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Measurement of technical efficiency of wine grape producers in Mendoza Argentina

S. Riera;

Georg-August-Universitaet Goettingen, Agricultural Economics, Germany

Corresponding author email: sriera@uni-goettingen.de

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Water is a key resource to agriculture in Mendoza but there are increasing concerns regarding the viability of current practices and availability. Some farms fall short of their production potential, which questions the economic viability of some vineyards, and might trigger structural change and lead to additional pressure on water use. Improvements in irrigation efficiency could help mitigate this problem. Farmers pay for the resource management but do not have to consider the opportunity cost of the resource itself. This paper estimates the technical efficiency (TE) of grapevine production controling for the use of water. The preliminary results point out average efficiency scores of 0.78, where relatively efficient farmers lack proper management practices on water resources. Further estimation of the intrinsic value of irrigation water will provide an additional tool to design specific policies for the sector.

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1 Introduction and motivation

Water is a key resource to agriculture in Mendoza but there are increasing concerns regarding the viability of current practices and availability. Strong dependency on the unstable economic framework, local markets and inefficient management practices, the grapevine producers are trapped in a declining spiral of water scarcity, production quality and profitability. The water demand for agricultural is nearly 90 per cent of the total resource availability, exceeding the world average by 20 per cent (Morábito et al., 2012; Scheierling et al., 2016). Agricultural activities represent 6 per cent of the provincial economy but drive the performance of other industries and services strongly linked with employment and economic development. For more than 130 years, the province of Mendoza has acknowledged the relevance of proper water management with the creation of the water agency (Direccion General de Irrigacion, DGI). This autonomous organization is in charge of delivering water throughout the 12,000 kilometer irrigation network. It is responsible for designing and executing the water policies but decentralizes operation and management on users associations named *Inspecciones de Cauce*. These associations plan the surface water delivery of their associates, estimate their budget and concentrates producers.

In Argentina, over the last three decades, agriculture has become a key and growing contributor to export earnings and wine has played a relevant and rising role to sustain the regional economies. Vineyard grapes are one of the most relevant crops in western Argentina. With over 240,000 hectares, the province of Mendoza concentrates 70 per cent of the grape production and 65 per cent of the wine elaboration (INV, 2017).

The growing reputation of Argentinean wines led to the settlement of international firms, which improved the industry in terms of technology adoption and market orientation. The increasing Argentinean wine production and exports have pushed this sector to make relevant changes in productive strategies, being especially focused on producing high quality grapes highly sensitive to water stress management.

Despite the major evolution of wine production and exports in Mendoza, the production of grapevine is undergoing significant challenges arising from low prices paid to producers, agronomic risks, and climate contingencies. More dependent on economic framework and local markets, the small wine grape producers may be trapped in a *declining spiral* of water scarcity, production quality and profitability. Although, the public sector creates policies oriented to small-scale producers, most of them aim to solve urgent needs instead of other core issues as quality and technical efficiency.

Any input improvement or changes in management practices may increase profitability of grapevine producers, that sell their production at a yearly-stable price per quality paid by wine makers. Therefore, it is relevant to analyze the production efficiency to estimate general scores controlling for location, water quality and technology adoption among others.

Furthermore, this paper will focus in two issues: (*i*) the role of water in improving farm productivity and (*ii*) the implications that can be derived from the frontier analysis of technical efficiency. Following a stochastic frontier analysis (SFA), this paper seeks to provide a clear perspective on the use of natural resources, labor and other inputs by the grapevine producers in Mendoza.

The following sections of this document present descriptive statistics and the following steps of this research project as follows: Section 2 reviews the documented literature in this subject; Section 3 reviews the data collection process and describes some imputation techniques to be performed; Section 4 propose the methodology and functional form, while Section 5 mentions the expected outcome of this research.

