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Agricultural Productivity Growth in the Andean Community

Lisa Pfeiffer

AGRICULTURAL PRODUCTIVITY GROWTH IN THE ANDEAN COMMUNITY

Abstract

This paper examines agricultural productivity growth in the Andean Community (Bolivia, Colombia, Ecuador, Peru, and Venezuela) through the period 1972-2000. Earlier research has identified negative productivity growth in agriculture in developing countries. These results imply that recent growth was based mainly on an increase in resource base instead of an increase in the quality and efficiency of resource use and the adoption of new techniques. A focus on a more homogeneous geographical area, the Andean Community, will help identify characteristics of this evolution specific to geographical, social, or political circumstances of these countries. Production and input time-series data are used to estimate a parametric translog production function, a stochastic frontier production function, and a nonparametric Malmquist productivity index to obtain the rate of total factor productivity growth. The results are consistent across methods and indicate that in contrast to previous studies, productivity growth in the Andean Community is positive and increasing over time. Furthermore, the TFP growth rates estimated are comparable to that of developed countries' agriculture. Land quality, war and violence, and political freedoms are important in understanding behavioral differences across countries.

Keywords: agricultural productivity, Andean Community, meta-production function, stochastic frontier production function, Malmquist productivity index.

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Agricultural Productivity Growth in the Andean Community

Introduction

Productivity growth in an economy is important because it is an essential source of overall growth. The other source is an increase in the factor supplies (labor, capital, land, etc), but since these factors are subject to diminishing marginal returns, it can be said that productivity is the source of permanent, long-run growth in an economy.

Aggregate productivity can be defined as the amount of output that can be obtained from given levels of inputs in a sector or economy. Therefore, increases in productivity occur when output from a given level of inputs increases. This phenomenon is attributable to improvements in the technical efficiency with which the inputs are used, new human capital, and innovations in technology that allow more output to be produced.

The analysis that follows will examine changes in agricultural productivity in the countries of the Andean Community (Bolivia, Colombia, Ecuador, Peru, and Venezuela). This group of countries is a subset of a larger study by Fulginiti, Perrin, and others looking at the agricultural productivity of many of the less developed countries (LDCs) around the world. Earlier studies by Fulginiti and Perrin (1998) identified negative productivity growth in a set of 18 developing countries, lending support to results obtained earlier by Kawagoe, Hayami, and Ruttan (1985) in a study that showed technological regression in 22 LDCs, but an increase in productivity in the 21 developed countries that were included. Analyses by Lau and Yotopoulos (1989) also found declining agricultural productivity in the 1970s, although they used different functional forms and data. More recently, Suhuriyanto, Lusigi, and Thirtle (2001) found negative

agricultural productivity growth rates in Asia from 1965-1980 and in Africa from 1971-1981. This study shows the rates in both regions improving in subsequent years.

The results of these studies are distressing, as they imply that growth in agriculture over the last half of the century in developing countries was based mainly on an increase in resource base, instead of an increase in the quality and efficiency of resource use, the adoption of new techniques, or the development of human capital. These results are surprising, given the incredible advances that have been made in agriculture over the past 40 years. For example, the “Green Revolution” of the late 1960s was characterized by the spectacular improvements in the yields of many major food crops, and throughout the past four decades, huge advances have been made in irrigation systems, fertilizer use, and genetic engineering. Why, then, would agricultural productivity in developing countries be declining? It may mean that returns to investments on agricultural research are very low, that knowledge and technology are not being effectively transferred, and that overall growth may be short-lived in these developing countries.

In contrast, recent studies of agricultural productivity growth in developed countries have found positive and rapid growth. Ahearn et al. (1998) found annual average agricultural productivity growth to be about 2.5% in the United States, over the period 1970-1994, while Ball et al. (2001) found the average annual agricultural productivity growth rates to be similar to or even higher than that of the US in many European countries.

