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Title
Economic performance of Chilean winegrowers: the impact of production approaches and the adoption of technologies.

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Keywords
Economic performance, production approaches, technology adoption, winegrowers profitability.

Research Question
What is the impact of production approaches and technologies on the economic performance of winegrowers in Chile? Revenues, Direct Costs and Profits are affected in the same manner?

Methods
A Seemingly Unrelated Regression model (SUR) of three equations was estimated, which allows for verifying the correlations of errors and, therefore, linear dependence between Revenues, Direct Costs and Profits.

Results
Technologies and production approaches have different implications on Revenues, Direct Costs and Profits. Higher profits are exhibited by pressurized irrigation, pergola conduction, reserve destiny of grapes and white strains culture.

Abstract
In the wine sector, one of the main components of competitiveness lies in the capacity to innovate, where winegrowers must decide between different technologies and production approaches with the aim of maximizing their net benefits. This may represent a virtuous circle insofar as production structures are one of the most important determinants of the economic situation of farms and profitability has also a significant effect on the farm's financial structure and investment capacity.

The objective of this work is to analyze the economic performance for a sample of Chilean winegrowers, evaluating the impact of three different production approaches and three technologies on Revenue, Direct Cost and Profit. The production approaches analyzed were: 1) variety type (red or white grapes), 2) conduction system (arbors or vertical structures), and 3) grape destination (reserve or varietal wines); while the technologies evaluated were: 1) pressurized irrigation, 2) instruments for irrigation scheduling, and 3) mechanization of management operations.

Chile is an interesting case study because wine grape is one of the most important crops within the agricultural sector and because in recent decades the country has experienced a prompt development of its export-oriented

wine industry , becoming an important player in international markets. In fact, between 1990 and 2015 vineyard plantations doubled, wine production increased by five times, and wine export volume grew from 22 to 1,445 million liters.

The study area covers the O'Higgins and Maule regions in Central-South Chile (33° 50' and 36° 33' S), which belong to the central portion of the country in the heart of the fruit and vineyard production. Both regions comprise 73% of the national planted area, distributed among three important valleys, from north to south: Rapel, Curicó and Maule. The data used in this study was generated at the vineyard-level from a stratified random sample of 452 winegrowers from irrigated lands, which were surveyed between October 2014 and March 2015. Due to incomplete information and outliers the database was reduced to 436 observations.

The questionnaire gathered information about the vineyard and the winegrower, plus detailed information on direct production costs for the main variety grown in the vineyard, which were divided into input and management costs. Input costs correspond to the expenditure in fertilizers and agrochemicals (i.e. insecticides, herbicides, acaricides, and fungicides) and management costs correspond to input application and activities related to pruning-mooring, removing sprouts, mowing, and harvest. In addition, winegrowers were consulted about yields, planted surface and grape prices to estimate revenues. Consecutively, profits were obtained from the difference between revenues and direct costs.

With respect to the method, winegrowers face different alternatives to invest but they have certain restrictions imposed by their own attributes and other territorial characteristics ranging from natural resources to production factors and techniques. Therefore, it is considered that Revenue (I), Direct Cost (C) and Profit (M) are function of the adopted technologies (T), production approaches (E) and the attributes of the productive unit (Z), composed by vineyard (V) and winegrowers´ characteristics (P), formally:

$I(T,E|Z)= f(T,E,[V,P])$
$C(T,E|Z)= f(T,E,[V,P])$
$M(T,E|Z)= f(T,E,[V,P])$

In this way, a Seemingly Unrelated Regression model (SUR) of three equations was estimated, which allows for verifying the correlations of errors and, therefore, linear dependence. This model allows us for a comprehensive analysis of economic performance since it analyzes simultaneously Revenues, Direct Costs and Profits, all in logarithms to obtain elasticities or semi-elasticities.

Meanwhile, when examining the frequency of vineyards that adopt the three technologies evaluated, it was obtained that 44% of them use pressurized irrigation, 24% possess instruments for irrigation scheduling and 61% fall into the category mechanized by performing at least one of the management activities of the vineyard using machinery. In terms of production approaches, 84% of the sample grow red grape varieties such as the main in the vineyard (the rest are white varieties), 19% of winegrowers uses Tendone, or Pergola, training system in contrast to vertical systems, and that only 13% produces grapes with a goal of reserve destination compared to varietal destination. Finally, in average for each hectare grown, Revenue is around 3,760 euros, Direct Costs 1,600 euros, and Profits 2,170 euros (Exchange rate= 718.64 Chilean pesos per Euro).