2 Literature review

Frontier function methodologies conform a captivating methodology to assess productivity and efficiency. These methods determine a benchmark frontier and provide measure of efficiency in terms of input reduction or potential output expansion with respect to the frontier. This model was first applied by Farrell (1957), who decompose economic efficiency into technical efficiency (TE) and allocative efficiency (AE). The former measures the firm ability to maximize the output given the input set; the latter measures the capability of the firm to relocate inputs according to their prices.

It is widely known that agriculture is the main recipient of water resources. Additionally, there is a wide consensus that the agricultural sector is the less efficient in terms of input oriented efficiency. Bravo et al. 2016 carried a meta-analysis study on production and water use efficiency. In terms of water efficiency, Latin America has the lower average mean on technical efficiency (AMTE) with 55 percent, where US and Western Europe achieved above 80 percent.

In this line, the preliminary task is to define a functional form of the production function that accomplish the axioms of production and achieve the regularity conditions of monotonicity and curvature (Coelli et al., 2005; Greene, 2008). According to the scarce literature on quality grape efficiency, the Cobb-Douglas function is preferred to the transcendental logarithmic for modeling grapevine production (Bravo-Ureta et al., 2016; Coelli and Sanders, 2012).

We start with Townsend et al. (1998) who analyzed the relationship between farm size, productivity and returns to scale for wine grape producers located in four regions of South Africa for the years 1992 to 1995. Moreira et al. (2011) examined the TE of wine grape production for a sample of Chilean firms for 2005-06 using a standard cross sectional models. A Cobb-Douglas SPF model using data for 38 farms for which input-output information is available at block level. The results reveal an average farm level TE of 77.2 per cent, with block level TE ranging from 23.4 to 95.0 per cent. Ma et al. (2012) use 1020 farm level observations collected across 24 grape producing provinces in China to estimate a Cobb-Douglas SPF model.

Coelli and Sanders (2012) used an unbalanced panel data set (2006-2007) to (2009-2010) for a sample of 135 farmers specializing in wine grape production located in the Murray and Murrumbidgee river basins in Australia. The authors used the translog functional form to fit SPF models using the Battese (1992) approach. The results revealed a mean TE equal to 79 per cent, a mean estimate of scale economies of 1.07, and a 2.7 per cent annual average rate of technological change. The findings also suggested that shadow price estimates for irrigation water exceeded average market prices.

Finally, Manevska-Tasevska (2012) uses a three-year (2006-2008) panel data set for a sample of 300 commercial grape producers from Macedonia along with a Cobb-Douglas SPF model and a second stage regression to analyze TE.

3 Sample data and variable selection

The total area of the research project has 740 sq. km. and holds nearly 15,000 ha of grapevine area, farmed by 510 producers. Bulk production is estimated at 11,000 tons in approximately 2,500 plots. As located on the Andes mountain range, the terrain and water resources vary substantially within this area. From northwest to southeast, elevation decreases from 980 to 770 meters above sea level and the depth of groundwater raises from -120 to -20 meters below the surface (Hernández et al., 2012).

Considering the heterogeneity of the region, the sampling procedure required careful stratification and randomization in order to ensure representativeness of the sample. The coordination with the General Direction of Irrigation (DGI) and the Statistics Bureau of the province (DEIE) allowed a detailed planning. Initial field visits were performed as a guest of DGI to measure the static groundwater levels in the region, and compared with historical values. Upon signature of agreements, preliminary data bases were provided by different government organizations. Furthermore, DEIE advised on the way how socio-economic characteristics of producers should be obtained, and supported the logistic planning to collect the data and corresponding retribution to enumerators according to their standards.

The data collection obtained 115 surveys that represent 420 grapevine plots. Survey questions gather straightforward information on management practices, external assistance, quality of water, and market orientation at plot level. On average, grapevine producers have at least 2.3 plots. Nearly 30 per cent have 15 plots per farm. The sample should gathered information on 1200 grapevine plots. In terms of data quality, the gathered information seeks to capture the unobserved heterogeneity in production functions for grapevine producers.

