The Dynamics of Latin American Agricultural Production Growth, 1950–2008

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Appendix: Methodology and Sources

A.1 Antecedents

Table A.1.1. *Summary of Studies: Percentage of Growth in Agricultural Total Factor Productivity in Selected Latin American Countries*

Author/s	**Ebata**	**Ludena**	**Coelli and Rao**	**Nin and Yu**	**Nin *et al.***	**Trueblood and Coggins**	**Fulginiti and Perrin**	**Arnade**	**Bravo-Ortega and Lederman**	**Avila and Evenson**	**Bharati and Fulginiti**	**Pfeiffer**	**Headey *et al.***	**Fuglie**
Date	2011	2010	2005	2009	2003	2003	1998	1998	2004	2010	2007	2003	2010	2012
No. countries	14	120	93	72	20	115	18	70	77	82	10	5	88	155
Period	1977–2006	1961–2007	1980–2000	1964–2003	1961–94	1961–91	1961–85	1961–93	1960–2000	1961–2001	1972–2002	1972–2000	1970–2001	1961–2009
Methodology [a]	Malmquist	DEA	DEA	DEA	DEA	DEA	DEA	DEA	Translog	Accounting Relationship	Translog	DEA/Translog	Stochastic Frontier Analysis	Cobb-Douglas
Argentina	n.a.	2.4	–2.7	2.9	2.5	–2.6	–4.8	–1.9	1.8	2.1	2.2	n.a.	n.a.	1.0
Brazil	n.a.	1.8	2.0	1.4	–0.3	–0.6	–0.5	–2.1	1.9	1.9	2.6	n.a.	1.1	2.0
Chile	n.a.	2.1	1.0	1.9	0.6	1.4	1.1	1.3	1.2	1.4	2.2	n.a.	1.9	1.8
Colombia	n.a.	2.1	1.4	2.7	1.5	1.6	0.0	1.8	1.4	1.6	1.1	1.9/1.4	n.a.	2.0
Honduras	3.5	1.3	0.3	1.7	n.a.	–1.3	n.a.	–0.4	0.8	1.6	n.a.	n.a.	n.a.	1.1
Mexico	n.a.	2.1	1.5	1.2	n.a.	0.5	n.a.	1.2	1.9	1.9	n.a.	n.a.	n.a.	1.6
Panama	1.7	1.1	n.a.	0.2	n.a.	0.4	n.a.	n.a.	n.a.	1.0	n.a.	n.a.	n.a.	0.8
Peru	n.a.	1.2	1.5	1.2	n.a.	–0.1	n.a.	0.6	1.4	1.2	1.1	1.4/1.9	2.2	1.2
Uruguay	n.a.	0.9	0.0	0.8	1.5	–0.1	n.a.	–1.3	n.a.	0.5	1.9	n.a.	n.a.	1.4
Venezuela	n.a.	2.1	0.6	1.5	n.a.	0.7	n.a.	0.2	1.4	2.0	2.4	1.5/1.1	1.4	2.1

Notes: n.a. = Not available.

[a] Methodologies: The Malmquist index is a measure of productivity change as a ratio between an output quantity change index and an input quantity change index. Data envelopment analysis (DEA) is a nonparametric method for the estimation of productive efficiency. The Translog and Cobb-Douglas production functions represent a mathematical relationship between output and inputs. The accounting relationship assumes that the value of the product is equal to the value of the inputs required to generate the product. Stochastic Frontier Analysis is a statistical technique used to estimate production functions, considering explicitly the existence of firm inefficiency.

Sources: Authors' elaboration, on the basis of:

Ayako Ebata, 'Agricultural Productivity Growth in Central America and the Caribbean', Master's Thesis, University of Nebraska-Lincoln, 2011

Carlos Ludena, 'Agricultural Productivity Growth, Efficiency Change and Technical Progress in Latin America and the Caribbean', IDB Working Paper Series No. IDB-WP-186 (2010), Appendix, Table 1, p. 30

Tim Coelli and D. S. Prasada Rao, 'Total Factor Productivity Growth in Agriculture: A Malmquist Index Analysis of 93 Countries, 1980–2000', *Agricultural Economics*, 32: s1 (2005), pp. 115–34

Alejandro Nin and Bingxin Yu, ‘Getting Implicit Shadow Prices Right for the Estimation of the Malmquist Index: The Case of Agricultural Total Factor Productivity in Developing Countries’, Document presented to the International Association of Agricultural Economists Conference, Beijing, China, 16–22 Aug. 2009

