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Analysis of Agricultural Productivity in Paraguay: A Micro Econometric Approach

by Daniel Lema and Nicolás Gatti

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Abstract

This paper investigates the micro determinants of agricultural productivity at a farm level in Paraguay, using the Permanent Household Survey (EPHC) from 2017 to 2019. We estimate an agricultural production function where the main determinants of output are land, machinery, labor, and purchased variable inputs using Cobb-Douglas and a Translog production frontier. Econometric results show that the most productive areas such as Paraguari, Guaira, Caaguazu, and Caazapa from Southeastern Paraguay are the most efficient. These areas have more infrastructure and have traditionally been the main agricultural areas. We also see that Western Paraguay, predominantly devoted to livestock, is less efficient. More efficient farmers have observed a slowdown in the growth rate of Technical Efficiency (TE) relative to districts such as Ñembucu, Itapúa, or Alto Paraná. While the latter areas had lower TE, Total Factor Productivity (TFP) growth is higher than in the main production areas. The difference between regions is probably due to places that lagged previously and received most of the investments in the last years. From a policy perspective, Paraguay can obtain productivity improvements from the intensification of agriculture rather than incorporating new lands. Considering regional specialization in agriculture and livestock, public and private investment should boost farmers' comparative advantage by region.

I. Introduction

The Paraguayan agricultural sector is one of the most prominent from the South Cone. Due to consistent macroeconomic policies, Paraguay expanded its economy boosted by agricultural trade (Blanco, 2021). Agricultural production from the main seasonal crops grew more 5.3% during the 2008-2017 period representing more 11% of the 2017 GDP (Instituto Nacional de Estadística, 2017). However, there is little evidence on how these changes echoed in efficiency and productivity gains in the different areas in Paraguay at the farm level.

This paper aims to investigate the drivers and the evolution of efficiency and productivity in Paraguay. We measure the micro determinants of agricultural productivity at a farm level using the Permanent Household Survey (EPHC) from Paraguay from 2017 to 2019. The data have a detailed description of the economic activity of the labor force, such as the use of time, income, and household characteristics (age, gender, education, among others). The survey has a specific module related to agriculture that contains information about agricultural production, use of inputs, expenditures, and sales. We estimate an agricultural production function where the main determinants of output are land, machinery, labor, and purchased variable inputs using Cobb-Douglas and a Translog production frontier.

Our results show that areas from Southeastern Paraguay are the most efficient and productive. These areas have been traditionally devoted to agriculture and where infrastructure is well developed. In contrast, in Western Paraguay, where livestock is predominant and has less economic development, where we find that farmers are less efficient. By estimating the Technical Change (TC) and the Technical Efficiency (TE) components of Total Factor Productivity (TFP), we find different patterns of growth across districts. Farmers from districts such as Paraguari, Guaira, Caaguazu, and Caazapa have observed a slowdown in the growth rate of technical efficiency relative to districts such as Ñembucu, Itapúa, or Alto Paraná. While the latter areas had lower TE, TFP growth is higher than in the main production areas.

In a recent paper, Nin Pratt (2018) study the effects of agricultural growth and the role of family agriculture and smallholders. Estimates using FAO data show that the TFP average annual growth rate from 1989 to 2012 was 1.25%. However, after a period of policy changes between 1989 and 2002 TFP growth rate increased to a yearly rate of 2.23%. The growth and the improved performance of agriculture after the year 2000 in Paraguay result from rapid growth in commercial farming of soybeans, maize, wheat, rice, and cattle. These changes resulted in rapid growth in TFP, output per hectare, and output per worker.

Additionally, small agricultural producers' economic and technical efficiency was estimated using farm-level data from the Encuesta Permanente de Hogares de Paraguay for the years 1997 and 2008. The empirical evidence presented suggests that the situation of family agriculture in Paraguay is diverse and complex. In the San Pedro and Caaguazu departments (North and East of Asunción), the evidence until 2008 shows that the average area of efficient farmers increased, expanding production of mixed systems that include fruits and vegetables, cash crops, and livestock. Alto Parana (East Border) situation is different because this region was part of the agricultural frontier during the “move to the east” to incorporate new lands to production and experienced producers from Brazil. The efficient and average groups are specialized in soybean production (60 and 90 percent of output value, respectively). In contrast, inefficient producers are not producing oil crops, but more than half of the output value in these groups comes from roots and tubers (55 percent).