Data collection included 140 groundwater quality samples. Unfortunately, some producers did not have groundwater wells or did not agreed to receive a water quality test. This groundwater quality analysis will contribute to improve the description of management practices considering the environmental quality of natural resources.

At the same time, many producers manage more than one vineyard and may share movable capital between them; which could imply lower management costs. The selected methodology considers hierarchical models. That is, clustering plots and vineyards per producer into a multi-level efficiency analysis. There is considerable heterogeneity in terms of grape type (red or white), quality (premium or varietal), and irrigation practices. Nearly halve of the sample use modern irrigation and the rest have irrigation by gravity; however, alternative mechanisms and scheduling strategies are observed for both systems that can drive water efficiency practices.

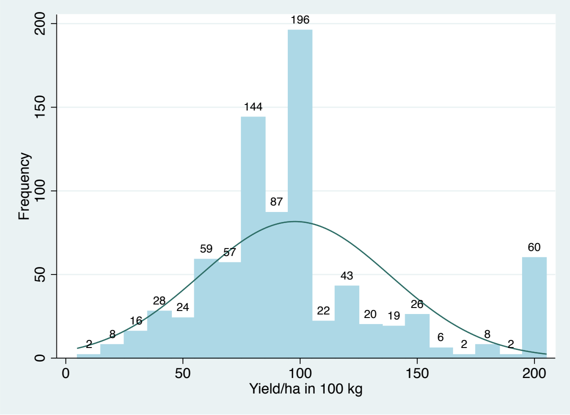
In order to improve the analysis in different research areas information on energy consumption, quality grape output, and soil composition shall be included in the database. These selected secondary data could improve the overall assessment of the producers' production process from the economic and environmental perspectives. To perform a spatial merge of the information, the use of analytical softwares for space-based navigation system softwares is necessary.

3.1 Data validation and interpretation

The organization of the collected data followed a hierarchical logic. Starting at the farm-level, where general endowments were consulted to later disaggregate production decisions at the plot level. This information was collected in the surveys and later validated through literature review, expert consultation, and institutional databases.

The figure on the right, represents the yield per grapevine plot and their frequency in the sample. At this point, we can mention that there is a bimodal distribution; while some producers aim at higher yields on the right side, others may prefer more quality vines conserving the yields at a lower standard rate.

Figure 1: Plot yield



At the plot level, productive information was collected on a detailed framework to assess the use of agrochemicals, water, labor, and the quality of the product. In many cases the collected information was available in monetary terms but not declared in units terms of the input. To overcome this issues, some tailored solutions were designed for each sector. For instance, farm labor wages (permanent or temporary) are regulated by labor syndicates.

With respect to agrochemicals use, the type management practice was always responded by producers and we counted with average input price per type of agrochemicals. Lastly, the delivered surface water was certainly measured by the water management authority that annually sets the water volume per hectare for an even service delivery. From August 2016 until March 2017, this volume was 10.426 m3/ha slightly higher than previous year.

3.2 Preliminary analysis and imputation techniques

Each farm is considered as a production unit that has access to different services in terms of capital, intermediate inputs, and human resources at the management level. For capital variable we considered the possession of tractors, storage facilities, water reservoirs, groundwater wells, irrigation systems, and hail protection.

Assess the capital endowment for agricultural producers in developing countries can be a real hustle. The real economic value of the endowments can differ substantially from the market value and historical information on investments is very scarce. *e.g.* The tractor produced in the 1940s has null market value but if a farmer still uses it, it definitely worths something to him.

