Total Factor Productivity in Brazil's and Argentina's Agriculture: A Comparative Analysis

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Abstract

We measure Malmquist index of total factor productivity (TFP) changes in the agricultural sector of Brazil and Argentina during 1971-2002. The TFP change index is further decomposed into efficiency change and technical change. We then compare the cumulative TFP growth and its components in both countries. Results show that agricultural TFP change as well as efficiency and technical change accelerated in Brazilian agriculture, where as Argentinean agriculture experienced a negative trend in TFP growth over the sample period. Efficiency change in Argentina's agriculture was found to be stagnant over time. The increasing productivity in Brazil is due to strong policy reform in 1980s. Argentina's imbalanced economy, including biased reforms explains the negative TFP growth and technical regress during this period.

Keywords: Total Factor Productivity, Data Envelopment Analysis, Agriculture in Brazil and Argentina, Policy Reform.

1. Introduction

Agriculture plays significantly important role in Brazil and Argentina. Both countries are world leaders in agriculture, especially in soybeans and grain (Gibson, 2009). Brazil is the largest coffee, sugar, and fruit juice producer, second largest soybeans and beef producer, and third largest broiler producer in the world (Production Supply and Distribution Database, 2008). Argentina is the eighth largest producer and 12th largest exporter of agricultural commodities in the world (based on 2005-2007 FAO data). It is also the top exporter of soybean oil and soybean meal, and third largest exporter of soybeans. However, agricultural production in Argentina is growing slowly over time in spite of such fascinating statistics. Moreover, agricultural output growth rate is comparatively sluggish in Argentina relative to the growth rate in Brazil.

Figure 1: Agricultural Production (in 2004-06 billion international dollars)

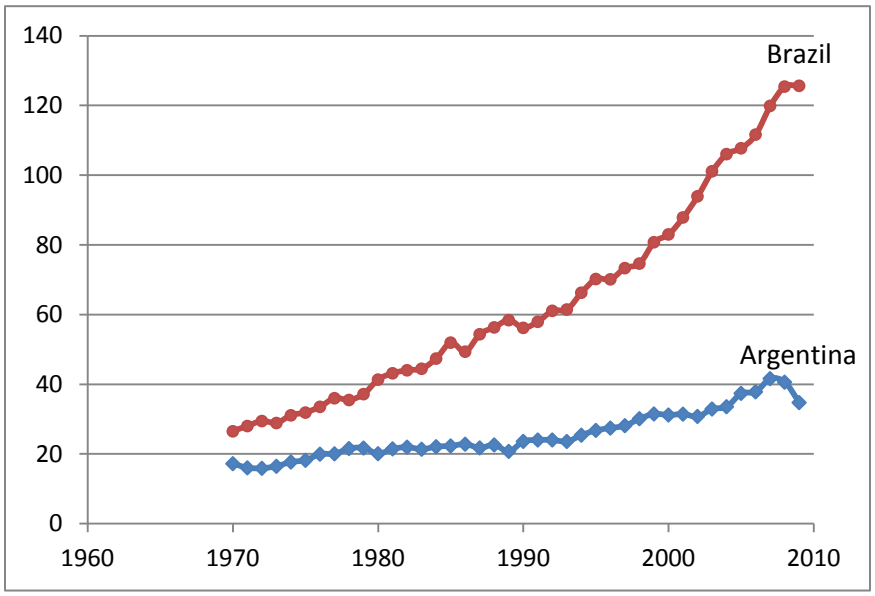

Figure 1 shows that in the early 1970s, there was no significant difference in the agricultural production in both the countries. However, the difference becomes greater and greater over time, and currently there is huge difference in both countries' agricultural production. Also, it is clear

from the graph that the growth rate in Brazil is significantly high as compared to the growth rate in Argentina.