In order to test the methodologies and results of these studies, it is useful to look at more homogenous sets of LDCs that share geographical, economic, and social characteristics.

Productivity Measurement

Productivity change can be measured by comparing observed changes in output with the conceptual change in output that would have been possible from the observed changes in input. This analysis uses a meta-production function to estimate productivity change. This function is estimated in three different ways: a fixed effects parametric production function, a stochastic frontier production function and a non-parametric Malmquist index.

The rate of technological change can be obtained from a parametric production function by using time series data and including a time-trend variable. For this analysis the translog form augmented for fixed-effects is usedⁱ, as it allows for more flexibility and inspection of trends over time.

$$(1) \quad \ln Y_{it} = \alpha_0 + \sum_m \alpha_m \ln x_{mit} + \alpha_t t + \frac{1}{2} \sum_m \sum_n \beta_{mn} \ln x_{mit} \ln x_{nit} + \frac{1}{2} \beta_{tt} t^2 + \sum_m \beta_{tm} \ln x_{mit} t + \varepsilon_t$$

where Y is the value of agricultural output, x_{it} is the input quantities of the i -th country in the t -th year, m, n are the five inputs specified below, and ε_t is the random error. The production elasticities of each input are defined by:

$$(2) \quad \varepsilon_m = \frac{\partial \ln f(x, t)}{\partial \ln x_m} = \alpha_m + \sum_{n \neq m} \beta_{mn} \ln x_n + \beta_{mm} \ln x_m + \beta_{tm} t$$

We are most interested in the derivative of equation (1) with respect to t , which provides an estimate of the percentage change in output resulting from technological change (TC)ⁱⁱ:

$$(3) \quad \frac{\partial \ln Y_{it}}{\partial t} = \alpha_t + \beta_{it} + \sum_m \beta_{im} \ln x_{mit} = TC$$

Figure 1 illustrates the production function in one-input, one-output space. The rate of technical change indicates the percentage shift of the production function given the level of input x_i . An estimate of TC will give an idea of the additional output produced due to technological innovations while traditional inputs are held constant.

Figure 1. Production function

The stochastic frontier production function differs from the standard OLS (or GLS) estimation in the structure of the error term. The error term is divided into two parts: a symmetric random error, associated with measurement error, random noise, and the contribution of omitted variables from the model, and a non-negative random error associated with technical inefficiencies of production that models country heterogeneity.

Here, this function is described by:

$$(4) \ln Y_{it} = \alpha_0 + \sum_m \alpha_m \ln x_{mit} + \alpha_t t + \frac{1}{2} \sum_m \sum_n \beta_{mn} \ln x_{mit} \ln x_{nit} + \frac{1}{2} \beta_{tt} t^2 + \sum_m \beta_{tm} \ln x_{mit} t + v_{it} - u_{it}$$

with the same specifications as the first model. The v_{it} s are assumed to be independent and identically distributed random errors which have normal distribution with mean zero and variance σ_v^2 . The u_{it} s are non-negative random variables, called the technical

inefficiency effects. It is hypothesized that inefficiency changes over time. Technical efficiency is defined as:

$$(5) \quad TE_{it} = \exp(-u_{it}).$$

In this analysis, the model assumes that the inefficiency effects are a function of a vector of explanatory variables (Battese and Coelli, 1995). The mean of u_{it} is assumed to be the non-negative truncation of the normal distribution with mean, μ_{it} and variance, σ^2 , where the mean is defined by:

$$(6) \quad \mu_{it} = \delta' z_{it}$$

where z_{it} is a vector of explanatory variables associated with the technical inefficiency effects and δ is a vector of unknown parameters to be estimated. This approach gives the opportunity of accounting for resource quality differences across countries and other socio-political and institutional differences that might have affected behavior.