To acknowledging this issue, we considered the perpetual inventory method, to assess the real economic value of farm endowments in agricultural economics. Considering the capital stock at the end of each period, K_t, as the sum of all previous investments weighted by the relative efficiency that decreases over time given by the hyperbolic function of d_τ:

$$K_t = \sum_{\tau=0}^{\infty} d_\tau I_{t-\tau} \tag{1}$$

$$d_\tau = \frac{L-\tau}{L-\beta_\tau} \tag{2}$$

where L is the life expectancy of the capital good, β represents the curvature of the decay parameter, and d_τ is the decay in efficiency at the age τ. The value of the capital stocks in the sample can be seen in the table below.

On average, the annual value of the capital stock is 121,246 US dollars. However, for those farmers that do not use drip irrigation as much as the previous group, the mean value of capital is 89,004 US dollars.

Generally, intermediate inputs consist of all supplies brought from other economy sectors. In this project, the term makes reference to materials, energy and purchased services. As a significant expenditure, energy consumption is relevant for those farmers that rely on groundwater for irrigation. On average, a farm can consume above 46,000 kWh annually, this item is of my particular interest since the energy tariff remains subsidized.

More in detail, the use of agrochemicals is a common practice in grapevine production. At the farm level, the mean values of table 1 in the appendix estate that 168,371 Argentinean pesos (11,224 US dollars) are spent annually on agrochemicals. The application of herbicides and fertilizers is strongly linked with the technological level of the farmer and seams to be correlated with the water source, irrigation system, and management system of the grapevine crop. More detailed composition of the input expenditure can be found on the Appendix.

Grapevine production is a labor intensive crop due to the special attention that is mainly executed by persons. Required management practices, irrigation techniques, and a diversity of hand-crafts actions are performed every year on the crop. In the survey, we aimed to capture the units, quality and expenditure of labor in this regard. According to the information on table 1, on average, each farm demands 930 labor days of permanent staff and 288 labor days of seasonal staff. From the seven main handcraft tasks, harvest, pruning and spring thinning seam to demand outsourced labor. Although, there is a high variability among farms; the mechanical harvesting expenditure is on average 4,684 US dollar per farm representing a growing trend of adapting vineyards to replace outsourced labor.

4 Preliminary empirical results

In this part of the document, some selected statistics will be discussed accompanying with the interpretation of the results. More detailed tables are available in the appendix.

4.1 Proposed model

According to the literature review the functional form of a *Cobb-Douglas* is the more preferred in the sector. Traditional specification include capital stock (K), land (L), labor (Lab), and intermediate inputs (I) as described above.

However, this specification may change due to the willingness to consider water (W) as a separate input for production. But the solely inclusion of water would not be correct without considering the soil characteristics and composition. Therefore, we consider soil characteristics into the analysis. This information is available using geospatial information obtained from the National Institute of Agricultural Technology from Argentina (INTA). This tool will account for soil heterogeneity and properly measure water (mis)management. We estimate grapevine production as a function of the following inputs:

$$Grapevine_i = f(K_i, L_i, Lab_i, F_i, P_i, W_i), i = 1, 2, ...N \tag{3}$$

where the intermediate inputs (I) is decomposed into fertilizer (F) and pesticides expenses (P). Then, the initial empirical model to estimate the technical efficiency (TE) scores for the grapevine producers in the region is:

$$lnGrapevine_i = \alpha_i + \beta_1 lnK_i + \beta_2 lnL_i + \beta_3 lnLab_i + \beta_4 lnF_i + \beta_5 lnP_i + \beta_6 lnW_i + \nu_i - \mu_i[\delta_j; z_i] \tag{4}$$

where the term ν_i - μ_i is a composed error term where ν_i represents statistical noise and μ_i represents technical inefficiency. To improve the analysis of technical efficiency, the modeling will be executed done with hierarchical models.

Initial approximation to the functional was carried out following a Cobb-Douglas production function, where the capital term

Further assumptions need to be made if there are producer-specific factors that influence technical efficiency. Differencing from classical linear regression model, where it is typically assumed that the error term is *homoskedastic*, in our analysis we aim to acknowledge *heteroskedasticity* in the composed error term.

