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Title
Water Use and Efficiency of Grapevine Production in
Mendoza, Argentina

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Conference Presentation

Corresponding Author
Sebastián Riera

E-Mail
sebary@gmail.com

Affiliation
Georg-August-Universität Göttingen | Universidad Nacional de Cuyo

Co-Author/s

Name	E-Mail	Affiliation
Bernhard Brümmer	bbruemm@gwdg.de	Georg-August-Universität Göttingen
Alejandro J. Gennari	ajgennari@hotmail.com	Universidad Nacional de Cuyo

Keywords
water use in viticulture;
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stochastic frontier analysis;
viticulture in semi-arid areas;
technical efficiency;
Argentina

Research Question
What are the determinants of technical efficiency of grapevine producers ?
What is the role of water management practices in improving farm productivity?

Methods
Stochastic Frontier Analysis

Results
The average TE score is 0.829 for viticulturists and 0.819 for winegrowers.
Winegrowers have a capital intensive technology.
Efficient water management improves TE but energy subsidies have a despaired effect

Abstract
In Argentina, over the last two decades, agriculture has become a key and growing contributor to export earnings and wine has played a relevant and rising role in sustaining regional economies. The growing reputation of Argentinean wines has led to the settlement of international firms in the country, which also contributed to the industry in terms of technology adoption and market orientation. With over 240,000 hectares, the province of

Mendoza concentrates 70 per cent of the grape production and 65 per cent of the Argentinean wine making (INV 2017).
Despite the robust production and exports from Mendoza, the grapevine sector is facing significant challenges arising from low prices paid to producers, agronomic risks, and climate contingencies. Small and medium producers face an uncertain business environment with fixed production costs and shrinking access to natural resources. Their economic performance is sensitive to changes in regional markets and macroeconomic policies. In the current setting, this group of producers could be trapped in a declining spiral of water scarcity, declining production quality and profitability.

Frontier function methodologies represent a captivating methodology to assess productivity and efficiency. Surprinsingly, the literature applying this methods to grapevine production is scarce. In general, the available literature has addressed the overall agroclimatic conditions of vineyards and employed the analysis at the farm level (Piesse et al. 2018; Latruffe et al. 2016 ; Latruffe and Nauges 2014; Conradie et al. 2006; Townsend et al. 1998). More in detail, the work of Moreira et al. (2011) decoupled the performance of vineyards at the plot level but did not include the water used as a productive input. Whilst, Coelli and Sanders (2012) and Andrieu et al. (2014) considered water at the vineyard level in the functional form at the Murray-Darlin Basin (Australia) and San Juan (Argentina) respectively. In general, literature has not addressed the water use for grapevine production at the plot level and there are no precedents for this type of study in Argentina.
This paper analyzes the economic performance of grapevine producers in Lujan de Cuyo, a promising but complex area for wine production due to existing conflicts over water management, pollution threats and dependence on policy tools. Moreover, it seeks to capture the unobserved heterogeneity of managerial decisions at the plot level accounting for the irrigation practices for two subgroups of farmers. To the authors' knowledge this work is unprecedented for grapevine production in the context of water scarcity in semi-arid areas.

The water consumption and irrigation infrastructure represents a challenge to the analysis of grapevine production, due to measurement difficulties. Coelli and Sanders (2013) and Andrieu et al. (2014) documented the only work that explicitly includes water as a production input. The former used a panel data set for 135 farmers in the Murray-Darlin basin (Australia) and measured a mean TE of 79 per cent and a mean shadow price ratio of 1.07 for water. The latter a cross-sectional of 700 farms in a district of San Juan (Argentina) and estimated an average TE score of 0.41. Both studies lack specific agroclimatic conditions and detailed information on irrigation systems.

Given the limitations of water measurement and location specificity of grape production, there are few studies that include information of agroclimatic conditions or irrigation systems in an attempt to better understand the vineyard performance (de Sousa Henriques et al. 2009; Moreira et al. 2011; Christ and Burritt 2013).