Previous studies have shown that agricultural total factor productivity (TFP) change, efficiency change, and technical change are important factors explaining the differences in agricultural growth (Rosegrant, 1992). Moreover, both countries have experienced tremendous economic and agricultural reforms after World War II. The policy environment also affects the agricultural performance of a country. Nin-Pratt, et al. (2010) has shown that the TFP differences in China and India are a result of difference in policy reforms. The objective of this paper is to study the pattern of total factor productivity change, efficiency change, and technical change in the agricultural sector of Brazil and Argentina, and to relate the pattern of change in TFP to policy changes in both the countries.

2. Agricultural policy and reforms in Brazil and Argentina

Historically, Brazilian agriculture has been more export oriented. Post World War II policies were focused on free trade and controlling inflation (Baer, 2008). In 1960, import substitution policies were created to establish capital formation that laid the industrial foundation for modernizing agricultural sector and the production of agricultural machinery, fertilizer, and chemical inputs. This was the first phase of agricultural transformation in the country (Baer, 2008). Cheap rural credit to domestic industrial foundation in 1965 led to mechanized agricultural production, increased land concentration, and rural-to-urban labor migration (Graham, et al., 1987). The second phase of agricultural transformation took place in 1970s and early 1980s, when the Brazilian economy continued opening up due to expansion of processed and semi-processed agricultural exports.

The establishment of Embrapa (Empresa Brasileria de Prequisa), a national agricultural research agency, in 1973 added to further transformation in agriculture. Embrapa was formed to increase human capital investments, to provide research and development to improve small farmers productivity, and increase yields (Graham, et al., 1987). In the late 1980s, Brazil began to move towards a more laissez-faire and free market oriented policy which significantly affected the agricultural sector (Fabio, et al., 2006). Agricultural policy focused on elimination of export taxes and price controls, deregulation and liberalization of commodity markets, unilateral trade reduction (Gibson, 2009). Significant changes in agricultural policy took place in 1995, which shifted priority to land reform and family farming in order to alleviate rural poverty. Under the program PRONAF in 1995, the government adopted a set of policies which included subsidized credit lines, capacity building, research, and extension services (Chaddad & Jank, 2006).

Argentinean agriculture has a different policy history. Since the 1970s oil shock, Argentina has gone through numerous periods of economic crisis. For example, from 1975-1988, inflation averaged over 200 percent per year (Gibson, 2009). Dramatic market-oriented reforms and strong price incentives took place in the 1990's (ERS/USDA Report, 1998). Prior to reforms, the policies were aimed at promoting industrial growth by favoring import substitution, and using resources from the agricultural sector to support them. The agricultural sector was taxed by means of export duties, and overvalued exchange rates (Lence, 2010). Studies have shown that such policies had a substantial negative effect on Argentina's agricultural sector (Reca & Parellada, 2001).

In the early 1990s, policy changes included reduction of tariff on imports of inputs, removal of export taxes, and reduction of inefficiencies in marketing. However, the agricultural sector continued to stagnate for several years. Agriculture had been adversely affected by a fixed and

increasingly overvalued real exchange rate. The Economy suffered from increased domestic taxes, high real interest rates, and insufficient credit access. This created tremendous pressure on the farm sector to become more efficient. However, no effective government policies, programs or subsidies were enacted to encourage agricultural production in Argentina (ERS/USDA Report, 1998).

3. Methodology

We estimate Malmquist index of TFP change using output distance functions as described in Fare, et al. (1994). An output distance function considers a maximal proportional expansion of the output vector, given an input vector. It can be defined as : $Do(x,y) = \min\{\delta : (y/\delta) \in P(x)\}$, where P(x) is the output set. We employ data envelopment analysis (DEA) technique to estimate the distance function in a multi input multi output framework. DEA is a linear programming technique, which uses input and output data for a set of countries to construct non-parametric piece-wise linear production frontier for each year in the sample. The frontier surface is constructed by the solution of a sequence of linear programming problems for each country in the sample. The distance between the observed point and the frontier is then produced to calculate the Malmquist index.