In earlier work, Bravo Ureta and Evenson (1994) use stochastic efficiency decomposition methodology is used to efficiency measures for small cotton and cassava farmers. They found an average economic efficiency of 40.1% for cotton and 52 % for cassava, suggesting considerable room for productivity gains. Authors suggest that improvements in educational and extension services would be needed to go beyond this threshold. Additional productivity gains could come from further investments in human capital and related factors. Masterson (2007) study assesses the relationship between farm size and productivity using parametric and nonparametric methods to derive efficiency measures. Smaller farms have higher net farm income per hectare and to be more technically efficient than larger farms. This result holds even taking into account the various other factors in the literature on the inverse relationship between farm size and productivity, such as land quality, Green Revolution technology, and supervision costs.

Our paper has three main contributions. First, we provide an updated analysis of efficiency and productivity in Paraguay to revisit and expand the research made by Nin-Pratt (2018). Second, from a policy perspective, we provide evidence that there is no one-size-fits-all solution for increasing productivity in Paraguay. Infrastructure investment would improve efficiency in livestock-predominant areas, while R&D should consider the potential comparative advantage of these farmers in livestock and grain production. Third, our findings suggest that technical efficiency in Paraguay is still low compared to similar studies in other south cone countries. Hence, it is possible to increase efficiency by improving knowledge about the existing production technology. Technical assistance while incorporating new technologies may be vital for increasing productivity.

II. Methods

To measure agricultural productivity in Paraguay, we estimate an agricultural production function where the main determinants of agricultural output, which includes crop and livestock production, are land, machinery, labor, and purchased variable inputs. Cobb-Douglas and a Translog production function are the selected functional forms (Coelli et al., 2005). For simplicity, we present here the Cobb-Douglas specification:

$$y_{it} = \alpha + \sum_{k=1}^{n} \beta_k X_{kit} + \sum_{m=1}^{n} \pi_m \mathrm{M}_m + u_{it} \quad (1)$$

$$u_{it} = \sum_{l=1}^{L} \beta_l Z_{ilt} + \varepsilon_{it} \quad (2)$$

The dependent variable (Y_{it}) is the log of the total value of production in Guarani (local currency) per hectare from household i in year t; X is a vector of inputs in logarithms and includes: agricultural area in hectares, the units of machinery used in agricultural production,[1] labor in days per year and the amount spent in variable inputs. The latter includes agrochemicals, fertilizer, seeds for crop production and corn feed, veterinary products, and animal supplements expenditure in livestock production. The value of production and the expenditure in variable inputs were deflated using the producers' price index of Paraguay (2017=100).

Since we have three years of data, we can use the production function to capture changes in TFP, Technological Change (TC), and TE following a Stochastic Production Frontier (SPF) framework with the application of Battese and Coelli (1995) model. We explain the inefficiency term using Z_i, a vector of household variables that affect the production decision-making of rural households in line with the "non-separable" agricultural household model; a dummy variable that takes the value of one when the household has internet, transportation (car or motorbike), cable TV, and if

[1] Machinery is the summation of tractors, harvesters, seeders, and other machinery used in agricultural production.

the household is located in a rural area or not. The model is also augmented by M_m which is a vector of district fixed effects (geographic fixed effects).

III. Data

The dataset we use is the Permanent Household Survey (EPHC) from Paraguay. The objective of the survey is to follow the main characteristics of the Paraguayan labor market. The data have a detailed description of the economic activity of the labor force, such as the use of time, income, and household characteristics (age, gender, education, among others). The survey has a specific module related to agriculture that contains information about agricultural production, use of agricultural inputs, expenditures, and sales.

The survey is implemented quarterly and is representative of the 2015 Paraguayan population. We have access to the surveys from 2017 to 2019, which yields an unbalanced panel dataset where we can follow the same household for two years (Table 1). We include a dummy variable that considers one if the household is repeated twice in the dataset.