Finally, the rate of total factor productivity (TFP) is defined as the rate of change in output that is not explained by the input change:

$$(7) \quad TFP = \dot{y} - \sum_m \varepsilon_m \dot{x}_m = \text{Technical change (TC)} + \text{Efficiency change (EC)}$$

where TC is as in equation (4) and EC is:

$$(8) \quad EC = \frac{TE_{it} - TE_{it-1}}{TE_{it-1}}.$$

A Malmquist productivity index has been used as an alternative approach to the econometric analysis of productivity growth (Fulginiti and Perrin, 1998). The Malmquist index is a non-parametric, nonstochastic index used to examine productivity change:

$$(9) \quad M_0(x_{t+1}, y_{t+1}, x_t, y_t) = \left[\frac{D'_0(x_{t+1}, y_{t+1})}{D'_0(x_t, y_t)} * \frac{D_0^{t+1}(x_{t+1}, y_{t+1})}{D_0^{t+1}(x_t, y_t)} \right]^{1/2}.$$

The subscript 0 shows that this is an output oriented Malmquist index. Here D_0 refers to an output distance function. Linear programming is used to calculate the distance functions in equation (9)ⁱⁱⁱ

Data and Results

This study examines agricultural productivity changes in the five developing countries included in the Andean Community. The data set used contain the same variables as the Hayami and Ruttan and the Fulginiti and Perrin series, although the data for this analysis was collected over a different time period, 1972-2000. Summary statistics are presented in table 1^{iv}.

Table 1. Summary Statistics: 1972-2000

	N	Mean	Standard Deviation	Variance	Minimum	Maximum
Output	145	313760	194340	3.37 E10	76296	843870
Labor	145	1922	1047	1.09 E6	751	3814
Land	145	3341	1039	1.08 E6	1770	5318
Fertilizers	145	170910	172090	2.96 E10	1940	666470
Tractors	145	15606	11906	1.41 E8	2400	47500
Livestock	145	10304000	6994300	4.49 E13	3133300	26215000

First, the production function in (1) is estimated using a pooled time-series fixed effects model. The estimation was done using SHAZAM Version 9 (see Whistler et al., 2001), and due to the panel nature of the data set and inspection of the estimated residuals, a generalized least squares (GLS) method is used. The method allows the errors to be correlated over time with the same correlation coefficient, and attempts to correct for heteroskedasticity, cross-section autocorrelations, and time-wise autoregression.^v

Table 2. Total Factor Productivity Change (%)

	Fixed Effects	Stochastic Frontier			Malmquist ^{vi}
	TFP change	Technical Change	Efficiency Change	TFP Change	TFP Change
Bolivia	1.20	0.82	-0.24	0.58	1.80
Colombia	1.37	0.47	0.13	0.60	1.90
Ecuador	2.11	2.96	0.28	3.24	0.0
Peru	1.85	2.80	-0.06	2.74	1.40
Venezuela	1.08	1.15	0.21	1.36	1.50
Average all	1.52	1.64	0.064	1.70	1.30

The results of equation (3), presented in the first column of table 2, are

particularly important to this analysis because they represent technological change which in this case is synonymous with productivity growth. We find that in the five Andean countries, over the period 1972-2000, average agricultural productivity grew at about 1.52% per year. Ecuador had the highest average annual growth rate of 2.11%, and Venezuela had the lowest of 1.08% per year. Because a translog production function is being used, the evolution of the growth rates can be calculated and are shown in figure 2. Figure 2 shows a marked increase in annual agricultural productivity growth rates in all five countries over the time period. Bolivia and Venezuela showed the greatest variability in agricultural productivity growth rates over the time period.

Figure 2. TFP growth rate, 1972-2000, fixed-effects translog.

Given the significance of the fixed-effects, the second approach used for the estimation of productivity growth in a panel of countries is the stochastic frontier production function approach. Maximum likelihood procedures are used to estimate the set of parameters.^{vii} The estimation is done using FRONTIER 4.1 (see Coelli, Prasada Rao, and Battese, 1998). The stochastic frontier method permits the simultaneous investigation of technical change and technical efficiency change over time.