An output oriented DEA model is used to find the production frontier. It seeks the maximum proportional increase in output, given the levels of input. For a group of N countries, the linear programming problem for the i-th country in such a DEA model is as follows:

$\max \theta,$

$st \quad -\theta y_i + Y\lambda \geq 0,$

$\quad x_i - X\lambda \geq 0,$

$$\lambda \geq 0$$

where y_i is a M×1 vector of output quantities for the i-th country, x_i is a K×1 vector of input quantities for the i-th country, Y is a N×M matrix of output quantities for all N countries, X is a N×K matrix of input quantities for all N countries, λ is a N×1 vector of weights, and θ is a scalar. The value of θ obtained is the technical efficiency score for the i-th country and it varies between 0 and 1, with a value of 1 indicates a point on the frontier and the i-th country will be technically efficient. The linear programming problem is solved N times and a value of θ is obtained for each country in the sample (Coelli, et al., 1998).

The Malmquist TFP index is the TFP change between two data points of a particular country in two adjacent time periods. It is calculated as the ratio of the distances of each data point relative to a common technology as follows:

$$m_0(y_s, x_s, y_t, x_t)=\left[\frac{d0^s(Yt,Xt)}{d0^s(Ys,Xs)} \times \frac{d0^t(Yt,Xt)}{d0^t(Ys,Xs)}\right]^{½}$$

where Y is a vector of outputs, X is a vector of inputs, s and t represent time, d_0 is the distance function. This TFP index can be decomposed into efficiency change and technical change as:

$$m_0(y_s, x_s, y_t, x_t)= \frac{d0^t(Yt,Xt)}{d0^s(Ys,Xs)} \left[\frac{d0^s(Yt,Xt)}{d0^t(Yt,Xt)} \times \frac{d0^s(Ys,Xs)}{d0^t(Ys,Xs)}\right]^{½}$$

The first ratio in the right hand side measures a country's efficiency change between period s and t. It provides information about the extent to which a country is able catching-up to the production frontier. The second part in the brackets measures the technical change between the two periods which provides an indication of pushing out the production frontier.

4. Data Description

The data used in this study are primarily collected from FAOSTAT, the statistical database of the Food and Agriculture Organization (FAO) of the United Nation. Annual data on two outputs namely, crop and livestock production, and 5 inputs namely, land, labor, tractors, fertilizers, and animal stock were collected for the period 1971-2002 for 76 countries including Brazil and Argentina. The outputs are the net production value in 2004-2006 international dollars. Land represents total agricultural area in a country. It includes arable land, land under permanent crops, and area under permanent pasture. Labor refers to economically active population in agricultural sector. The number of tractors is used as a proxy for machinery. Fertilizer is the total amount of nitrogen, potassium, and phosphate consumed and is expressed in thousands of metric tons. The livestock input variable includes five categories of animals which are converted into sheep-equivalent using conversion factors, i.e., 8.0 for buffalo and cattle, 1.0 for sheep, goat, and pigs (Hayami & Ruttan, 1970).

5. Results and Discussion

The malmquist indices of TFP change, efficiency change and technical change are obtained for all 76 countries using DEA technique. However, the indices for Brazil and Argentina are presented below for our study purpose.

Table 1: Annual Efficiency change, Technical change, and TFP change in Brazil and Argentina