Here we analyze the economic performance of small and medium grapevine producers in the area Lujan de Cuyo; a promising area for high-quality grape production and environmentally challenging due to existing conflicts over pollution potential that affect water quality. This area is located next to the Andes mountain range and has high heterogeneity in natural characteristics and primary access to pure surfacewater from the mountains.
The information used for the analysis was collected through applied surveys to grapevine producers for wine production in 5 districts from November 2016 until January 2017. The sample is composed by 177 randomly selected farmers, who were questioned on the production process, commercialization and water resource management practices.
The organization of the collected data followed a hierarchical logic. Starting at the farm-level, where general endowments were considered in order to later disaggregate production decisions down to the plot level.
Water availability depends on the location within the research area and water infrastructure. Water resources for irrigation are granted through water rights that are entitled to the producer and attached to the land, which means that they are not tradable and can only be transferred with the land property.
The collected data seeks to capture the unobserved heterogeneity in production functions for grapevine producers addressing the different management practices with respect to their quality or enological potential.

The total area of the research project has 600 sq. km. and covers nearly 15,000 ha of grapevine area, farmed by 510 producers. Bulk production is estimated at 11,000 tons from approximately 2,500 plots. As the area is situated along the Andes mountain range, the terrain and water resources vary substantially within this area.
The use of energy data at the farm level is relevant mainly because it allowes for the estimation of pumped

groundwater but also acknowledges the contradictory effects of such policies that subsidize water pumping practices without considering the effectiveness of the irrigation systems.

At the plot level, productive information was collected using a detailed framework to assess the use of agrochemicals, water, labor, and the quality of the product.

In terms of production yield, it is possible to recognise a bimodal distribution which indicates that some producers aim at higher yields while others may prefer more quality vines maintaining the yields at a lower stable rate. Essentially, those that produce grapes only for selling to other wineries (viticulturists) and farmers that produce their own wine (winegrowers) are reflected in this distribution.

Each vineyard plot 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: the plot size in hectares, the use of tractors, storage facilities, water reservoirs, groundwater wells, irrigation systems, and hail protection were considered.
On average, the annual value of the capital stock is 29,792 US dollars. However, for those farmers that do not use drip irrigation as much as the previous group, the mean value of capital is 28,697 US dollars. More in detail, the mean values of table state that 430 US dollars are spent annually on agrochemicals.
As a significant expenditure, energy consumption is relevant for those farmers that rely on groundwater for irrigation. On average, a farm consumes 21,608 kWh annually, this item is of particular interest since the energy tariff remains subsidized and the effect of this policy tool on the vineyard performance is analyzed below. According to the information on table , each farm demands 80.2 labor days of permanent staff and 12.9 labor days of seasonal staff on average; that focuses in crafts as harvesting, pruning and leaf removal.
In other words, the sample was split into two groups: on one hand producers that produce their own wine (winegrowers or vintners) and farmers that sell grapevine production in the market (vitciculturists). They represent a share of 24 and 76 per cent of the sample respectively.

Results

The results are presented for the complete sample accompanied by the two subgroups, where the analysis is focused. The level variables are training system, grape color variety, age of the vines, total vineyard size and soil characteristics.

In this region, the production of grapevine is better explained econometrically with a translog functional form: where capital, labor, agrochemical expenses, and water used are the main inputs. The first order coefficients of the production function are all significant and positive with the exception of labor in the subgroup of winegrowers.
The average TE score is 0.829 for viticulturists and 0.819 for winegrowers. The histograms of the efficiency scores in deploy the frequency for each subgroup. Moreover, the mean yield for viticulturists (10.6 tons) is significatly higher than that reported by winegrowers (9.19 tons), as confirmed by the t-test (p-value=0.0001).
The contribution of capital is relatively higher for winegrowers (0.72) than for viticulturists (0.22). It is possible that viticulturists are unable to invest in irrigated land and increase their capital services with other assets, which may contribute to production but the variable may be beyond their optimum (capital^2=0.53). Similarly, the use of agrochemicals is relatively more important for winegrowers (0.25) than viticulturists (0.14) that would rely on professional advice.
The coefficients of labor hours at the plot level have different values for the different groups. This is not surprising considering that grapevine production is the main input for a high-value product such as wine, whose quality is also subject to labor quality crafts and management practices.
Regarding the water input, the coefficient is the greatest among the other production factors for the viticulturists subgroup (0.38). In the case of the winegrowers, the coefficient is significant and represents the third greatest value among the production factors (0.16). Both subgroups seem to employ the resource near the optimum .

Regarding the exogenous variables, the resulting coefficients for the inefficiency variance (σ_μ^2) are generally similar but with notable exceptions between the subgroups. More effective irrigation systems have the effect of decreasing inefficiency for both clusters but this is only significant for the viticulturists (-9.11). This could be interpreted as efficiency gains from improvements in the irrigation systems.

