	18360	1041	40320	2416	6984	1977	1465	2779	1826	2677
1982	19070	1053	40841	2401	6729	1970	1471	2792	1847	2717
1983	18502	876	41626	2268	6588	1723	1544	2930	1944	2892
1984	19171	1012	43686	2398	6875	1899	1696	3219	1603	2782
1985	19135	1125	48133	2400	6816	2087	1905	3614	1665	3004
1986	19583	1112	45909	2520	7118	2125	1644	3119	1690	3131
1987	18701	1159	50379	2652	7275	2195	1717	3258	1631	3119
1988	19446	1230	52369	2820	7716	2375	2070	3928	1806	3356
1989	17902	1281	54413	3045	8135	2403	2279	4325	1951	3241
1990	20358	1379	52089	3227	8719	2544	2378	4512	1816	3260
1991	20737	1415	55315	3300	9024	2646	2340	4441	1799	3298
1992	20813	1351	58183	3454	8839	2772	2293	4351	1918	3382

1993	20420	1412	58526	3645	8796	2849	2362	4482	1885	3509
1994	21973	1539	62591	3902	8877	3191	2267	4301	2076	3448
1995	23165	1691	66276	4110	9550	3184	2515	4772	2103	3504
1996	24044	1759	65529	4228	9428	3477	2457	4661	2317	3681
1997	24538	1826	68297	4213	9535	3633	2498	4740	2466	3954
1998	26333	1851	69292	4329	9534	3096	2612	4955	2455	3917
1999	27452	1866	74857	4250	9540	3538	2702	5127	2510	4166
2000	27242	2051	76909	4422	9991	3579	2579	4893	2368	4420
2001	27162	2016	81426	4736	10190	3765	2808	5328	2030	4601
2002	26723	2157	87295	4733	10402	3687	2664	5056	2118	4510

B.2 Land in thousands of hectares of arable and permanent crops

	Argentina	Bolivia	Brazil	Chile	Colombia	Ecuador	Paraguay	Peru	Uruguay	Venezuela
1972	26936	1770	44337	4200	5068	2575	918	3143	1428	3465
1973	26942	1808	45261	4300	5084	2585	917	3190	1427	3490
1974	26947	1843	47243	4350	5099	2609	1033	3190	1432	3510
1975	26953	1880	48416	4350	5115	2585	1154	3200	1437	3530
1976	26958	1916	49707	4400	5130	2555	1274	3290	1449	3550
1977	26964	1953	50950	4300	5146	2535	1384	3413	1449	3620
1978	26969	1989	51239	4200	5161	2505	1505	3465	1449	3640
1979	26975	2025	52413	4100	5177	2490	1615	3501	1449	3650
1980	26981	2062	52864	4050	5192	2462	1735	3550	1449	3670
1981	26986	2099	53124	3950	5208	2542	1857	3575	1426	3540
1982	27992	2136	54136	3800	5223	2540	1893	3625	1396	3560
1983	27997	2173	53621	3750	5239	2595	1930	3673	1376	3480
1984	28003	2217	53424	3700	5256	2655	1967	3724	1346	3490
1985	28008	2187	53241	3672	5275	2720	2004	3736	1326	3690
1986	28014	2203	55055	3586	5295	2780	2051	3765	1303	3850
1987	27819	2227	55391	3313	5318	2836	2088	3790	1304	3860
1988	27392	2250	56087	3304	5200	2852	2125	3800	1304	3860
1989	27420	2270	56532	3319	5100	2853	2162	3810	1305	3610
1990	27420	2255	57408	3049	5000	2925	2199	3920	1305	3610
1991	27420	2296	58987	2939	4801	2995	2235	3980	1305	3612
1992	28020	2331	59000	2706	4900	3020	2385	4040	1325	3362
1993	28020	2378	60000	2577	4820	2974	2385	4050	1325	3362
1994	28020	2516	60200	2550	4782	3036	2535	4064	1325	3370
1995	28020	2665	65500	2400	4430	3001	2685	4074	1335	3380
1996	28520	2753	65400	2300	4096	2991	2685	4120	1364	3392
1997	28515	3030	65300	2297	4257	3004	2685	4160	1363	3396
1998	28515	3137	65200	2294	4377	3004	2936	4205	1392	3402