	Argentina			**Brazil**		
year	Efficiency Change	Technical Change	TFP Change	Efficiency Change	Technical Change	TFP Change
1971	1.000	1.000	1.000	1.000	1.000	1.000
1972	1.000	0.931	0.931	1.051	0.963	1.013
1973	1.000	1.050	1.050	0.950	1.002	0.952
1974	1.000	1.121	1.121	0.971	1.035	1.005
1975	1.000	1.127	1.127	0.911	1.018	0.927
1976	1.000	0.983	0.983	0.964	1.028	0.991
1977	1.000	1.013	1.013	1.067	1.000	1.066
1978	1.000	0.922	0.922	0.883	1.032	0.911
1979	1.000	0.920	0.920	0.973	1.026	0.998
1980	1.000	0.983	0.983	1.078	0.977	1.053
1981	1.000	1.036	1.036	1.038	1.010	1.048
1982	1.000	0.989	0.989	0.958	1.053	1.009
1983	1.000	0.927	0.927	0.969	1.019	0.987
1984	1.000	0.895	0.895	1.058	0.980	1.037
1985	1.000	1.004	1.004	1.138	0.988	1.125
1986	1.000	1.015	1.015	0.910	0.971	0.883
1987	1.000	0.912	0.912	1.138	0.980	1.115
1988	1.000	1.016	1.016	1.028	0.998	1.027
1989	1.000	0.946	0.946	1.042	1.024	1.067
1990	1.000	1.083	1.083	0.894	1.076	0.961
1991	1.000	1.009	1.009	1.015	0.993	1.008
1992	1.000	0.828	0.828	1.039	1.009	1.049
1993	1.000	0.921	0.921	0.920	1.024	0.942
1994	1.000	0.862	0.862	1.016	1.012	1.028
1995	1.000	0.989	0.989	1.071	1.037	1.110
1996	1.000	0.805	0.805	0.968	0.987	0.955
1997	1.000	1.059	1.059	1.001	1.009	1.009
1998	1.000	1.094	1.094	1.028	0.990	1.018
1999	1.000	1.003	1.003	1.041	1.041	1.083
2000	1.000	0.971	0.971	0.983	1.022	1.005
2001	1.000	1.001	1.001	0.986	1.053	1.038
2002	1.000	1.062	1.062	1.061	0.969	1.028

Figure 2a: Cumulative Efficiency Change (1971 =1)

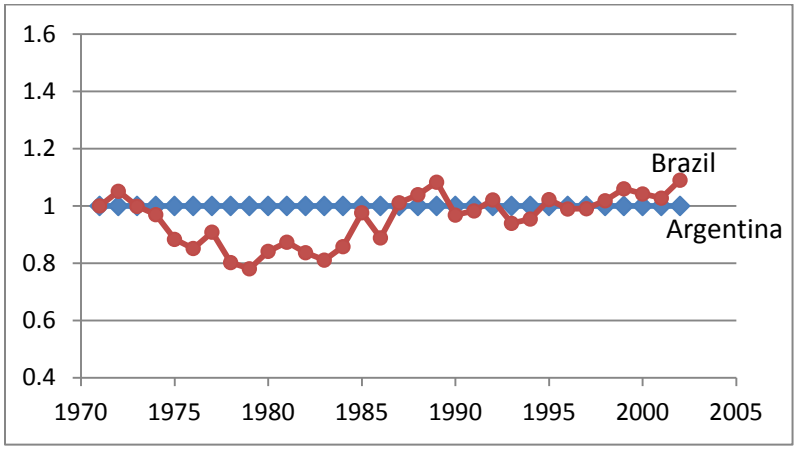

Figure 2b: Cumulative Technical Change (1971 =1)