Some external variables have dispair effects between the subgroups. In the case of machine technology for viticulturists (-1.61) and winegrowers (1.74), which seeks to capture the use of machinery that could supplement labor in vineyard tasks. While some winegrowers could seek to minimize labor costs through adopting these technologies, they could also apply machinery for regular management and have specialized labor to focus on quality optimization crafts.
The effect of energy subsidies on the variance of TE is also different between the subgroups but is only significant for the viticulturists. The benefit of this policy tool translates into efficiency gains only to grapevine producers that sell their output to third parties for wine production (-0.79). The depth of the aquifer decreases inefficiency for winegrowers (-0.04), which is explained by the fact that better water quality for irrigation is found deeper in the second confined aquifer.
Estimations of the mean TE scores were performed at the district level and are displayed in table . The performance of winegrowers is relatively better than viticulturists in every district with the exception of El Carrizal. Within the viticulturists subsample, better performances were estimated in the districts of Agrelo and El Carrizal.

In the case of winegrowers of these districts, they seem to manage their resources more wisely as oposed to the farmers in Perdriel, where surface water is guaranteed since the location is ideal in the distributional scheme.

Acknowledgements
The coordination with the General Direction of Irrigation (DGI) and the Statistics Bureau of the province (DEIE) allowed a detailed planning for fieldwork execution between November 2016 and January 2017. 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 assessment methodology of the socio-economic characteristics of the agricultural producers should be obtained, and supported the logistic planning to collect the data and corresponding retribution to enumerators according to their standards. The Ente Provincial Regulador Electrico (EPRE) contributed with the subsidized energy data for estimating groundwater volumes used for agricultural irrigation. Soil characteristics like composition, depth of different layers, and agricultural suitability was obtained from the server of Instituto Nacional de Tecnologia Agropecuaria (INTA).

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Water Use and Efficiency of Grapevine Production in Mendoza, Argentina

Sebastián Riera
Bernhard Brümmer
Alejandro Gennari

Abstract

In a the scarcity context, climate variability raises questions whether farmers are using the resource efficiently or performing below their potential and not fully benefiting from their water supply. This paper seeks to estimate and analyze the determinants of technical efficiency accounting for applied water, agroclimatic conditions and management practices and to disentangle the effects of water management according to production objectives. The analysis is performed following the parametric methodology of Stochastic frontier analysis (SFA) utilized on the 647 grapevine plot observations from 177 farm observations. The sample is divided in two accounting for producers that sell their output (viticulturists) or those that elaborate their own wine (winegrowers). Mean technical efficiency is similar between viticulturists (0.83) and winegrowers (0.82), which implies that viticulturists produce 1.81 fewer tons less per hectare and winegrowers forgo 1.66 tons due to systematic pitfalls. Results point towards effective irrigation systems, associativity, technical advice and vine density as factors that improve vineyard performance. The economic performance of farmers is good with respect to the regional documented literature but still needs improvement to face changes in the tax scheme and climate contingencies in the near future.

1 Introduction

In Argentina, over the last two decades, agriculture has become a key and growing contributor to export earnings and wine has played a relevant and rising role in sustaining regional economies. The growing reputation of Argentinean wines has led to the settlement of international firms in the country, which also contributed to the industry in terms of technology adoption and market orientation. With over 240,000 hectares, the province of Mendoza concentrates 70 per cent of the grape production and 65 per cent of the Argentinean wine making (INV 2017).

Despite the robust production and exports from Mendoza, the grapevine sector is facing significant challenges arising from low prices paid to producers, agronomic risks, and climate contingencies. Small and medium producers face an uncertain business environment with fixed production costs and shrinking access to natural resources. Their economic performance is sensitive to changes in regional markets and macroeconomic policies. In the current setting, this group of producers could be trapped in a *declining spiral* of water scarcity, declining production quality and profitability.

Frontier function methodologies represent a captivating methodology to assess productivity and efficiency. Surprinsingly, the literature applying this methods to grapevine production is scarce. In general, the available literature has addressed the overall agroclimatic conditions of vineyards and employed the analysis at the farm level (Piesse et al. 2018; Latruffe et al. 2016 ; Latruffe and Nauges 2014; Conradie et al. 2006; Townsend et al. 1998). More in detail, the work of Moreira et al. (2011) decoupled the performance of vineyards at the plot level but did not include the water used as a productive input. Whilst, Coelli and Sanders (2012) and Andrieu et al. (2014) considered water at the vineyard level in the functional form at the Murray-Darlin Basin (Australia) and San Juan (Argentina) respectively. In general, literature has not addressed the water use for grapevine production at the plot level and there are no precedents for this type of study in Argentina.