1999	28800	3168	65200	2295	4364	2980	2937	4260	1391	3403
2000	28800	3131	65200	2297	4545	2979	2938	4285	1415	3405
2001	28800	3101	66465	2300	4249	2985	3110	4300	1412	3408
2002	28862	3256	66580	2307	3850	2985	3115	4310	1412	3408

B.3 Labor in thousands of persons actively engaged in agriculture

	Argentina	Bolivia	Brazil	Chile	Colombia	Ecuador	Paraguay	Peru	Uruguay	Venezuela
1972	1481	908	16407	734	3218	1006	424	1974	204	828
1973	1474	927	16564	743	3285	1009	433	2003	202	825
1974	1465	946	16714	752	3351	1012	442	2031	200	821
1975	1455	965	16860	760	3419	1014	452	2059	198	816
1976	1443	985	17002	768	3489	1016	463	2086	197	809
1977	1429	1004	17137	776	3560	1017	476	2112	195	800
1978	1414	1024	17264	784	3632	1016	489	2137	194	788
1979	1398	1044	17379	792	3704	1015	502	2161	193	772
1980	1384	1064	17480	800	3776	1013	514	2183	192	751
1981	1393	1082	17420	812	3792	1034	522	2231	192	765
1982	1404	1099	17332	824	3805	1055	529	2280	192	777
1983	1415	1116	17210	837	3812	1075	536	2327	192	788
1984	1425	1134	17053	850	3814	1095	544	2375	192	799
1985	1436	1152	16856	863	3810	1114	552	2422	192	810
1986	1446	1170	16619	877	3801	1133	560	2470	192	823
1987	1455	1189	16339	892	3785	1151	570	2517	192	836
1988	1464	1209	16015	907	3762	1169	579	2564	192	849
1989	1473	1228	15647	922	3732	1185	588	2610	193	862
1990	1482	1249	15232	938	3696	1201	595	2654	193	874
1991	1481	1273	15067	943	3705	1211	608	2689	192	870
1992	1480	1298	14888	949	3713	1220	619	2723	192	865
1993	1478	1323	14699	955	3720	1228	631	2755	192	859
1994	1477	1349	14501	960	3726	1235	642	2786	191	853
1995	1475	1374	14297	965	3729	1240	653	2817	191	846
1996	1473	1400	14088	969	3731	1244	663	2848	191	839
1997	1471	1425	13874	972	3731	1247	674	2879	191	831
1998	1469	1449	13656	975	3729	1248	685	2909	190	823

1999	1467	1474	13435	977	3725	1249	696	2937	190	814
2000	1464	1497	13211	980	3719	1249	706	2965	190	805
2001	1462	1528	12942	982	3709	1248	719	2994	190	797
2002	1460	1558	12673	985	3697	1247	731	3021	189	788

B.4 Livestock in sheep equivalent

	Argentina	Bolivia	Brazil	Chile	Colombia	Ecuador	Paraguay	Peru	Uruguay	Venezuela
1972	7091	359	7176	815	1737	410	358	777	975	1121
1973	6937	371	7521	719	1664	423	333	789	945	1208
1974	6998	384	7530	936	1648	449	338	830	956	1282
1975	7642	407	8085	995	1793	462	315	868	944	1367
1976	8412	433	8769	949	2008	479	326	891	1010	1393
1977	8524	456	8844	910	2050	507	373	897	1010	1390
1978	9037	466	9358	907	2049	550	371	871	1048	1493
1979	8816	490	9975	951	2165	581	380	861	1107	1573
1980	8483	579	11047	1024	2169	567	386	878	1144	1630
1981	8684	565	11382	1138	2305	573	393	955	1201	1651
1982	7927	564	11525	1117	2285	597	398	996	1207	1659
1983	7738	584	11865	1068	2271	605	406	1033	1220	1698
1984	7929	561	12120	1024	2394	670	425	975	1219	1586
1985	8474	594	12502	1028	2437	721	436	1014	1256	1710
1986	8808	561	13083	1073	2530	739	450	1053	1301	1727
1987	8199	596	14008	1112	2587	776	422	1179	1367	1620
1988	7923	652	14799	1179	2814	805	486	1262	1405	1780
1989	8166	675	15316	1273	3038	803	574	1093	1467	1832
1990	8936	697	15565	1394	3258	867	615	1153	1532	1837
1991	8720	713	16858	1411	3332	929	676	1208	1599	1721
1992	8624	710	17716	1458	3176	953	718	1238	1678	1870
1993	9071	736	18196	1603	3319	998	710	1214	1732	1995
1994	9256	793	19202	1706	3531	1057	729	1289	1844	1737
1995	9287	847	21198	1809	3812	1150	746	1418	1898	1606
1996	9249	877	22589	1856	3783	1230	744	1428	1992	1718
1997	9365	912	22551	1929	3849	1274	760	1537	2062	1924
1998	9117	929	22789	1990	3949	1203	773	1640	2105	1921