Table 1. Structure of the panel

		Year		
Times surveyed	2017	2018	2019	Total
1	4,932	1,241	1,201	7,374
2	0	1,265	1,213	2,478
Total	4,932	2,506	2,414	9,852

Table 2 presents summary statistics of the value of production, inputs, and the augmented variables that we use in our production function estimation. The average value of production is 19 thousand dollars per household per year. These households have on average 212 hectares under production and apply 26 hours of labor per week. They purchase inputs for 224 dollars per household year. Lastly, 74 percent of the households own private means of transportation, only 7 percent have internet, and 74 percent are located in rural areas.

Table 2. Summary Statistics

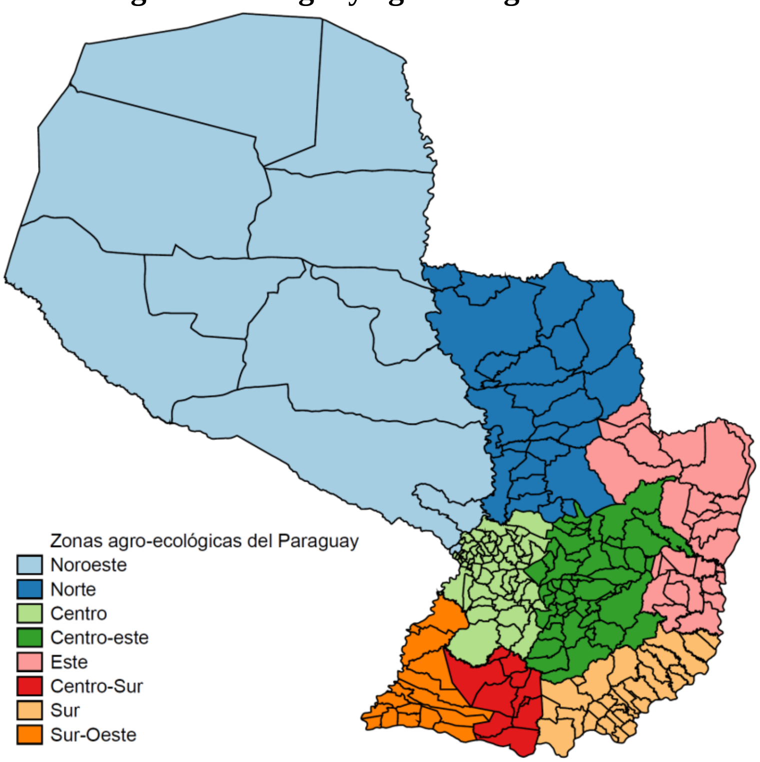
Variable	Mean	Std. Dev.	Min	Max
Value of production (2017 U$S)	19,334.51	444,795.49	0	17,839,575.99
Land (Ha)	212.83	155.76	0.10	1,218.00

Machinery (#)	1.32	2.72	0	42
Labor (#)	26.42	89.08	0	365
Purchased inputs (2017 U$S)	224.76	8,794.84	-	401,905.44
Cable TV (=1 if available)	0.36	0.48	0	1
Internet (=1 if available)	0.08	0.27	0	1
Transportation (=1 if available)	0.74	0.44	0	1
Rural (=1 if HH is in rural area)	0.74	0.43	0	1
Observations	9,852			

Source: Permanent Household Survey (EPHC) from Paraguay. Value of production and purchased inputs are deflated by the producer price index of Paraguay (2017=100).

The dataset contains information about agricultural households' representatives of 16 districts of Paraguay that are part of 7 agroecological zones (Figure 1). Most of the households are concentrated in the Eastern areas of Paraguay, where crop production is more important. There are no households from the Northwestern area, which is less developed and focus on livestock production.

Figure 1. Paraguay agroecological zones.



IV. Results

We estimate the stochastic production functions using Paraguayan households from the EPHC. The outcome variable is the total value of production, and the inputs include land area, agricultural machinery, labor, purchased inputs. In Table 3, we have four specifications. Column 1 is the Cobb-Douglas function without any controls, while in column 2, we add district fixed effects. Column 3 includes the district fixed effects and a dummy to control for the panel structure since it is an unbalanced panel. In column 4, we add the Translog specification. In column 5, we expand our Translog frontier using households' education, availability of irrigation, transportation, internet, and whether the household is located in a rural area as determinants of farmers' inefficiency.