This paper analyzes the economic performance of grapevine producers in Lujan de Cuyo, a promising but complex area for wine production due to existing conflicts over water management, pollution threats and dependence on policy tools. Moreover, it seeks to capture the unobserved heterogeneity of managerial decisions at the plot level accounting for the irrigation practices for two subgroups of farmers. To the authors' knowledge this work is unprecedented for grapevine production in the context of water scarcity in semi-arid areas.

Furthermore, this paper focuses on two issues: (*i*) the analysis of the determinants of technical efficiency of grapevine producers and (*ii*) the role of water management practices in improving farm productivity. In order to disentangle the implications of efficiency determinants, the Stochastic Frontier Analysis (SFA) is utilized on a primary data set from the Carrizal basin of Mendoza, Argentina. Where functional forms are tested considering the market orientation of farmers, extension services, use of policy tools and irrigation practices.

2 Background literature

Although, the Stochastic Frontier Analysis (SFA) is very popular in the field of agricultural economics (Battese 1992), there is scarce literature on the application of this methodology to grapevine production (Piesse et al. 2018; Townsend et al. 1998; Latruffe et al. 2014; Manevska-Tasevska 2012; Ma et al. 2012). In particular, considering the regional effects of potential spill over of grapevine production (Van den Bosch 2008; SSPE 2016; COVIAR/OVA 2018).

In an effort to improve the understanding of the underlying heterogeneity in vineyard performance, Moreira et al. (2011) examined the TE of wine grape production at the plot level. They used a cross-sectional sample for Chilean farms in 2006 and found an average TE of 77.2 per cent at the farm level, with plot efficiency scores that varied between 23.4 and 95.0 per cent.

The water consumption and irrigation infrastructure represents a challenge to the analysis of grapevine production, due to measurement difficulties. Coelli and Sanders (2013) and Andrieu et al. (2014) documented the only work that explicitly includes water as a production input. The former used a panel data set for 135 farmers in the Murray-Darlin basin (Australia) and measured a mean TE of 79 per cent and a mean shadow price ratio of 1.07 for water. The latter a cross-sectional of 700 farms in a district of San Juan (Argentina) and estimated an average TE score of 0.41. Both studies lack specific agroclimatic conditions and detailed information on irrigation systems.

Given the limitations of water measurement and location specificity of grape production, there are few studies that include information of agroclimatic conditions or irrigation systems in an attempt to better understand the vineyard performance (de Sousa Henriques et al. 2009; Moreira et al. 2011; Christ and Burritt 2013).

3 Data

Here we analyze the economic performance of small and medium grapevine producers in the area Lujan de Cuyo; a promising area for high-quality grape production and environmentally challenging due to existing conflicts over pollution potential that affect water quality. This area is located next to the Andes mountain range and has high heterogeneity in natural characteristics and primary access to pure surfacewater from the mountains.

The information used for the analysis was collected through applied surveys to grapevine producers for wine production in 5 districts from November 2016 until January 2017. The sample is composed by 177 randomly selected farmers, who were questioned on the production process, commercialization and water resource management practices.

The organization of the collected data followed a hierarchical logic. Starting at the farm-level, where general endowments were considered in order to later disaggregate production decisions down to the plot level.

Water availability depends on the location within the research area and water infrastructure. Water resources for irrigation are granted through *water rights* that are entitled to the producer and attached to the land, which means that they are not tradable and can only be transferred with the land property.

The collected data seeks to capture the unobserved heterogeneity in production functions for grapevine producers addressing the different management practices with respect to their quality or enological potential.