Three inefficiency variables were used to attempt to explain the differential country performance, including an estimate of land quality, obtained from the USDA ERS (see Weibe et al., 2002), and estimate of wars and violence in the country (see Gleditsch et al., 2002), and an approximation of the amount of civil freedoms that people in the country possess, from the database maintained by the Freedom House (2002). The coefficients on the inefficiency variables in Table 3 indicate that once quality is accounted for the performance discrepancy across countries increases, while accounting for wars and violence and civil liberties freedoms has decreased the performance discrepancy between countries.

Table 3. Stochastic Frontier Model, inefficiency variables.

Inefficiency Variable	Coefficient	T-Statistic
Constant	-0.03007	-0.521
Land Quality	0.01158	5.177
Wars and Violence	-0.15774	-4.144
Civil Freedoms	-0.06385	-3.671

Figure 3 presents the evolution of the inefficiency effects over time for each country. A perfectly efficient value would be equal to one. Bolivia is the most technically inefficient country while Colombia and Peru seem to be defining the

production frontier. This chart illustrates the decrease in efficiency in Bolivia, and less notably in Ecuador, from 1972 to 1986 and the upturn since then.

Figure 3. Evolution of efficiency level per country, 1972-2000

In table 2, the average annual growth rates of technical change for each country obtained from the stochastic frontier estimation are presented, with Ecuador and Peru showing the highest annual average growth rates of agricultural productivity. The evolution of the growth rates of technical change are presented in Figure 4 showing marked increases over the time period for all countries. It is interesting to note that once war and violence are included in the analysis Colombia's growth rate turns negative for the period 1972-82. Once again, Bolivia and Venezuela show the greatest variability in their growth rates of technical change. Inclusion of land quality might be responsible for Bolivia's negative growth rate from 1974-1980. Venezuela appears to level off or even slightly decrease from 1988-98.

Figure 4. Technical change per country over the period 1972-2000

The most important concept in this study is the estimation of TFP growth rate

shown in Table 2. Figure 5 shows its evolution over the time period by country.

Efficiency change enhanced technical change in the case of Colombia, Ecuador, and Venezuela, while it detracted from technical change in the case of Bolivia and Peru. An upward trend in TFP change appears, although not nearly as consistent as in the average annual growth rates of technical change chart from the parametric production function estimation (figure 2). The efficiency change estimates had no consistent trend, causing the extreme figures that are noticeable in figure 5, but when averaged across countries the data is consistent with the fixed effects model (figure 6). However, this shows that efficiency change is growing a less consistent rate than technical change.

Figure 5. Total Factor Productivity change per country, stochastic frontier.

Finally, as an alternative to the parametric production function approach, a nonparametric frontier Malmquist index is estimated, using the Data Envelopment Analysis (Computer) Program (DEAP) (see Coelli, Prasado Rao, and Battese, 1998) to calculate the contemporaneous^{viii} Malmquist index.

The results of the Malmquist analysis are presented in the last column of Table 2 as the average over the period for each country. Figure 6 includes the evolution over time. Indexes smaller than one represent inefficiency and regressive technical change. It can be noted that the results from the Malmquist index support those obtained from the two econometric approaches, as it shows an average annual rate of agricultural productivity growth of about 1.3% per year. It also shows a very slight upward trend in TFP change, as did the stochastic frontier method.

Figure 6. Estimates of total factor productivity change, three methods.

Figure 6 compares the three different methods used to estimate agricultural productivity growth, including the fixed effects model, the stochastic frontier model, and the Malmquist productivity index. It can be noted that growth, on average, is positive

with a slight upward trend occurring, especially over the last 15 years. Results are robust across all three models. The fixed-effects estimates are smooth given the imposition of a time trend to capture TFP, the Malmquist estimates are the most variable given that they fit consecutive data points without error, while the stochastic frontier allows for departures from a trend due to the specification of the one-sided error term.