Table 3. Stochastic production frontiers

	Ln(value of production)				
	Cobb Douglas (CD)	CD+fixed effects	CD+fixed effects+ panel	Translog (TL)	TL+ inefficiency
	(1)	(2)	(3)	(4)	(5)
Land	0.571***	0.518***	0.514***	0.812***	0.727***
	(0.0215)	(0.0220)	(0.0222)	(0.0687)	(0.0686)
Machinery	0.958***	0.944***	0.944***	0.334**	0.352**
	(0.0378)	(0.0376)	(0.0376)	(0.155)	(0.154)
Labor	0.0879***	0.0895***	0.0902***	-0.292***	-0.255***
	(0.0138)	(0.0137)	(0.0137)	(0.0735)	(0.0729)
Inputs	0.0665***	0.0663***	0.0672***	0.0596*	0.0522
	(0.0104)	(0.0104)	(0.0104)	(0.0339)	(0.0337)
Land^2				0.177***	0.164***
				(0.0124)	(0.0124)
Land*Machinery				0.00846	0.000380
				(0.0775)	(0.0768)
Land*Labor				0.00120	0.0118
				(0.0338)	(0.0335)
Land*Inputs				0.0258**	0.0329***
				(0.0108)	(0.0107)
Machinery^2				0.623***	0.614***
				(0.0506)	(0.0503)
Machinery*Labor				-0.0572	-0.0500
				(0.0354)	(0.0351)
Machinery*Inputs				-0.0811***	-0.0807***
				(0.0225)	(0.0223)
Labor^2				0.0319***	0.0360***
				(0.00742)	(0.00737)
Labor*Inputs				0.00550	0.00565
				(0.0107)	(0.0106)
Inputs^2				0.0107***	0.00975***

				(0.00315)	(0.00312)
t*land				0.0543	0.0384
				(0.0544)	(0.0539)
t*Machinery				-0.0210	-0.00483
				(0.110)	(0.109)
t*Labor				0.232***	0.221***
				(0.0520)	(0.0516)
t*Inputs				0.0399	0.0451*
				(0.0257)	(0.0255)
Constant	-5.201***	-5.044***	-5.175***	-2.483***	-1.793
	(0.419)	(0.218)	(0.237)	(0.260)	(28.54)
t	0.0343	-0.0143	0.146	0.134	0.0109
	(0.0528)	(0.0525)	(0.111)	(0.115)	(0.115)
Cable TV					-0.0625***
					(0.00912)
Internet					0.0735
					(0.0830)
Rural area					-0.570***
					(0.0557)
Transportation					-0.0898*
					(0.0488)
Inverse logit of gamma (γ)	-9.464	-9.432	-9.332	-9.162	-7.701
	(227.1)	(60.01)	(64.29)	(71.46)	(259.7)
Log of Stochastic variance (σ_v^2)	1.453***	1.432***	1.432***	1.447***	1.428***
	(0.0225)	(0.0150)	(0.0153)	(0.0160)	(0.0142)
Panel dummy	No	No	Yes	Yes	Yes
District FE	No	Yes	Yes	Yes	Yes
Inefficiency equation	No	No	No	No	Yes
Observations			9,852		

Note: The main inputs in the Translog specifications in columns 4 and 5 are expressed in deviations with respect to their geometric mean to make coefficients comparable to the Cobb-Douglas production function. Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1

From the CD versus TL comparison, we see that coefficients vary between specifications. Overall, agricultural area and machinery are the most critical factors that positively affect agricultural output. There are some significant differences in the machinery and area factor shares across models that could be explained by including the non-linear effects in the TL function. In terms of the shifting factors, in column 5, having cable TV, transportation, and living in rural areas reduce inefficiency. In contrast, having internet does not affect inefficiency, which might be due to the low percentage (7%) of households with some type of connectivity.

Given the differences between specifications, we adopt the Translog specification with expansion variables to account for nonlinearities. We use this model to obtain Technical Efficiency (TE), Technical Change (TC), and Total Factor Productivity (TFP) from Paraguayan farmers. In Table 4, we show the results by district ordered from highest to lowest TFP. Amambay is the district with the highest TFP and TE growth rate on average. Paraguarí and Central are the districts with the lowest TFP having a -2.47% and -4.56%, respectively. Overall, in Paraguay, most of the increases in TFP are coming from TE rather than TC.