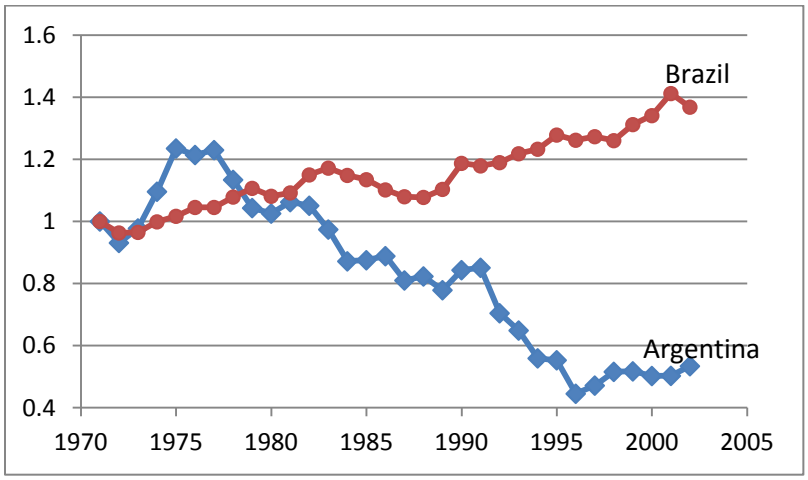

Figure 2c: Cumulative TFP Change (1971 =1)

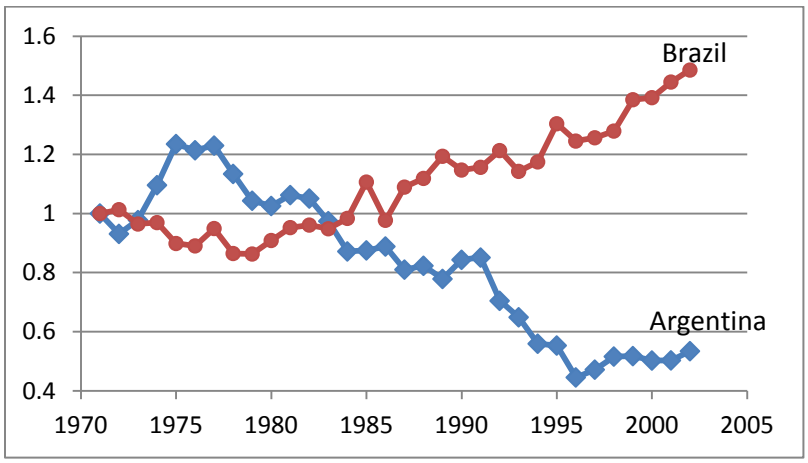

Figure 2a, 2b and 2c represents cumulative efficiency change, technical change and TFP change in Brazil and Argentina. Figure 2a shows that efficiency change in Brazil is decreasing initially, but it is showing an upward trend over time starting from 1980. In Argentina, efficiency change is almost stagnant over the period 1971-2002 as seen in figure 2a, which is really surprising. Figure 2b indicates that Brazil is experiencing technical progress over time. On the other hand, Argentina is experiencing technical regress after mid 70s to mid 90s. The graph shows technical progress for Argentina after 1995. The trend in TFP change looks very much contrasting in both the countries. TFP change in Argentina is resulting from technical change as it's efficiency change is stagnant over time. TFP is increasing in Brazil over time where as in Argentina TFP has started increasing after mid 90s.

6. TFP change and Policy reform

In order to know whether TFP change over time is related to policy regimes in both countries, we test for any structural break in TFP change series by implying Additive Outlier (AO) and Innovative Outlier (IO) models as described in Baum, 2001. AO model captures any sudden change in a series where as IO model allows for gradual shift in the mean of a series. We allow for two structural breaks following Clemente, et al. (1998).

The double–break additive outlier (AO) model is estimated as:

$$Yt = \mu + \delta_1 DU_{1t} + \delta_2 DU_{2t} + \hat{Y}t$$

Where, $\hat{Y}t = \sum\beta_1 DT_{b1,t-i} + \sum\beta_2 DT_{b2,t-i} + \alpha\, \hat{Y}t\text{-}i + \sum\theta_i \Delta\hat{Y}t\text{-}i + e_t$

$DU_{mt} = 1$ for $t > T_{bm}$ and 0 otherwise, for m = 1, 2. T_{b1} and T_{b2} are the breakpoints, to be located by grid search. $DT_{bm,t} = 1$ for $t = T_{bm} + 1$ and 0 otherwise, for m = 1, 2.