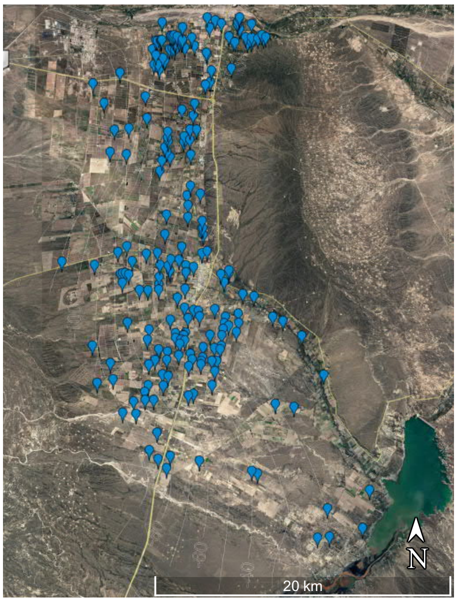

Figure 1: Research area

3.1 Sample data and variable selection

The total area of the research project has 600 sq. km. and covers nearly 15,000 ha of grapevine area, farmed by 510 producers. Bulk production is estimated at 11,000 tons from approximately 2,500 plots. As the area is situated along the Andes mountain range, the terrain and water resources vary substantially within this area.

The use of energy data at the farm level is relevant mainly because it allowes for the estimation of pumped groundwater but also acknowledges the contradictory effects of such policies that subsidize water pumping practices without considering the effectiveness of the irrigation systems.

3.2 Data validation and interpretation

At the plot level, productive information was collected using a detailed framework to assess the use of agrochemicals, water, labor, and the quality of the product.

The figure 2 represents the yield per grapevine plot and their frequency in the sample. It is possible to recognize a bimodal distribution which indicates that some producers aim at higher yields while others may prefer more quality vines maintaining the yields at a lower stable rate. Essentially, those that produce grapes only for selling to other wineries (*viticulturists*) and farmers that produce their own wine (*winegrowers*) are reflected in this distribution.

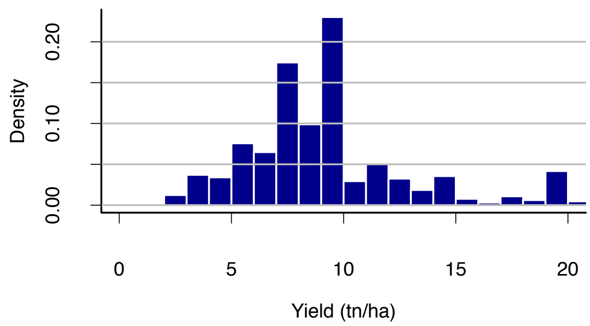

Figure 2: Grapevine yield per hectare

3.3 Analysis and imputation techniques

Each vineyard plot 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: the plot size in hectares, the use of tractors, storage facilities, water reservoirs, groundwater wells, irrigation systems, and hail protection were considered.

On average, the annual value of the capital stock is 29,792 US dollars. However, for those farmers that do not use drip irrigation as much as the previous group, the mean value of capital is 28,697 US dollars. More in detail, the mean values of table 1 state that 430 US dollars are spent annually on agrochemicals.

Table 1: Descriptive values per hectare

Component	Unit	Mean	Sdt.Dev.
Production	tons	10.2	4.7
Capital services	USD	29128.8	13259.6
Labor	days	92.4	146.2
- Permanent	days	80.2	147.8
- Temporary	days	12.9	12.3
Agrochemicals	USD	429.8	268.8
- Fertilizer	USD	13.8	8.8
- Pesticides	USD	27.7	17.5
Water	m^3	9339.9	4905.8
Average plot size	ha	4.2	4.1
Producer Age	years	53.1	11.8
Agricultural income dependence	% total	73.3	35.0
Vine density	Plants/ha	4370.1	2254.2
Average planted year	year	1990.0	25.3

Source: Own calculation.

As a significant expenditure, energy consumption is relevant for those farmers that rely on groundwater for irrigation. On average, a farm consumes 21,608 kWh annually, this item is of particular interest since the energy tariff remains subsidized and the effect of this policy tool on the vineyard performance is analyzed below. According to the information on table 1, each farm demands 80.2 labor days of permanent staff and 12.9 labor days of seasonal staff on average; that focuses in crafts as harvesting, pruning and leaf removal.

In other words, the sample was split into two groups: on one hand producers that produce their own wine (*winegrowers* or *vintners*) and farmers that sell grapevine production in the market (*vitciculturists*). They represent a share of 24 and 76 per cent of the sample respectively.

4 Results and discussion

The results are presented for the complete sample accompanied by the two subgroups, where the analysis is focused. The level variables are training system, grape color variety, age of the vines, total vineyard size and soil characteristics.