Turning to the regression analysis, first at all it is important to note that Total Revenue, Direct Cost and Profit are significantly correlated with the planted area with estimated elasticities of 1.00, 1.05, and 0.95, respectively. These coefficients were tested to be different from the unit in order to validate constant economies of scale. Only in the case of Direct Cost was possible to reject the null hypothesis, indicating that there are increasing direct cost to scale ($p<0.01$). However, this result is not surprising since it is expected that larger vineyards address production more intensively. On the other hand, specialization in variety is not relevant on Revenue nor Profit but significant on Direct Cost, where a positive change of 1% reduces costs by 0.15% ($p<0.01$). This may be because specialization has the possibility of reducing unit costs and structure of expenditures by limiting complexity in management (Czyżewski y Smędzik-Ambroży, 2015).

Of the three agricultural technologies evaluated, we can observe that each one has different implications in the economic performance of winegrowers. For example, producers with pressurized irrigation versus those irrigating

in a gravitational manner, have significantly higher Revenue (17%) but no higher Direct Cost, resulting in 43% higher Profit ($p<0.01$). However, with respect to have instruments that measure meteorological conditions to schedule irrigation, there is no evidence that they affect statistically neither Revenue, Direct Cost nor Profit. As for mechanization, the result is significantly increases in Revenue and Direct Cost ($p <0.05$); where the effect is not transferred to the margins due they are counteracted.

Finally, in terms of production approaches interesting results were obtained, since basically all have a significant impact on the economic performance of the vineyards. When the main variety grown is red grape compared to white grape, Revenue is 37% lower and Direct Cost are not significantly different, which translates into 75% lower Profits. On the other hand, the vine training system is key along the three equations, since conducting the vines as Tendone or Pergola, versus vertical systems, increases 58% the Revenue, 30% the Direct Cost and therefore, 92% the Profit ($p<0.01$).

Regarding grape destination, when vineyard produces reserve grapes of higher quality than varietals, the Revenue is 22% higher and Direct Cost 11% higher, resulting also in 41% higher Profit ($p<0.01$). The above indicates that choosing a production approach may be associated with higher Direct Costs, however, this fact is compensated by obtaining a greater Revenue that also lead to higher Profit. That is, there is a prize for the effort made, which clearly makes sense from the economic point of view.

As conclusion, the economic performance analysis carried out in this study showed how vineyards could improve their profits by adopting different production approaches or technologies, and also to understand their effect on revenues and direct cost. In this sense, it has been demonstrated that managerial performance, quality product and productivity is essential to be profitable within the bounds that winegrowers face. The above is relevant in terms of agricultural policy to the extent that efficiency at the vineyard level can have an impact on the commercial success of a whole industry.

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Economic performance of Chilean winegrowers: the impact of production approaches and the adoption of technologies.

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Introduction

The ability of a company to remain within the industry with high economic performance is related to the completion of investments that translate into benefits, which will depend on the intensity of the competition to which it is subject (Porter, 1980). In the wine sector, one of the main components of competitiveness lies in the capacity to innovate (Pappalardo et al., 2013), where winegrowers must decide between different technologies and production approaches with the aim of maximizing their net benefits (Tudisca et al., 2013). This constant process of innovation has played a prominent role in emerging New World producing countries, which are examples of how a traditional industry can become highly competitive in a very short period of time, following a different trajectory from the former leading countries, such as Italy and France (Cusmano et al., 2010; Giuliani et al., 2011; Smith, 2007).

In this context, Chile is an interesting case study because wine grape is one of the most important crops within the agricultural sector (Engler et al., 2016). Likewise, in recent decades Chile has experienced a prompt development of its export-oriented wine industry, becoming an important player in international markets (Moreira et al., 2011). In fact, between 1990 and 2015 vineyard plantations doubled and wine production increased by

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five times[1]. During the same period wine export volume grew from 22 to 1,445 million liters[1]. The objective of this work is to analyze the economic performance of winegrowers in Chile, evaluating the impact of three different production approaches and three technologies on Revenue, Direct Cost and Profit. The production approaches analyzed were: 1) variety type (red or white grapes), 2) conduction system (arbors or vertical structures), and 3) grape destination (reserve or varietal wines), while the technologies evaluated were: 1) pressurized irrigation, 2) instruments for irrigation scheduling, and 3) mechanization of management operations. This task is relevant to study because it represents a virtuous circle insofar as production structures are one of the most important determinants of the economic situation of farms (Czyżewski y Smędzik-Ambroży, 2015) and profitability has also a significant effect on the farm's financial structure and investment capacity (Tudisca et al., 2013).