Alejandro Nin, Channing Arndt, Thomas W. Hertel and Paul V. Preckel, ‘Bridging the Gap between Partial and Total Factor Productivity Measures using Directional Distance Functions’, *American Journal of Agricultural Economics*, 85: 4 (2003), pp. 928–42

Michael A. Trueblood and Jay Coggins, ‘Intercountry Agricultural Efficiency and Productivity: A Malmquist Index Approach’ (2003), http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.518.9512&rep=rep1&type=pdf, last access 23 Oct. 2018

Lylian E. Fulginiti and Richard K. Perrin, ‘Agricultural Productivity in Developing Countries’, *Agricultural Economics*, 19: 1–2 (1998), pp. 45–51

Carlos Arnade, ‘Using a Programming Approach to Measure International Agricultural Efficiency and Productivity’, *Journal of Agricultural Economics*, 49: 1 (1998), pp. 67–84

Claudio Bravo-Ortega and Daniel Lederman, ‘Agricultural Productivity and Its Determinants: Revisiting International Experiences’, *Estudios de Economía*, 31: 2 (2004), pp. 133–63

Antonio F. D. Avila and Robert E. Evenson, ‘Total Factor Productivity Growth in Agriculture: The Role of Technological Capital’, in Prabhu Pinghali and Robert Evenson (eds.), *Handbook of Agricultural Economics*, vol. 4 (Amsterdam: North Holland, 2010), pp. 3769–822

Preeti Bharati and Lylian E. Fulginiti, ‘Institutions and Agricultural Productivity in Mercosur’, in E. Teixeira and M. Braga (eds.), *Institutions and Economic Development* (Vicosa: Os Editores, 2007), pp. 139–69

Lisa M. Pfeiffer, ‘Agricultural Productivity Growth in the Andean Community’, *American Journal of Agricultural Economics*, 85: 5 (2003), pp. 1335–41

Derek Headey, Mohammad Alauddin and D. S. Prasada Rao, ‘Explaining Agricultural Productivity Growth: An International Perspective’, *Agricultural Economics*, 41: 1 (2010), pp. 1–14

Keith O. Fuglie, ‘Productivity Growth and Technology Capital in the Global Agricultural Economy’, in Keith O. Fuglie, Sun Ling Wang and V. Eldon Ball (eds.), *Productivity Growth in Agriculture: An International Perspective* (Wallingford and Cambridge, MA: CAB International, 2012), pp. 335–69

A.2 Construction of the Statistical Series

For the variables for which there were no continuous series during the 1950s, we calculated the data which were lacking through linear interpolation among the data which appear in the Food and Agriculture Organization (FAO) production yearbooks and the data for 1961 from the FAOSTAT database.[1] In this way we obtained an annual series from 1950; we have linked this with those of FAOSTAT, which began in 1961. We comment below on the concrete estimations which require more detail.

Gross Agricultural Production

For the calculation of an annual series between 1950 and 2008 we have had to make certain calculations. On the one hand, the FAOSTAT database offers data only from 1961, in 2004–6 US dollars. To obtain a homogenous series for our entire sample, we used the agricultural production indexes in the FAO production yearbooks. As a first step, we took the 1963 yearbook, obtaining from it the index which goes from 1952 to 1962. For the years prior to 1952, we undertook the same operation with the indexes from 1948 onwards, which appear in the 1952 yearbook. Linking these indexes with those offered by FAOSTAT, we managed to obtain a series which covers almost 60 years of Latin American agricultural production.

Land

The data from the FAO production yearbook for 1950 are not consistent with those available in the literature for Argentina, Chile and Uruguay.

Argentina: We calculated the arable land area for the 1950s assuming that this variable followed the same trend as the aggregate land area sown with the 15 principal crops of Argentine agriculture.[2]

Chile: Faced with the absence in of comparable census values between 1950 and 1961, we have utilised the datum which appears in the FAO production yearbook for 1949. Then we calculated the annual series through a linear interpolation between this datum from 1949 and that from 1961 from FAOSTAT. The correlation coefficient between the data series interpolated between 1949 and 1961 and Mitchell's data for the cultivated area of the principal crops in those years is 0.81.[3]

Uruguay: To obtain an annual data series of arable land in Uruguay between 1951 and 1961 we assumed that it followed the same trend as the number of hectares of tillage, orchards, vineyards and fruit trees which appear in the censuses of 1951 and 1956. With these two data points from 1951 and 1956, we can estimate an annual series from 1951 to 1961 through

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[1] Until 2004 the FAO published its data in yearbooks, variously named *Production Yearbook* (1947–75), *FAO Production Yearbook* (1976–87) and *FAO Yearbook. Production* (1988–2004). Data from 1961 are available on FAOSTAT's webpage (http://www.fao.org/faostat/en/#home); FAOSTAT is the FAO's Corporate Statistical Database).