4.1 Functional form and efficiency determinants

In this region, the production of grapevine is better explained econometrically with a translog functional form: where capital, labor, agrochemical expenses, and water used are the main inputs. The first order coefficients of the production function are all significant and positive with the exception of labor in the subgroup of winegrowers.

The average TE score is 0.829 for viticulturists and 0.819 for winegrowers. The histograms of the efficiency scores in 3 deploy the frequency for each subgroup. Moreover, the mean yield for viticulturists (10.6 tons) is significatly higher than that reported by winegrowers (9.19 tons), as confirmed by the t-test (p-value=0.0001).

Table 2: Estimation coefficients of production function

	Complete sample		Viticulturists		Winegrowers	
	β_{sample}	SE_{sample}	β_{Vit}	SE_{Vit}	β_{Wine}	SE_{Wine}
intercept	5.653***	(1.343)	6.196***	(1.808)	8.463***	(2.442)
capital	0.287***	(0.047)	0.217***	(0.058)	0.719***	(0.095)
labor	0.120***	(0.030)	0.215***	(0.040)	-0.211***	(0.070)
agrochemicals	0.142***	(0.032)	0.144***	(0.041)	0.247***	(0.066)
water	0.382***	(0.036)	0.376***	(0.052)	0.157**	(0.074)
capital^2	0.428***	(0.105)	0.528***	(0.129)	0.209	(0.162)
labor^2	-0.106**	(0.044)	-0.107**	(0.050)	0.180	(0.176)
agrochemicals^2	-0.045	(0.061)	0.073	(0.085)	0.030	(0.098)
water^2	-0.010	(0.060)	0.055	(0.094)	-0.005	(0.105)
capital × labor	-0.004	(0.054)	0.082	(0.060)	-0.120	(0.153)
capital × agroch	-0.143**	(0.057)	-0.238***	(0.074)	0.006	(0.101)
capital × water	-0.092	(0.080)	-0.190*	(0.100)	-0.042	(0.143)
labor × agroch	0.063	(0.043)	0.065	(0.046)	-0.112	(0.096)
labor × water	-0.028	(0.048)	-0.058	(0.057)	-0.081	(0.130)
agroch × water	0.089*	(0.049)	0.083	(0.078)	0.119	(0.094)
pergola training syst.	0.161***	(0.042)	0.228***	(0.054)	0.212***	(0.081)
white variety	0.112*	(0.059)	0.098	(0.064)	0.152	(0.164)
vine age	-0.003***	(0.001)	-0.003***	(0.001)	-0.004***	(0.001)
vineyard size	0.001**	(0.001)	0.003**	(0.001)	0.003***	(0.001)
well drained soil	0.225**	(0.094)	0.261***	(0.101)	0.013	(0.392)
excessively drained soil	-0.057	(0.038)	-0.015	(0.052)	0.113	(0.079)

Source: Own estimation.

Significance level: 10%(*); 5%(**); 1%(***).

The contribution of capital is relatively higher for winegrowers (0.72) than for viticulturists (0.22). It is possible that viticulturists are unable to invest in irrigated land and increase their capital services with other assets, which may contribute to production but the variable may be beyond their optimum ($capital^2$=0.53). Similarly, the use of agrochemicals is relatively more important for winegrowers (0.25) than viticulturists (0.14) that would rely on professional advice.

The coefficients of labor hours at the plot level have different values for the different groups. This is not surprising considering that grapevine production is the main input for a high-value product such as wine, whose quality is also subject to labor quality crafts and management practices.

Regarding the water input, the coefficient is the greatest among the other production factors for the viticulturists subgroup (0.38). In the case of the winegrowers, the coefficient is significant and represents the third greatest value among the production factors (0.16). Both subgroups seem to employ the resource near the optimum[1].