1999	9941	953	24775	1941	3896	1260	804	1772	2219	1826
2000	9824	960	25889	1993	3888	1373	835	1773	2261	1969
2001	9173	959	26673	2122	3986	1532	864	1822	2280	1992
2002	9305	975	28825	2087	4035	1545	868	1930	2356	2041

B.5 Fertilizer in metric tons of N plus P_2O_5 plus K_2O consumed

	Argentina	Bolivia	Brazil	Chile	Colombia	Ecuador	Paraguay	Peru	Uruguay	Venezuela
1972	86200	4967	1624339	126579	206259	42387	5114	121845	78264	84726
1973	83243	5299	1672557	171280	255600	52410	3070	97571	77180	91100
1974	75100	6000	1824637	158785	249900	40867	1758	142066	67900	128605
1975	60300	3200	1977696	90559	215267	32724	1136	104394	47400	140484
1976	78229	2900	2528141	117791	246079	81384	1000	128909	74000	160997
1977	74305	3614	3208894	101732	292400	85938	1100	139189	63200	175611
1978	107075	4640	3222386	126889	291114	71367	2800	136649	58000	196800
1979	130082	3255	3567039	140212	312424	79359	5858	117348	91760	222083
1980	115568	2968	4200519	132736	312300	72579	6320	118130	80900	241125
1981	96475	6918	2752786	114374	280000	70400	9265	131739	63600	145658
1982	106700	2700	2729081	107825	303400	72052	7602	98150	60500	158800
1983	118500	8387	2286911	137695	317560	73800	9000	78413	40200	154300
1984	158500	5147	3445377	180057	362490	73086	9200	85753	53000	267700
1985	162600	5800	3203388	204652	365200	72338	11271	75503	60200	407900
1986	151144	6700	3931000	261566	437529	74477	12400	179125	53473	508400
1987	167900	6531	3887200	277400	498299	63244	15000	231879	60600	607700
1988	162500	4508	3728237	292300	512100	76801	8184	225525	68999	666465
1989	153100	10234	3362304	310520	524282	74228	19626	152112	70643	515270
1990	165500	5162	3207800	306682	602300	68021	17923	105256	71884	434000
1991	167300	7752	3386800	306000	601200	82600	20571	75652	78823	396600
1992	248200	13737	3535540	344000	511400	97800	21897	80572	81200	322000
1993	293900	10155	4450000	385000	514900	94000	20900	138697	91000	282000
1994	462000	10796	5017800	381000	497800	93000	22900	174900	63000	246000
1995	524700	6769	4205900	405000	486200	101000	23000	153300	66000	298000
1996	855200	9059	5020000	423000	485000	118000	33000	185300	153500	305000
1997	809600	12555	5839900	435000	556700	162600	59000	214900	129200	291000

1998	775500	5054	5851100	470000	595900	161711	71832	238125	130000	221700
1999	823500	1940	5869772	475196	585900	175500	65446	238825	105487	206000
2000	862983	7503	6568000	482000	658200	164400	65200	254270	104122	282000
2001	859729	12119	6773000	481000	640400	230600	66800	300700	119586	300000
2002	739526	13741	7682000	455000	691500	229522	153168	274007	128929	300000