Table 4. Average TE, TC, and TFP growth rates by the district during the period 2017-2019

District	TE	TC	TFP
Amambay	8.72%	0.22%	8.94%
Asunción	1.79%	5.23%	7.02%
Ñeembucú	1.57%	5.11%	6.68%
Itapúa	1.18%	3.60%	4.78%
Alto Paraná	3.15%	1.28%	4.43%
San Pedro	0.81%	3.54%	4.34%
Caaguazú	0.85%	3.41%	4.27%
Misiones	4.39%	-1.18%	3.20%
Caazapá	2.04%	1.13%	3.16%
Concepción	4.08%	-1.14%	2.94%
Guairá	2.93%	-0.29%	2.64%
Canindeyú	2.25%	-0.23%	2.02%
Presidente Hayes	1.46%	0.43%	1.89%
Cordillera	-1.20%	-1.20%	-2.40%
Paraguarí	-1.04%	-1.43%	-2.47%
Central	-0.14%	-4.42%	-4.56%
Total	**1.72%**	**1.09%**	**2.81%**

Figure 2. Technical Efficiency by district

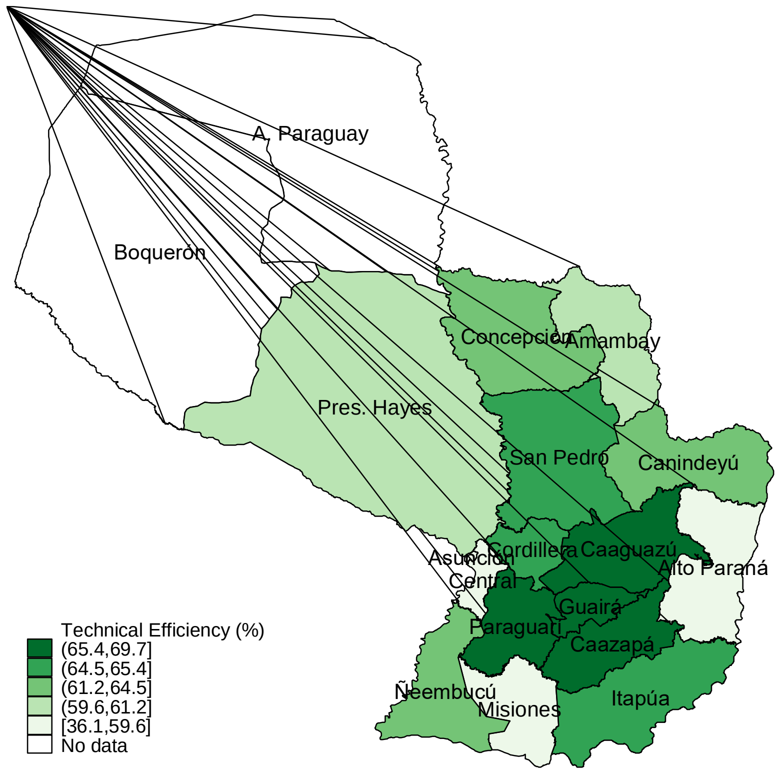
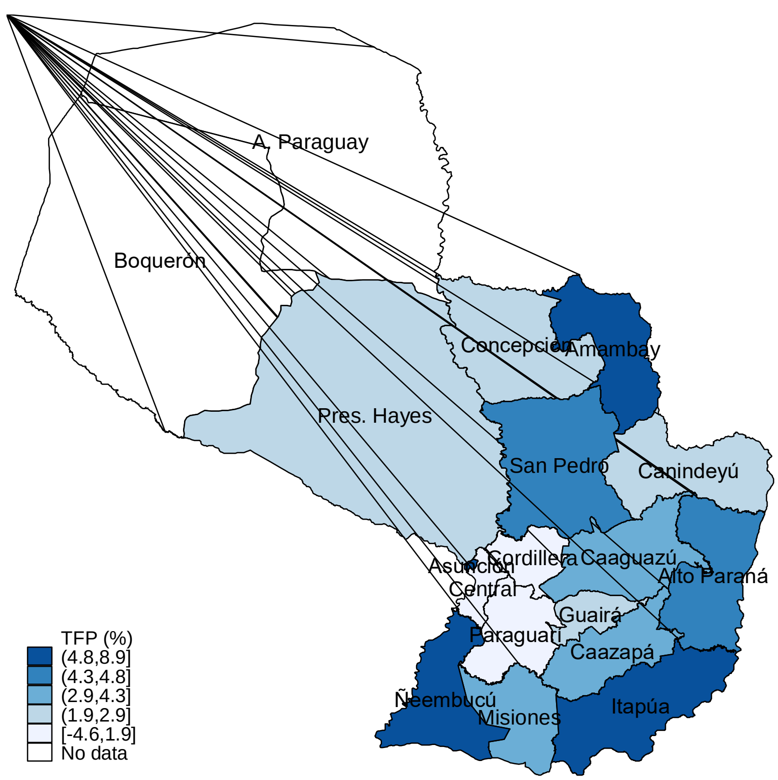