Data

The study area covers the O'Higgins and Maule regions in Central-South Chile (33° 50' and 36° 33' S), which belong to the central portion of the country in the heart of the fruit and vineyard production. Both regions comprise 73% of the national planted area, distributed among three important valleys from north to south: Rapel, Curicó and Maule[2]. The data used in this study was generated at the vineyard-level from a stratified random sample of 452 winegrowers from irrigated lands, which were surveyed between October 2014 and March 2015, across 16 municipalities[3]. Due to incomplete information and outliers the database was reduced to 436 observations.

[1] ODEPA (Office of Agricultural Studies and Policies). 2016. Foreign Trade Statistics: Advance by product of exports/imports. http://www.odepa.gob.cl/. Visited October 2016.
[2] A brief description of these valleys is presented in Annex 1.
[3] The municipalities were, in order of number of surveyed producers: San Javier, Sagrada Familia, Curicó, Nancagua, Villa Alegre, Santa Cruz, Talca, Palmilla, San Clemente, Peralillo, Río Claro, Requínoa, Chimbarongo, Maule, San Vicente, and Peumo.

The questionnaire gathered detailed information on direct production costs for the main variety grown in the vineyard, which were divided into input and management costs. Input costs correspond to the expenditure in fertilizers and agrochemicals (insecticides, herbicides, acaricides, and fungicides) and management costs correspond to the labor and machinery costs of the input application and activities related to pruning-mooring, removing sprouts, mowing, and harvest. In addition, winegrowers were consulted about yields, planted surface and grape prices for the main variety grown in the vineyard to estimate revenues. Consecutively, profits were obtained from the difference between revenues and direct costs. These components of the economic performance in vineyard production along with the aspects of farm structure and general demographic information were used to achieve the objectives of this work.

Methods

According to Chinnici et al. (2013), evaluating the operational choices of a vineyard involves identifying the specific features of the sector in question, together with knowledge of the potentials and restrictions of both a technical and economic-managerial nature. In fact, producers face different alternatives to invest but they have certain restrictions imposed by their own attributes and other territorial characteristics ranging from natural resources to the availability of production factors and techniques (Pappalardo et al., 2013). Therefore, it is considered that Revenue (I), Direct Cost (C) and Profit (M) are function of the adopted technologies (T), production approaches (E) and the attributes of the productive unit (Z), composed by vineyard (V) and winegrowers´ characteristics (P), formally:

$$I(T, E|Z) = f(T, E, [V, P])$$
$$C(T, E|Z) = f(T, E, [V, P])$$
$$M(T, E|Z) = f(T, E, [V, P])$$

In this way, a Seemingly Unrelated Regression model (SUR) of three equations was estimated, which allows for verifying the correlations of errors and, therefore, linear dependence. This model allows us for a comprehensive analysis of economic performance since it analyzes simultaneously Revenues, Direct Costs and Profits. Thus, the empirical model underlying the three equations mentioned follows the form:

$$\begin{aligned} log\ Y_i = {} & \beta_0 + \beta_1\ log\ surface + \beta_2\ log\ specialization + \beta_3\ water\ availability \\ & + \beta_4\ valley1 + \beta_5\ valley2 + \beta_6 valley3 + \beta_7\ log\ education \\ & + \beta_8\ log\ experience + \beta_9\ log\ acquaintances + \beta_{10}\ internet \\ & + \beta_{11}\ associations + \beta_{12}\ pressurized\ irrigation \\ & + \beta_{13}\ scheduling\ instrument + \beta_{14}\ mechanized + \beta_{15}\ variety\ type \\ & + \beta_{16}\ vine\ training + \beta_{17}\ grape\ destination + \epsilon_i \end{aligned}$$

where Y_i represents the three dependent variables: Total Revenue, Total Direct Cost and Total Profit. Apart from the constant, the first six variables account for the vineyard attributes and the next five correspond to the winegrowers' characteristics, then, a set of three different technologies and three production approaches are evaluated. It is important to note that the prefix log means that the variable is used as natural logarithm; otherwise the variables are dichotomous.

Results and Discussion

Descriptive statistics

Table 1 shows the descriptive statistics of the variables used in the model, characterizing the vineyards and the producers, highlighting the relevance of production approaches and

technologies used in the sample. In addition, Total Revenue, Total Direct Costs and Total Profits are detailed for the main variety in the vineyard[4].

Table 1. Variable descriptions and statistics (N=436).