Conclusions

This paper examines changes in agricultural productivity in Bolivia, Colombia, Ecuador, Peru, and Venezuela using several distinct methods. Two parametric methods were used, a fixed-effects approach and a stochastic frontier production function approach. A non-parametric contemporaneous Malmquist index is used as an alternative approach and to support the findings from the parametric methods. The results **do not** support previous findings of negative productivity growth in agriculture in developing countries, and in fact indicate positive growth which has been slightly increasing over the 29 year time period, in particular in the last 15 years. In fact, the rate of growth of TFP is comparable to that estimated for the U.S. and G-7 countries. The results are robust across models. However, the stochastic frontier inefficiency effects model seems to indicate a divergence of efficiency between the countries, with Ecuador, and most notably Bolivia, well below the production frontier defined by Colombia and Peru. It is also interesting to note that controlling for social unrest decreases the behavioral differences in terms of productivity growth rates, while controlling for the quality of land increases it. It can be concluded for this study that agricultural productivity growth in the Andean Community is based mainly on technical progress rather than increases in efficiency, with parametric and non-parametric results supporting these findings. It is interesting to note that two of the

sixteen Consultative Groups on International Agricultural Research (CGIAR) are located in member countries^{ix}, and intra- and extra-regional trade agreements have caused a tremendous increase in the trade of agricultural and other products. It suggests that agricultural producers are benefiting from research and the introduction of new technology and products, but the gap between the best practice countries and Bolivia and Ecuador is widening. Educational channels such as extension services and technical schools may not yet be sufficient to effectively disseminate information about available technologies and their uses to all farmers. The Andean countries have an extreme disparity in the distribution of wealth among income levels; thus social and political institutions may prevent new knowledge and technology from being effectively used by parts of the population. This may also mean that any stagnation in innovations or technical progress, perhaps due to political, economic, or social conditions, would cause a decline in total factor productivity growth in agriculture.

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Footnotes

ⁱ The results from a Cobb-Douglas production function were also obtained, but the Cobb-Douglas form was rejected by the data in favor of the translog form.

ⁱⁱ When a fixed effects method is used to estimate the production function, technical change and total factor productivity change are synonymous. When a frontier production function is estimated, total factor productivity is the sum of technical change and efficiency change.

ⁱⁱⁱ D_o is calculated as follows:

$$[d'_o(x_i, y_i)]^{-1} = \max_{\phi, \lambda} \phi, \text{ st. } -\phi y_{ii} + Y_i \lambda \geq 0, x_{ii} - X_i \lambda \geq 0, \lambda \geq 0$$

where x and y are input and output vectors, $X (K \times N)$ and $Y (M \times N)$ respectively. λ is a $N \times 1$ vector of constants. Here $1 = \phi < \infty$ and $\phi - 1$ is the proportional increase in inputs that could be achieved by the i -th region, with input quantities held constant.

^{iv} Details on sources, units etc. can be obtained from the author.

^v The average production elasticities for this estimation are: land, -0.462, labor, 1.913, fertilizers, 0.004, tractors, -0.0005, and livestock, 0.301. The production elasticities estimated for land and tractors have been problematic in most cross-country studies. It is believed that a better definition of the variables and/or the inclusion of quality indicators would alleviate the problem (Fulginiti and Perrin, 1998, Lau and Yotopoulos, 1989, Suhuriyanto, Lusigi, and Thirtle, 2001).

^{vi} It is not possible to identify the efficiency change because we have the same number of countries as inputs.

^{vii} The estimated production elasticities are: land, -0.276, labor, 0.683, fertilizers, 0.030, tractors, 0.207, and livestock, 0.053.

^{viii} This index only uses data for two consecutive time periods.

^{ix} The Centro Internacional de Agricultura Tropical (CIAT) is located in Cali, Colombia, and the Centro Internacional de la Papa (CIP) is located in Lima, Peru. The objective of CGIAR is to contribute to food security and poverty reduction through strategic and applied agricultural research.