B.6 No. of Tractors employed in agriculture

	Argentina	Bolivia	Brazil	Chile	Colombia	Ecuador	Paraguay	Peru	Uruguay	Venezuela
1972	174660	2400	201000	34100	24051	3700	5000	11200	30240	21100
1973	180000	2600	218500	34150	23800	4200	5100	11350	30570	25345
1974	180000	2800	236000	34200	23753	4945	5200	11500	30900	23460
1975	180000	3000	323113	34300	24187	5100	5300	11600	31230	28644
1976	180000	3200	350000	34407	24621	5208	5500	11650	31560	31164
1977	180000	3400	370000	34400	25594	5440	5800	11650	31890	33888
1978	173000	3600	428000	34395	26500	5564	6200	11750	32220	35000
1979	171400	3800	485000	34385	27500	5880	6700	11800	32550	37000
1980	166700	4000	545205	34380	28423	6198	7300	11900	32878	38000
1981	213000	4200	569000	34370	29500	6844	8035	11900	33160	39000
1982	203700	4400	593000	34365	31000	7186	8800	11900	33450	40000
1983	201800	4500	617000	34360	32000	7601	9600	11900	33750	41500
1984	203700	4600	641000	34350	33066	8016	10400	12000	34000	42500
1985	204000	4750	666309	34340	33450	8430	11200	12000	34600	43500
1986	225000	4900	680000	37920	33757	8845	12000	12500	35274	44500
1987	245000	5000	690000	41270	34232	9260	12700	12500	34700	46000
1988	267782	5100	700000	37450	34200	9675	13500	12500	34100	47000
1989	270000	5100	710000	36620	33000	10089	14300	12700	33500	47500
1990	272514	5200	720000	35750	32000	10504	15100	12700	32804	48000
1991	274034	5300	730000	37570	31000	10919	15878	12750	32800	48500
1992	276905	5350	740000	39900	29000	11334	16500	12800	33000	49000
1993	281298	5350	750000	41710	27000	11749	16500	13000	33000	49000
1994	285691	5350	780000	41312	25000	12163	16500	13000	33000	49000
1995	288206	5500	790000	43201	23000	12578	16500	13191	33000	49000
1996	293426	5600	803742	44265	21000	12993	16500	13191	33000	49000
1997	295527	5700	805000	53710	21000	13408	16500	13191	33000	49000

1998	298952	5700	806000	54000	21000	13822	16500	13191	33000	49000
1999	299172	5700	806000	54000	21000	14237	16500	13191	33000	49000
2000	299280	6000	806000	54000	21000	14652	16500	13191	32770	49000
2001	299608	6000	806000	54000	21000	14680	16500	13191	33000	49000
2002	299620	6000	806000	54000	21000	14700	16500	13191	33000	49000

B.7 Land Quality

	Argentina	Bolivia	Brazil	Chile	Colombia	Ecuador	Paraguay	Peru	Uruguay	Venezuela
1972	62.7	42.2	7.1	31.38	31.9	20.12	9.28	22.3	85.2	15.25
1973	62.7	42.2	7.1	31.38	31.9	20.12	9.28	22.3	85.2	15.25
1974	62.7	42.2	7.1	31.38	31.9	20.12	9.28	22.3	85.2	15.25
1975	62.7	42.2	7.1	31.38	31.9	20.12	9.28	22.3	85.2	15.25
1976	62.7	42.2	7.1	31.38	31.9	20.12	9.28	22.3	85.2	15.25
1977	62.7	42.2	7.1	31.38	31.9	20.12	9.28	22.3	85.2	15.25
1978	62.7	42.2	7.1	31.38	31.9	20.12	9.28	22.3	85.2	15.25
1979	62.7	42.2	7.1	31.38	31.9	20.12	9.28	22.3	85.2	15.25
1980	62.7	42.2	7.1	31.38	31.9	20.12	9.28	22.3	85.2	15.25
1981	62.7	42.2	7.1	31.38	31.9	20.12	9.28	22.3	85.2	15.25
1982	62.7	42.2	7.1	31.38	31.9	20.12	9.28	22.3	85.2	15.25
1983	62.7	42.2	7.1	31.38	31.9	20.12	9.28	22.3	85.2	15.25
1984	62.7	42.2	7.1	31.38	31.9	20.12	9.28	22.3	85.2	15.25
1985	62.7	42.2	7.1	31.38	31.9	20.12	9.28	22.3	85.2	15.25
1986	62.7	42.2	7.1	31.38	31.9	20.12	9.28	22.3	85.2	15.25
1987	62.7	42.2	7.1	31.38	31.9	20.12	9.28	22.3	85.2	15.25
1988	62.7	42.2	7.1	31.38	31.9	20.12	9.28	22.3	85.2	15.25
1989	62.7	42.2	7.1	31.38	31.9	20.12	9.28	22.3	85.2	15.25
1990	62.7	42.2	7.1	31.38	31.9	20.12	9.28	22.3	85.2	15.25
1991	62.7	42.2	7.1	31.38	31.9	20.12	9.28	22.3	85.2	15.25
1992	62.7	42.2	7.1	31.38	31.9	20.12	9.28	22.3	85.2	15.25
1993	62.7	42.2	7.1	31.38	31.9	20.12	9.28	22.3	85.2	15.25
1994	62.7	42.2	7.1	31.38	31.9	20.12	9.28	22.3	85.2	15.25
1995	62.7	42.2	7.1	31.38	31.9	20.12	9.28	22.3	85.2	15.25
1996	62.7	42.2	7.1	31.38	31.9	20.12	9.28	22.3	85.2	15.25
1997	62.7	42.2	7.1	31.38	31.9	20.12	9.28	22.3	85.2	15.25