4.2 Preliminary results

Considering the assumption that each plot takes individual decisions in terms of agronomic management and resource allocation. Therefore, we compared the functional forms of a Cobb-Douglas and the transcendental logarithmic function (translog) through R software using the frontier package.

The results of the likelihood-ratio test indicate that the efficiency estimates based on the translog stochastic production frontier is the preferable functional form for the analysis.

5 Expected outcome

After interpretation of collected data and interviews with experts, it is expected lower efficiency scores at some locations. At the southern end of the research area, within the districts of Ugarteche, El Carrizal and Anchoris, producers can only irrigate with deeper groundwater from the second aquifer due to salinization of the resource. DGI applied a zoning restriction for new drilling and later increased the annual fee for existing wells. By all means this translate into higher production costs and lower profitability which, limited investments, technology adoption and new practices. These characteristics were reviewed during data collection and might determine lower efficiency scores

As a major outcome, this research project aims to provide reliable water efficiency estimations for designing policy instruments that address economic and environmental challenges focusing on the responsible use of natural resources. Furthermore, the directional distance functions approach is applicable as policy valuation tool for decision makers and as a cost internalization strategy for stakeholders. At the same time that facilitate the decision-making process for public policy on environmental adaptation and mitigation in affected area.

Some evidence shows that agricultural extension services were not effective as planned (Cerdán-Infantes, 2008), maybe due to inaccurate planning and baseline information. Currently, agricultural policies are very much in focus for their environmental effects. Therefore, a solely standing analysis of technical efficiency will enhance understanding of farmers limitations at the individual level. Moreover, an environmental analysis will assess the management of resources from a greater perspective that includes the environmental trade-offs into the equation.

Incorporating the irrigation efficiency practices into the production function represent a step forward to conducting technical efficiency analysis for grapevine production. Irrigation practices can be aggregated controlling for soil and agronomic characteristics of the vineyard. With the one-step approach of using a multi-output, multi-input stochastic input-oriented distance function based on the field survey data, we will estimate the TE of grapevine production on the northern basin of Mendoza, Argentina. The inclusion of TE analysis could improve policy making to tackle specific aspects on water management practices considering environmental effects of their decisions.

References

Battese, G. E. (1992). Frotier production functions and technical efficiency: a survey of empirical application in agricutural economics. *Agricultural Economics*, (7):185 – 208.

Bravo-Ureta, B. E., Jara-Rojas, R., Martinez, D., Scheierling, S. M., and Treguer, D. O. (2016). Improving water use in farming: Implications derived from frontier function studies. In *XII Annual Meeting. International Water Resource Economics Consortium (IWREC)*, pages 1–32, Washington, D.C.

Cerdán-Infantes, P. (2008). The impact of agricultural extension services: The case of grape production in Argentina. *OVE Working Papers.*

Coelli, T. and Sanders, O. (2012). The technical efficiency of wine grape growers in the Murray-Darling Basin in Australia. In *Enometrics XIX*, Coimbra & Viseu.

Coelli, T. J., Prasada Rao, D. S., O'Donnell, C. J., and Battese, G. E. (2005). *An introduction to efficiency and productivity analysis.* Springer, New York, 2 edition.

Farrell, M. J. (1957). The measurement of productive efficiency. *Journal of the Royal Statistical Society*, 120(3):253–290.

Greene, W. H. (2008). The econometric approach to efficiency analysis. *The Measurement of Productive Efficiency and Productivity Growth*, pages 92–250.

Hernández, J., Martinis, N., and Fornero, L. (2012). Modelación hidrológica de la cuenca norte de Mendoza. Technical Report 146, Instituto Nacional del Agua (INA), Mendoza, Argentina.

INV (2017). Analisis de la evolucion de superficie de vid por provincias - Periodo 2000-2016. Technical report, Instituto Nacional de Vitivinicultura (INV), Mendoza, Argentina.