[2] Orlando J. Ferreres, *Dos siglos de economía argentina (1810–2004): Historia argentina en cifras* (Buenos Aires: Fundación Norte y Sur, 2005).

[3] B. R. Mitchell, *International Historical Statistics: The Americas, 1750–2000* (Basingstoke: Macmillan, 2003). The figure represents a strong correlation and shows that the estimated series is a good approximation to the real one.

linear interpolations (1951–6 and 1956–61). For the 1950 calculation, we assumed that this variable grew in that year at the same annual rate as between 1951 and 1955.

Livestock

Argentina: In the FAO yearbooks there are no data for ducks, geese, rabbits or turkeys for the 1950s. To calculate an annual series for this decade we assumed the same trend as that between 1961 and 1971.

Brazil: In the FAO yearbooks there are no data for ducks, geese or buffalo for the 1950s. To calculate an annual series for this decade we assumed the same trend as that between 1961 and 1971.

Chile: In the FAO yearbooks there are no data for asses or mules for the 1950s. To calculate an annual series for this decade we assumed the same trend as that between 1961 and 1971.

Mexico: In the FAO yearbooks there are no data for ducks or geese for the 1950s. To calculate an annual series for this decade we assumed the same trend as that between 1961 and 1971.

Panama: There are no data in the FAO yearbooks for ducks or turkeys for 1950 or for previous years. To calculate the values for these poultry animals for that year we assumed that they followed the same trend as chickens. Neither for goats are there data for the year 1950. For this calculation, we assumed that during this year they increased at the same rate as between 1951 and 1955.

Uruguay: In the absence of data for ducks, geese and turkeys for the year 1950 in FAO yearbooks, we assumed that during this year the number of these poultry animals followed the same trend as chickens.

Venezuela: In the absence of data for all animals for the year 1950 in FAO yearbooks, we assumed that during this year the aggregate data for livestock followed the same trend as between 1951 and 1955.

Mechanisation

For the countries for which from 2002 onwards FAOSTAT did not offer data regarding tractors (Argentina, Colombia, Honduras, Panama, Peru and Venezuela; we use tractors as a proxy for mechanisation), we assumed that they followed the same trend between 2002 and 2006 as the aggregate of Brazil, Chile, Mexico and Uruguay, i.e. that from 2006 until 2008 tractor use remained constant.

Fertilisers

The data for fertilisers were taken from the IFA database (available in this form since 1961),[4] while for Honduras and Panama the data come from FAOSTAT. For the 1950s (i.e. before the IFA data became available) we assumed that the trend in fertiliser use was the same as that given by the FAO production yearbook data. In the case of Peru, the FAO data for the 1950s on the consumption of fertilisers are not reliable: they are too high because they show both organic and inorganic fertilisers increasing, when in reality organic fertilisers were being

[4] IFA data are available from https://www.ifastat.org/databases.

substituted by inorganic. In order to resolve this situation, fertiliser consumption for the 1950s was adjusted using Raúl Hopkins's estimates.[5]

A.3 Calculation of Total Factor Productivity

The data employed for the calculation of the TFP come from FAO databases, from both the electronic version (FAOSTAT) and the yearbooks. The production data correspond to gross production valued in constant 2004–6 US dollars. The land data are an aggregate of the hectares of arable land and permanent crops and irrigated hectares. Agricultural labour is measured as the active population in agriculture.[6] Machinery is measured as number of tractors. Chemical fertilisers are the sum of the consumption of nitrogenous, potassium-based and phosphoric fertilisers. Livestock units have been calculated by aggregating the number of live animals with Hayami and Ruttan weightings.[7]

For the calculation of the TFP, it was necessary to weight the above variables. For our calculation we took into account three types of weightings, from studies of Mexico, Brazil and Argentina.[8] We applied the Argentina weightings to Argentina, Chile and Uruguay; the Mexico weightings to Mexico, Colombia, Honduras and Peru; and the Brazil weightings to the remaining countries. These groupings follow the typologies of the Latin American economies provided by Luis Bértola and José Antonio Ocampo.[9] These authors offer several possibilities for the economy of Latin America as a whole and for our timeframe. In our opinion, for our case it was appropriate to select principally on the basis of agriculture. Therefore, we classified the countries into three groups:

> Mixed temperate–tropical-climate agricultures, with traditional subsistence farming and a predominantly Indo-American workforce: Mexico, Colombia, Honduras, Peru (Table A.3.1)
>
> Tropical agricultures with a largely Afro-American workforce: Brazil, Venezuela and Panama (Table A.3.2)
>
> Temperate-climate agricultures: Argentina, Chile, Uruguay (Table A.3.3).