1998	62.7	42.2	7.1	31.38	31.9	20.12	9.28	22.3	85.2	15.25
1999	62.7	42.2	7.1	31.38	31.9	20.12	9.28	22.3	85.2	15.25
2000	62.7	42.2	7.1	31.38	31.9	20.12	9.28	22.3	85.2	15.25
2001	62.7	42.2	7.1	31.38	31.9	20.12	9.28	22.3	85.2	15.25
2002	62.7	42.2	7.1	31.38	31.9	20.12	9.28	22.3	85.2	15.25

B.8 Irrigation Ratio

	Argentina	Bolivia	Brazil	Chile	Colombia	Ecuador	Paraguay	Peru	Uruguay	Venezuela
1972	0.05	0.05	0	0.29	0.05	0.291	0.05	0.35	0.04	0.081
1973	0.05	0.06	0	0.29	0.06	0.29	0.05	0.35	0.04	0.082
1974	0.05	0.06	0	0.29	0.06	0.28	0.05	0.35	0.04	0.083
1975	0.05	0.06	0	0.29	0.05	0.285	0.05	0.35	0.04	0.084
1976	0.05	0.06	0	0.28	0.05	0.288	0.04	0.34	0.04	0.085
1977	0.06	0.06	0	0.29	0.06	0.286	0.04	0.33	0.04	0.083
1978	0.06	0.06	0	0.3	0.06	0.307	0.04	0.33	0.04	0.088
1979	0.06	0.06	0	0.31	0.06	0.321	0.03	0.33	0.05	0.09
1980	0.06	0.07	0	0.31	0.06	0.316	0.03	0.32	0.05	0.101
1981	0.06	0.07	0	0.32	0.06	0.324	0.03	0.32	0.06	0.113
1982	0.06	0.06	0	0.33	0.06	0.335	0.03	0.32	0.06	0.118
1983	0.06	0.06	0	0.34	0.07	0.395	0.03	0.32	0.07	0.124
1984	0.06	0.06	0	0.35	0.07	0.369	0.03	0.31	0.07	0.129
1985	0.06	0.06	0	0.37	0.07	0.345	0.03	0.31	0.07	0.122
1986	0.06	0.05	0	0.39	0.07	0.348	0.03	0.31	0.08	0.117
1987	0.06	0.05	0	0.44	0.07	0.346	0.03	0.31	0.08	0.117
1988	0.06	0.05	0	0.45	0.07	0.328	0.03	0.31	0.08	0.117
1989	0.06	0.05	0	0.47	0.07	0.333	0.03	0.31	0.09	0.125
1990	0.06	0.06	0	0.52	0.07	0.322	0.03	0.3	0.1	0.133
1991	0.06	0.05	0	0.56	0.08	0.314	0.03	0.3	0.1	0.135
1992	0.06	0.05	0	0.63	0.08	0.303	0.03	0.29	0.11	0.149
1993	0.06	0.05	0	0.68	0.09	0.298	0.03	0.29	0.11	0.155
1994	0.06	0.05	0	0.71	0.1	0.268	0.03	0.29	0.12	0.159
1995	0.06	0.05	0	0.79	0.09	0.27	0.02	0.29	0.12	0.16
1996	0.05	0.05	0	0.83	0.1	0.248	0.02	0.29	0.12	0.162
1997	0.05	0.04	0	0.83	0.09	0.238	0.02	0.29	0.13	0.165

1998	0.05	0.04	0	0.83	0.09	0.279	0.02	0.28	0.13	0.168
1999	0.05	0.04	0	0.83	0.09	0.244	0.02	0.28	0.13	0.169
2000	0.05	0.04	0	0.83	0.09	0.242	0.02	0.28	0.13	0.169
2001	0.05	0.04	0	0.83	0.09	0.23	0.02	0.28	0.14	0.169
2002	0.05	0.04	0	0.82	0.09	0.235	0.02	0.28	0.14	0.169