Manevska-Tasevska, G. (2012). *Efficiency analysis of commercial grape-producing family farms in the Republic of Macedonia.* Doctoral thesis, Swedish Universit of Agricultural Sciences. Uppsala.

Morábito, J. A., Salatino, S. E., and Schilardi, C. (2012). El desempeño del uso agrícola del agua en los oasis de los ríos Mendoza y Tunuyán a través de nuevos indicadores. In *VI Jornadas de Actualización en Riego y Fertirriego. Prácticas para Incrementar la Productividad y Asegurar la Sostenibilidad del Uso del Agua y del Suelo*, Mendoza, Argentina.

Moreira, V. H., Troncoso, J. L., and Bravo-Ureta, B. E. (2011). Technical efficiency for a sample of Chilean wine grape producers: A stochastic production frontier analysis. *Ciencia e investigación agraria*, 38(3):321–329.

Scheierling, S., Treguer, D. O., and Booker, J. F. (2016). Water productivity in agriculture: looking for water in the agricultural productivity and efficiency literature. *Water Economics and Policy*, 2(3):1650007.

Townsend, R. F., Kirsten, J., and Vink, N. (1998). Farm size, productivity and returns to scale in agriculture revisited: a case study of wine producers in South Africa. *Agricultural Economics*, 19(1-2):175–180.

Table 1: Estimation of the quadratic functional form

$Coeficient$	$CoeficientEstimate$	$Std.Error$	$zvalue$	$Pr(> \lvert z \rvert)$
Intercept	2.6179525	0.8405278	3.1147	0.0018416 **
mlncapitalf	0.5038393	0.2167422	2.3246	0.0200933 *
mlnland	1.5259731	0.2490917	6.1262	9.003e-10 ***
mlnlabfarm	0.0618087	0.0487232	1.2686	0.2045947
mlnwaterf	0.1743427	0.1022517	1.7050	0.0881880 .
mlnfertilizerf	0.1661411	0.0366942	4.5277	5.962e-06 ***
mlnpestinputf	-0.1058133	0.0469722	-2.2527	0.0242793 *
I(0.5 * mlncapitalf2)	-0.1340749	0.0496020	-2.7030	0.0068714 **
I(0.5 * mlnland2)	0.1145373	0.0508595	2.2520	0.0243202 *
I(0.5 * mlnlabfarm2)	-0.0368124	0.0648925	-0.5673	0.5705226
I(0.5 * mlnpestinputf2)	-0.0034729	0.0232932	-0.1491	0.8814796
I(0.5 * mlnwaterf2)	-0.0501874	0.0210919	-2.3795	0.0173376 *
I(0.5 * mlnfertilizer2)	-0.0274506	0.0260265	-1.0547	0.2915550
techdummy	0.1499096	0.0519790	2.8840	0.0039260 **
pergoladummy	0.0107060	0.0511592	0.2093	0.8342389
whitedummy	0.2156316	0.0662583	3.2544	0.0011363 **
sigmaSq	0.1887333	0.0327768	5.7581	8.505e-09 ***
gamma	0.5968209	0.1438423	4.1491	3.337e-05 ***
sigmaSqU	0.1126400	0.0457451	2.4623	0.0138034 *
sigmaSqV	0.0760933	0.0159490	4.7710	1.833e-06 ***
sigma	0.4344345	0.0377235	11.5163	¡ 2.2e-16 ***
sigmaU	0.3356188	0.0681504	4.9247	8.450e-07 ***
sigmaV	0.2758502	0.0289089	9.5421	¡ 2.2e-16 ***
lambdaSq	1.4802875	0.8848929	1.6728	0.0943581 .
lambda	1.2166706	0.3636534	3.3457	0.0008208 ***
varU	0.0409311	NA	NA	NA
sdU	0.2023145	NA	NA	NA
gammaVar	0.3497657	NA	NA	NA