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[5] Raúl Hopkins, *Desarrollo desigual y crisis en la agricultura peruana 1944–1969* (Lima: IEP, 1981), pp. 104–8.

[6] The correct measurement of labour would be hours worked. Because of the chronological and spatial amplitude of the sample, a proxy such as active agricultural population is necessary.

[7] Yujiro Hayami and Vernon W. Ruttan, *Agricultural Development: An International Perspective* (Baltimore, MD, and London: Johns Hopkins University Press, 1985).

[8] Fuglie, 'Productivity Growth'; Carlos Díaz Alejandro, *Essays on the Economic History of the Argentine Republic* (New Haven, CT: Yale University Press, 1970); Víctor J. Elías, *Sources of Growth. A Study of Seven Latin American Economies* (San Francisco, CA: International Center of Economic Growth, 1992).

[9] Luis Bértola and José Antonio Ocampo, *The Economic Development of Latin America since Independence* (Oxford: Oxford University Press, 2012), pp. 9–13.

Table A.3.1. *Weightings Corresponding to Mexico*

	Labour	Land	Cattle	Fixed capital	Chemicals
1950	0.256	0.489	0.118	0.089	0.048
1973	0.242	0.373	0.200	0.147	0.038
1990	0.117	0.202	0.362	0.289	0.031
2008	0.115	0.225	0.353	0.263	0.045

Source: Authors' elaboration using data from Fuglie, 'Productivity Growth'.

Table A.3.2. *Weightings Corresponding to Brazil*

	Labour	Land	Cattle	Fixed capital	Chemicals
1950	0.434	0.342	0.126	0.071	0.027
1973	0.434	0.342	0.126	0.071	0.027
1990	0.429	0.137	0.1745	0.144	0.116
2008	0.373	0.083	0.129	0.161	0.255

Source: Authors' elaboration using data from Fuglie, 'Productivity Growth'.

Table A.3.3 *Weightings Corresponding to Argentina*

	Labour	Land	Cattle	Fixed capital	Chemicals
1950	0.333	0.333	0.188	0.106	0.040
1973	0.340	0.261	0.160	0.122	0.117
1990	0.345	0.207	0.140	0.135	0.174
2008	0.350	0.150	0.118	0.148	0.234

Source: Díaz Alejandro, *Essays on the Economic History of the Argentine Republic*; Elías, *Sources of Growth.*

In order to confirm the robustness of the criteria adopted and to determine how sensitive the calculations are to a change in the weightings, we ran simulations using alternative values. When we calculate the correlation between the results obtained for each corresponding group of weightings (Argentina, Mexico and Brazil respectively), we find high coefficients: 0.94 (between the values obtained with the weightings of Argentina and Mexico), 0.96 (Argentina and Brazil) and 0.86 (Mexico and Brazil). We believe that these correlation coefficients, which are high and close to the values obtained, constitute solid proof of robustness, although it should be taken into account that different weightings do not generate exactly the same results.

A.4 Calculation of Agricultural Trade Openness

We obtained data for agricultural and food exports and imports from FAOSTAT (at current prices). For the calculation of an annual series of agricultural gross production between 1950 and 2008 (at current prices) we used our estimated agricultural production at constant 2004–6 prices. We transformed this series into current prices using Raúl Serrano and Vicente

Pinilla's agricultural and food trade deflator for the years 1961 to 2000.[10] Between 2000 and 2006 we have used as a deflator the price index for agricultural food commodities provided by Stephan Pfaffenzeller *et al*.[11] These calculations have been made for all the Latin American countries included in our sample.

[10] Raúl Serrano and Vicente Pinilla, 'Terms of Trade for Agricultural and Food Products, 1951–2000', *Revista de Historia Económica/Journal of Iberian and Latin American Economic History*, 29: 2 (2011), pp. 213–43.

[11] Stephan Pfaffenzeller, Paul Newbold and Anthony Rayner, 'A Short Note on Updating the Grilli and Yang Commodity Price Index', *The World Bank Economic Review*, 21: 1 (2007), pp. 151–63.