Figure 3. TFP growth rates by district



V. Discussion

Results show that the most productive areas, such as Paraguari, Guaira, Caaguazu, and Caazapa from Southeastern Paraguay, are the most efficient. These areas have more infrastructure and have traditionally been the main agricultural areas. We also see that Western Paraguay, predominantly devoted to livestock, is less efficient. We estimate the TE growth rate and TC rates to study TFP in Paraguay during the 2017-2019 period. More efficient farmers have observed a slowdown in the growth rate of technical efficiency relative to districts such as Ñembucu, Itapúa, or Alto Paraná. While the latter areas had lower TE, TFP growth is higher than in the main production areas, probably because they are lagged and received most investments (public and private) in the last years. From a policy perspective, technical efficiency is still low compared to similar studies in other south cone countries. Therefore, it is possible to increase TE by improving knowledge about the existing production technology. Technical assistance while incorporating new technologies may be vital for increasing productivity.

Another critical issue is that West Paraguay is far less developed. Infrastructure investment would improve efficiency in these areas. Given the predominance of livestock in these areas, there is no one-size-fits-all solution for increasing productivity in that area. Public investments should concentrate on infrastructure, as rural roads and efficient water provision, and R&D, considering the potential comparative advantage of these farmers in livestock and grain production.

VI. Concluding Remarks

This study looked at an updated micro econometric analysis of productivity and efficiency change in Paraguay from 2017 to 2019 using data from rural household surveys. To measure the micro determinants of agricultural productivity at a farm level, we use the Permanent Household Survey (EPHC) from Paraguay from 2017 to 2019. We estimate an agricultural production function where the main determinants of output are land, machinery, labor, and purchased variable inputs using Cobb-Douglas and a Translog production frontier. Results show that the most productive areas, such as Paraguari, Guaira, Caaguazu, and Caazapa from Southeastern Paraguay, are the most efficient. These areas have more infrastructure and have traditionally been the main agricultural areas. We also see that Western Paraguay, predominantly devoted to livestock, is less efficient probably due to the lack of infrastructure and other public goods as agricultural extension services.

We also estimate the TE growth rate and TC rates to study TFP in Paraguay during these three years. More efficient farmers have observed a slowdown in the growth rate of technical efficiency relative to districts such as Ñembucu, Itapúa, or Alto Paraná. We observe different patterns in TE, TFP growth by region. The East of Paraguay has been historically more productive, while the West is less developed and concentrated in cattle production.

From a policy perspective, Paraguay has a solid potential to increase agricultural efficiency and productivity. Technical efficiency in Paraguay is still low compared to similar studies in other south cone countries. Therefore, there is space for increasing TE by improving knowledge about the existing production technology. Technical assistance and agricultural extension while incorporating new technologies can increasing productivity in less developed areas. Further, investments in infrastructure such as roads and telecommunication could improve productivity in both areas, but more importantly in Western Paraguay. Areas specialized in agriculture could benefit from the intensification of agriculture rather than incorporating new lands. Given the specialization in agriculture and livestock in different areas, public and private investment in agricultural research and development should consider regional differences that are linked to their own comparative advatanges.

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