B.9 Life Expectancy

	Argentina	Bolivia	Brazil	Chile	Colombia	Ecuador	Paraguay	Peru	Uruguay	Venezuela
1972	66	45	57	58	59	57	58	50	68	59
1973	67	45	58	60	60	58	59	52	69	61
1974	66	46	59	61	60	59	61	54	70	63
1975	69	47	61	63	61	60	62	56	70	65
1976	70	50	61	65	61.5	60	62	56	70	65
1977	71	52	62	67	62	60	63	56	71	66
1978	71	52	62	67	62	60	63	56	71	66
1979	71	50	63	67	63	61	64	58	71	67
1980	70	50	63	67	63	61	65	58	71	67
1981	71	51	64	68	63	62	65	58	71	68
1982	70	51	64	72	63.5	61	67	62	71	69
1983	70	51	64	72	64	62.67	67	62	72	69
1984	70	52	64	72	64.5	64.2	67	63	72	70
1985	71	53	64	72	65	66	67	63	72	70
1986	71	53.5	65	72.5	65	66	67.5	63.5	72	70.5
1987	71	54	65	73	66	66	68	64	72	71
1988	71	55	65	72	66.7	66.33	68	65	72	70
1989	71	57	66	73	67.3	66.66	68	66	72	71
1990	72	59	66	74	68	67	68	66	73	71
1991	72	60	67	74	68.5	67.5	69	67	73	71
1992	72	60	67	74	69	68	69	67	73	72
1993	72	60	67	74	69.5	68.5	69	67	73	72
1994	73	61	68	75	70	69	69	68	73	72
1995	73	61	68	75	70	69	69	68	73	72
1996	73	61	69	76	70.5	70.5	70	68	74	72
1997	73	62	69	76	71	72	70	68	74	73

1998	73	62	69	76	71.3	72.33	70	68	74	73
1999	74	63	70	77	71.7	72.66	70	69	74	73
2000	74	63	70	77	72	73	70	69	75	73
2001	74	63	70	77	72	73.5	70	69	75	73
2002	74	64	70	78	72	74	71	70	75	74

B.10 Full Time Equivalent

	Argentina	Bolivia	Brazil	Chile	Colombia	Ecuador	Paraguay	Peru	Uruguay	Venezuela
1972	820	48	1037	150	414	123	24	198	64	285
1973	840	49	1037	150	463	158	26	217	85	348
1974	880	49	1037	151	517	157	29	235	79	354
1975	953	61	1037	152	431	158	31	254	76	365
1976	847	69	1328	158	392	160	33	223	76	379
1977	890	68	1311	163	359	178	36	269	76	392
1978	880	90	1336	177	333	188	41	257	67	391
1979	919	101	1448	191	321	176	44	265	70	389
1980	1065	102	1553	164	380	200	53	273	72	388
1981	1045	110	1576	169	385	176	64	265	79	386
1982	1025	124	1597	167	384	177	75	258	79	385
1983	1005	126	1610	175	375	202	86	250	80	383
1984	1001	124	1619	178	406	235	95	262	78	396
1985	997	143	1650	189	454	233	103	273	69	410
1986	1028	135	1724	196	471	208	112	256	71	423
1987	1060	124	1870	206	478	205	113	239	73	437
1988	1093	115	1911	214	554	191	113	222	75	450
1989	1127	173	2165	222	688	197	114	204	77	464
1990	1162	180	2146	224	474	200	114	187	79	477
1991	955	215	2105	207	426	238	115	170	81	491

1992	1015	217	2097	210	422	238	112	153	83	504
1993	1036	224	2155	214	427	243	116	152	85	513
1994	1057	232	2213	217	432	247	120	150	87	522
1995	1078	239	2271	220	437	252	124	149	89	531
1996	1099	246	2329	224	442	257	128	148	91	540
1997	1120	254	2387	227	447	262	132	146	93	549
1998	1141	261	2445	230	452	266	136	145	95	557
1999	1162	269	2503	234	457	271	140	144	97	566
2000	1183	276	2561	237	462	276	144	142	99	575
2001	1204	283	2619	240	467	280	148	141	101	584
2002	1225	291	2677	244	472	285	152	140	103	593