Similarly, the double-break innovative outlier (IO) model is estimated as:

$$Yt = \mu + \delta_1 DU_{1t} + \delta_2 DU_{2t} + \gamma 1DT_{b1,t} + \gamma 2DT_{b2,t} + \alpha Y_{t-1} + \sum \theta_i \Delta Y_{t-i} + e_t$$

In both these models, the breakpoints T_{b1}, T_{b2} and the appropriate lag order are unknown. The breakpoints are located by a two–dimensional grid search for the maximal (most negative) t–statistic for the unit root hypothesis ($\alpha = 1$), while k is determined by a set of sequential F–tests (Baum, 2001). The null hypothesis of a unit root is rejected if the absolute value of the t-statistic for $\alpha = 1$is greater than the corresponding critical value. The results from this analysis are presented in table 2.

Table 2: Structural Breaks for TFP, efficiency, and technical change index

	Argentina				**Brazil**			
	Year of first break	t-stat	Year of second break	t-stat	Year of first break	t-stat	Year of second break	t-stat
Efficiency Change								
AO1							1984	4.836***
AO2					1976	-4.11 ***	1984	7.256***
IO1							1985	2.543 **
IO2					1973	-2.88***	1985	4.028***
Technical Change								
AO1	1988	-8.50***					1991	8.169***
AO2	1981	-8.13***	1993	-6.29***	1979	4.31***	1991	7.220***
IO1			1990	-3.56***	1988	3.56**		
IO2	1981	-3.52***	1990	-3.26***	1988	2.67**	1998	1.529
TFP Change								
AO1	1988	-8.50***					1996	6.054***
AO2	1981	-8.13***	1993	-6.29***	1984	7.71***	1996	6.15***
IO1			1990	-3.56***	1986	1.78*		
IO2	1981	-3.52***	1990	-3.26***	1983	2.84***	1993	2.795**

TFP growth in Brazil accelerated around mid 1980s, when it began to move toward a more laissez-faire and free market oriented policy for its economy. It attains higher peaks after 1995

when the Brazilian economy adopted policy on land reform and family agriculture. We can see structural breaks around the mid 1980s and 1996 from our AO/IO result. Acceleration in efficiency change and technical change were seen at the same time. Results from AO/IO analysis indicated that TFP growth accelerates after policy reforms in Brazil. We see structural breaks in Argentina's TFP in 1981 and 1988. This is the time when inflation in Argentina was extremely high. In the early 1990s, Argentinian policy changes included tariff reduction on imports of inputs, removal of export taxes, and reduction of inefficiencies in marketing. However in table 2 we see further downturn in TFP around 1991 and 1993. In spite of the agricultural reforms in Argentina, the stagnant efficiency change and technical regress could be the results of imbalances in an economy suffering from high inflation rate, interest rate, and overvalued exchange rate. Insufficient credit and lack of subsidies again hampers agricultural productivity and growth in Argentina.

7. Conclusion

The agricultural sector in both Brazil and Argentina is competitive in the world market. In the early 1970s, there was little difference in both countries' agricultural production. However, over time differences have been increasing. The annual growth rate in agriculture is much higher in Brazil than in Argentina. The results of this study shows that TFP change in Brazilian agriculture has a positive trend where as the agricultural sector in Argentina experiences a negative trend in TFP. More importantly, the change in TFP accelerated in Brazil in mid 1980s after the agricultural reform took place. However, around the same time period, agricultural TFP in Argentina started decelerating more intensely. Surprisingly, efficiency change in Argentina's agriculture is almost stagnant over the sample period, and it was facing technical regress from mid-1980s to mid-1990s. Argentina has a very strong agricultural background with the capacity

to produce many crops, most notably the ability to produce a large amount of wheat and soybeans. But the policy background of its government has been very different from that of Brazil. Argentina's policy focuses on taxing its agricultural sector in order to subsidize other economic sectors. Argentina is sharply contrasted with Brazil by the lack of policies designed to promote agriculture and capture the growth potential of this export oriented sector.

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