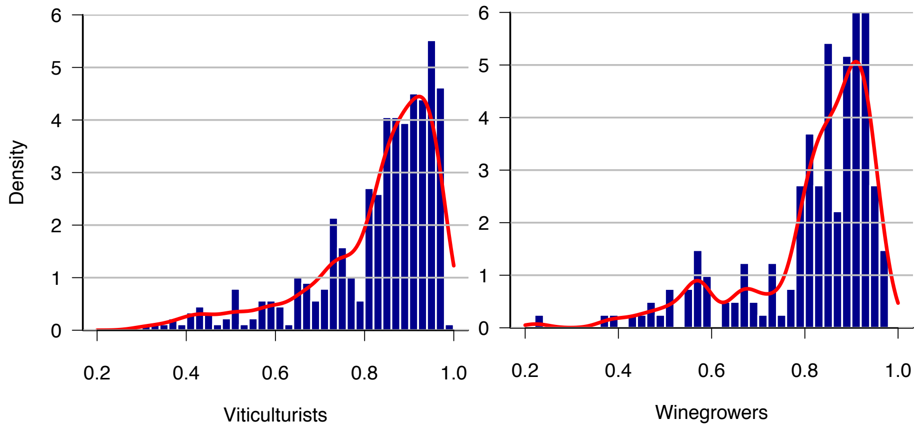

Figure 3: Histograms of TE scores

Regarding the exogenous variables, the resulting coefficients for the inefficiency variance (σ_μ^2) are generally similar but with notable exceptions between the subgroups. More effective irrigation systems have the effect of decreasing inefficiency for both clusters but this is only significant for the viticulturists (-9.11). This could be interpreted as efficiency gains from improvements in the irrigation systems.

Some external variables have dispair effects between the subgroups. In the case of machine technology for viticulturists (-1.61) and winegrowers (1.74), which seeks to capture the use of machinery that could supplement labor in vineyard tasks. While some winegrowers could seek to minimize labor costs through adopting these technologies, they could also apply machinery for regular management and have specialized labor to focus on quality optimization crafts.

The effect of energy subsidies on the variance of TE is also different between the subgroups but is only significant for the viticulturists. The benefit of this policy tool translates into efficiency gains only to grapevine producers that sell their output to third parties for wine production (-0.79). The depth of the aquifer decreases inefficiency for winegrowers (-0.04), which is explained by the fact that better water quality for irrigation is found deeper in the second confined aquifer.

Estimations of the mean TE scores were performed at the district level and are displayed in table 4. The performance of winegrowers is relatively better than viticulturists in every district with the exception of *El*

[1]The second order coefficient for water is almost zero in both subgroups.

Table 3: Estimation coefficients for external variables

	Complete sample		Viticulturists		Winegrowers	
	Estimate	Std. Dev.	Estimate	Std. Dev.	Estimate	Std. Dev.
Technical inefficiency						
ρ intercept	4.301**	(1.886)	3.827.	(2.331)	3.850	(3.321)
ρ irrigation syst.	-9.554***	(2.937)	-9.111**	(3.638)	-5.830	(5.404)
ρ extensionist	-1.419***	(0.387)	-0.732**	(0.365)	-2.028***	(0.731)
ρ vine density	-0.300	(0.221)	-0.483**	(0.241)	-0.546	(0.447)
ρ energy subsidy	-1.386**	(0.625)	-0.791*	(0.448)	0.656	(0.655)
ρ machine technology	-0.649	(0.766)	-1.609**	(0.819)	1.738*	(1.006)
ρ associativity	-0.746	(0.557)	-0.584	(0.555)	-2.295**	(1.121)
ρ depth aquifer	0.007	(0.005)	0.006	(0.007)	-0.036***	(0.011)
ρ leaf removal	0.980***	(0.312)	1.104***	(0.394)	0.849	(0.627)
Statistical noise						
δ intercept	-2.680***	(0.606)	-3.104***	(0.749)	-2.465***	(0.178)
δ irrigation syst.	0.791	(0.765)	1.228	(0.982)	-	-
δ extensionist	-0.547***	(0.180)	0.050	(0.309)	-	-
δ vine density	-0.598***	(0.106)	-0.571***	(0.129)	-	-
δ energy subsidy	0.259	(0.184)	0.144	(0.256)	-	-
δ machine technology	0.277	(0.187)	-0.194	(0.228)	-	-
δ associativity	-0.419	(0.277)	-0.449	(0.458)	-	-
δ depth aquifer	-0.008***	(0.003)	-0.009**	(0.004)	-	-
δ leaf removal	0.556***	(0.179)	0.293	(0.254)	-	-
σ_u	-	-	-	-	0.292***	(0.026)

Source: Own estimation.

Significance level: 10%(*); 5%(**); 1%(***).

Carrizal. Within the viticulturists subsample, better performances were estimated in the districts of *Agrelo* and *El Carrizal*.