B.11Freedom

	Argentina	Bolivia	Brazil	Chile	Colombia	Ecuador	Paraguay	Peru	Uruguay	Venezuela
1972	0	0	0	1	1	0	0	0	0	1
1973	0	0	0	0	1	0	0	0	0	1
1974	0	0	0	0	1	0	0	0	0	1
1975	0	0	0	0	1	0	0	0	0	1
1976	0	0	0	0	1	0	0	0	0	1
1977	0	0	0	0	1	0	0	0	0	1
1978	0	0	0	0	1	0	0	0	0	1
1979	0	0	0	0	1	1	0	0	0	1
1980	0	0	0	0	1	1	0	1	0	1
1981	0	1	0	0	1	1	0	1	0	1
1982	0	1	0	0	1	1	0	1	0	1
1983	1	1	0	0	1	1	0	1	0	1
1984	1	1	1	0	1	1	0	1	1	1
1985	1	1	1	0	1	1	0	1	1	1
1986	1	1	1	0	1	1	0	1	1	1
1987	1	1	1	0	1	1	0	1	1	1
1988	1	1	1	0	0	1	0	1	1	1
1989	1	1	1	0	0	1	0	0	1	1
1990	1	1	1	1	0	1	0	0	1	1
1991	1	1	1	1	0	1	0	0	1	1
1992	1	1	1	1	0	1	0	0	1	0
1993	1	1	0	1	0	1	0	0	1	0
1994	1	1	0	1	0	1	0	0	1	0
1995	1	0	0	1	0	1	0	0	1	0
1996	1	1	0	1	0	0	0	0	1	1

1997	1	1	0	1	0	0	0	0	1	1
1998	1	1	0	1	0	1	0	0	1	1
1999	1	1	0	1	0	1	0	0	1	0
2000	1	1	0	1	0	0	0	0	1	0
2001	0	1	0	1	0	0	0	1	1	0
2002	0	1	1	1	0	0	0	1	1	0

B.12 Trade Intensity

	Argentina	Bolivia	Brazil	Chile	Colombia	Ecuador	Paraguay	Peru	Uruguay	Venezuela
1972	7.08	42.5	13	23.5	25.2	60.36	29.2	26.7	17.8	41.22
1973	7.23	41.8	14	23.8	25	63.71	30.1	24.8	18.4	42.27
1974	7.01	37.3	16	27	24.6	69	33.7	27.4	18.7	48.28
1975	6.77	38.4	15	23.8	24.1	68.68	30.1	25.9	20.1	40.7
1976	7.16	37.5	13	26.5	23.9	62.87	30.1	23.5	21.4	40.54
1977	8.87	35.1	12	29.8	23.6	63.15	36.5	24.3	22.7	40.12
1978	9.38	35.4	12	31.5	26.7	61.58	38.5	22.9	22.6	37.34
1979	10.3	34.5	12	34.4	26.4	59.3	47.7	26.8	23.8	35.12
1980	12	29.4	12	38.1	28.3	59.7	42	27.8	23.8	31.84
1981	12.3	32.3	13	37.8	27	54.34	35.9	28.8	24.3	31.87
1982	10	27.2	12	35	27.8	55.41	36.8	29.5	23.6	32.82
1983	9.5	27.5	11	32.9	25.8	47.57	29.6	25.7	25	24.65
1984	9.27	29.9	12	33.6	25.4	47.7	34.7	23.4	23.7	31.06
1985	10.4	32.1	11	33.6	25.2	50.86	30.5	22.4	24.3	29.79
1986	9.61	38.5	11	35	27	51.23	41.4	21	26	30.22
1987	9.61	38	11	37.1	27.4	55.74	43.8	20.1	24.1	29.79
1988	10.5	34	12	38.9	27.1	52.84	50.6	20.2	25.4	32.01
1989	11.2	35.9	12	42.5	26.9	54.31	46.2	21.8	26.9	30.11
1990	12.6	38.4	13	44.2	29.3	54.07	64.1	22.3	28.2	30.81
1991	13.2	40.8	14	45.1	31	59.22	69.5	25.4	30.2	32.6
1992	15.2	42.6	14	47.4	36	60.64	67.8	27.3	31.3	33.21
1993	15.5	41.6	16	48	41.6	61.27	87.7	27	33.7	34.88
1994	17.4	42	17	50.3	43.7	67.02	101	29.8	36.7	35.47
1995	18.6	44	20	53.7	44	71.55	109	32.5	36.2	38.3
1996	20	45.2	20	55.8	44.3	67.07	98.1	32.7	38	39.53

1997	22.2	46.4	23	58.8	44.7	72.28	90.6	34.6	40.9	43.51
1998	23.4	52.1	23	60.4	44.3	72.79	84	36	40.2	46.03
1999	22.2	42.6	21	59.5	39.5	65.16	60.3	33.3	38.5	42.54
2000	22.7	45.3	23	61.8	40.9	68.06	53.8	34.1	40.3	44.77
2001	22.4	44.8	24	62.7	43.4	71.38	51.7	35.7	38.6	44.69
2002	19.4	48.1	24	61.9	40.5	76.67	53.2	35.6	36.1	41.24

B.13 No. of Telephone lines per thousand persons

	Argentina	Bolivia	Brazil	Chile	Colombia	Ecuador	Paraguay	Peru	Uruguay	Venezuela
1972	59.2	13.5	11	26.3	30.2	21.23	7.56	15.1	57.3	28.7
1973	60.5	14.6	14	27.2	31.1	22.12	8.71	15.4	60.2	32.13
1974	61.7	15.8	15	28	32	23.04	9.33	15.7	62.7	34.34
1975	63	17	20	29	33	24	11	16	66	39
1976	63	18.4	23	29	33	25	12	16	68	44
1977	63	19.8	27	30	35	25	12	17	71	45
1978	63	21.4	32	32	37	27	14	17	71	47
1979	65	23.2	36	32	37	28	15	17	73	48
1980	67	25	41	32	38	29	16	17	76	53
1981	77	26	43	34	39	30	17	18	77	55
1982	82	26	46	35	44	31	18	18	79	60
1983	77	26	48	37	43	31	20	19	83	62
1984	87	27	50	40	49	30	21	20	87	65
1985	89	27	53	44	54	30	21	21	96	70
1986	93	26	54	45	56	31	22	22	101	74
1987	95	26	55	46	58	35	22	22	102	76
1988	100	26	57	49	62	39	24	23	113	77
1989	96	26	60	50	63	45	25	25	122	76
1990	93	27	63	66	69	48	27	26	134	75
1991	95	30	66	79	74	47	28	24	144	79
1992	107	30	70	94	78	49	29	27	156	89
1993	117	32	72	109	85	55	31	29	167	99
1994	142	33	77	112	93	59	32	33	182	108
1995	161	33	82	126	100	61	35	47	193	112
1996	177	46	92	147	118	69	36	59	206	119

1997	192	49	102	182	135	76	43	67	233	122
1998	203	57	118	203	156	83	50	62	250	111
1999	202	62	146	204	161	93	50	66	270	107
2000	214	61	178	214	171	100	52	66	278	104
2001	218	62	212	223	172	107	52	60	282	109
2002	205	68	217	220	178	113	48	62	279	113

Appendix C

Program used in Stochastic Frontier Estimation

2	1=ERROR COMPONENTS MODEL, 2=TE EFFECTS MODEL
eg1.dta	DATA FILE NAME
eg1.out	OUTPUT FILE NAME
1	1=PRODUCTION FUNCTION, 2=COST FUNCTION
y	LOGGED DEPENDENT VARIABLE (Y/N)
4	NUMBER OF CROSS-SECTIONS[17]
31	NUMBER OF TIME PERIODS
124	NUMBER OF OBSERVATIONS IN TOTAL
27	NUMBER OF REGRESSOR VARIABLES (Xs)
y	MU (Y/N) [OR DELTA0 (Y/N) IF USING TE EFFECTS MODEL]
7	ETA (Y/N) [OR NUMBER OF TE EFFECTS REGRESSORS (Zs)]
n	STARTING VALUES (Y/N)
	IF YES THEN BETA0
	BETA1 TO
	BETAK
	SIGMA SQUARED
	GAMMA

[17] No. of cross sections will be 10 in case of ten-country analysis in section B.

	MU [OR DELTA0
	ETA DELTA1 TO
	DELTAP]
	NOTE: IF YOU ARE SUPPLYING STARTING VALUES
	AND YOU HAVE RESTRICTED MU [OR DELTA0] TO BE
	ZERO THEN YOU SHOULD NOT SUPPLY A STARTING
	VALUE FOR THIS PARAMETER.