Table 4: Mean efficiency scores per district

District	$\bar{TE}_{Vit}$	$\bar{TE}_{Wine}$
Agrelo	0.868	0.848
Anchoris	0.600	0.849
El Carrizal	0.868	0.799
Perdriel	0.742	0.777
Ugarteche	0.793	0.830

Source: Own estimation.

In the case of winegrowers of these districts, they seem to manage their resources more wisely as oposed to the farmers in *Perdriel*, where surface water is guaranteed since the location is ideal in the distributional scheme.

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References

Andrieu, J., O. Miranda, N. Gatti, and R. Novello. 2014. "Riego y acción colectiva: impacto en la eficiencia técnica de la producción vitícola de San Juan." In *Asociación argentina de economía agraria.* pp. 1–23. Available at: https://goo.gl/A6NdDe.

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

Christ, K.L., and R.L. Burritt. 2013. "Critical environmental concerns in wine production: an integrative review." *Journal of Cleaner Production* 53:232–242. Available at: http://linkinghub.elsevier.com/retrieve/pii/S0959652613002084.

Coelli, T.J., and O. Sanders. 2013. "The Technical Efficiency of Wine Grape Growers in the Murray-Darling Basin in Australia." In *Wine economics.* London: Palgrave Macmillan UK, pp. 231–249. Available at: http://link.springer.com/10.1057/9781137289520{_}11.

Coelli, T.J., and O. Sanders. 2012. "The technical efficiency of wine grape growers in the Murray-Darling Basin in Australia." In *Enometrics xix.* Coimbra & Viseu. Available at: www.vdqs.net/2012Coimbra.

Conradie, B., G. Cookson, and C. Thirtle. 2006. "Efficiency and farm size in Western Cape grape production: Pooling small datasets." *South African Journal of Economics* 74(2):334–343.

COVIAR/OVA. 2018. "Impacto de la Vitivinicultura en la Economía Argentina." Corporación Vitivinícola Argentina; Observatorio Vitivinícola Argentino; COVIAR. Available at: https://goo.gl/A9AUDQ.

de Sousa Henriques, P.D., M.L. da Silva Carvalho, and R.M. de Sousa Fragoso. 2009. "Technical efficiency of portuguese wine farms." *New Medit* 8(1):4–9.

INV. 2017. "Analisis de la evolucion de superficie de vid por provincias - Periodo 2000-2016." Instituto Nacional de Vitivinicultura (INV). Available at: https://goo.gl/VfYEq1.

Latruffe, L., and C. Nauges. 2014. "Technical efficiency and conversion to organic farming: the case of France." *European Review of Agricultural Economics* 41(2):227–253. Available at: https://academic.oup.com/erae/article-lookup/doi/10.1093/erae/jbt024.

Latruffe, L., B.E. Bravo-Ureta, A. Carpentier, Y. Desjeux, and V.H. Moreira. 2016. "Subsidies and Technical

Efficiency in Agriculture: Evidence from European Dairy Farms." *American Journal of Agricultural Economics* 0(Massot):aaw077. Available at: http://ajae.oxfordjournals.org/lookup/doi/10.1093/ajae/aaw077.

Ma, C., W. Mu, J. Feng, and W. Jiao. 2012. "Assessing the technical efficiency of grape production in open field cultivation in China." *Journal of Food, Agriculture & Environment* 10(1):345–349.

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. Available at: https://core.ac.uk/download/files/385/11697915.pdf.

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

Piesse, J., B. Conradie, C. Thirtle, and N. Vink. 2018. "Efficiency in wine grape production: comparing long-established and newly developed regions of South Africa." *Agricultural Economics* 49(2):203–212. Available at: http://doi.wiley.com/10.1111/agec.12409.

SSPE. 2016. "Informes de cadenas de valor. Vitivinicultura." Informes de cadenas de valor Subsecretaría de Planificación Económica. Available at: https://goo.gl/Gj9LrC.

Townsend, R.F., J. Kirsten, and N. Vink. 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. Available at: http://doi.wiley.com/10.1016/S0169-5150(98)00033-4.

Van den Bosch, M.E. 2008. *Un modelo de desarrollo sustentable en las áreas bajo riego de los distritos Ugarteche y El Carrizal. Departamento de Luján de Cuyo. Provincia de Mendoza: Un aporte para el ordenamiento territorial rural.* Master thesis. Universidad Nacional de Cuyo. Available at: http://www.bdigital.uncu.edu.ar/4631.