Variable	Description	Mean
Education	Years of education.	11.9
Experience	Years of experience.	28.3
Acquaintances	Number of acquaintances (colleagues, friends).	20.3
Internet	Using Internet for meteorological data = 1; 0 otherwise.	0.73
Associations	Belonging to agricultural associations = 1; 0 otherwise.	0.26
Water availability	Having water availability problems = 1; 0 otherwise.	0.33
Surface	Hectares of the main strain in the vineyard.	18.9
Specialization	Percentage of the main strain surface to total vineyards.	0.65
Valley1	Rapel valley = 1; 0 otherwise.	0.38
Valley2	Curicó valley = 1; 0 otherwise.	0.21
Valley3	Maule valley = 1; 0 otherwise.	0.41
Pressurized irrigation	Adopting pressurized irrigation = 1; 0 otherwise.	0.44
Irrigation instrument	Adopting instruments for irrigation = 1; 0 otherwise.	0.24
Mechanized	Doing at least one labor mechanized = 1; 0 otherwise.	0.61
Strain type	Having red grape variety as main strain = 1; 0 otherwise.	0.84
Vine Training	Tendone or Pergola training system = 1; 0 otherwise.	0.19
Grape Destination	Reserve wines = 1; 0 otherwise.	0.13
Revenues	Total revenue for the main strain (euros).	71,024
Direct Costs	Total direct costs for the main strain (euros).	30,013
Profits	Total profits for the main strain (euros).	41,011

In terms of human capital, it is possible to see that in average winegrowers have 12 years of education, which is equivalent to complete secondary education, the experience in

[4] Exchange rate observed on November 14, 2016: 1 Euro = 718.64 Chilean pesos. Central Bank of Chile (http://si3.bcentral.cl/).

agriculture is 28 years, and that 73% of the sample use Internet to obtain meteorological information. Regarding social capital characteristics of winegrowers, the variables are referred to the number of acquaintances (about 20 persons among colleagues and friends) and the participation in agricultural associations (26% of winegrowers).

On the other hand, the average area for the main variety in the vineyard is 19 ha and the degree of specialization is 65% in relation to the total number of existing varieties. The valleys included in the study allow controlling for dissimilar edaphoclimatic conditions across vineyards, indicating that 41, 38 and 21% of the sample belongs to the Maule, Rapel and Curicó valleys, respectively. Concerning water availability variable, on average, 33% of the producers have been faced with problems of scarcity in their provision of water for irrigation.

Meanwhile, when examining the frequency of vineyards that adopt the three technologies evaluated, it was obtained that 44% of them use pressurized irrigation, 24% possess instruments for irrigation scheduling and 61% fall into the category mechanized by performing at least one of the management activities of the vineyard using machinery. In terms of production approaches, 84% of the sample grow red grape varieties such as the main in the vineyard (the rest are white varieties), 19% of winegrowers uses Tendone, or Pergola, training system in contrast to vertical systems, and that only 13% produces grapes with a goal of reserve destination compared to varietal destination.

With reference to the economic performance figures shown in Table 1, if these amounts are divided by the average planted surface of the main variety it is obtained that, for each hectare grown, Revenue is around 3,760 euros, Direct Costs 1,600 euros, and Profits 2,170 euros.

Modeling the effect of production approaches and technologies on economic performance.

Turning to the regression analysis, Table 2 presents the results of the estimation of the SUR model for Total Revenue, Direct Cost, and Profit for the main variety in the vineyard, all in logs. The use of this kind of model is justified by the hypothesis of non-independence relation between equations. The Breusch-Pagan test indicate that there is correlation of residuals across the three equations ($p<0.00001$). It should be mentioned that the model was estimated using 386 of 436 observations because there were vineyards with negative profit in the sample, which were automatically excluded from the analysis because it could not be converted into logarithms.

Table 2. Seemingly unrelated regression for Total Revenue, Direct Cost, and Profit (N= 386).

Variable	Log of total revenues	Log of total direct costs	Log of total profits
Log_surface	1.00 ***	1.05 ***	0.95 ***
Log_specialization	-0.02	-0.12 ***	0.17
Water availability	-0.11 **	-0.04	-0.30 ***
Valley1 (Rapel)	0.10	-0.08 *	0.41 ***
Valley2 (Curicó)	-	-	-
Valley3 (Maule)	-0.22 ***	-0.27 ***	-0.16
Log_education	-0.08	-0.07 *	-0.12
Log_experience	-0.03	-0.05 *	-0.04
Log_acquaintances	0.09 ***	0.01	0.18 ***
Internet	0.14 **	0.02	0.28 **
Associations	-0.08	-0.05	-0.11
Pressurized irrigation	0.17 ***	0.02	0.43 ***
Scheduling instruments	0.00	-0.01	0.00
Mechanized level	0.11 **	0.09 **	0.09
Strain type	-0.37 ***	-0.06	-0.75 ***
Conduction	0.58 ***	0.30 ***	0.92 ***
Destiny	0.22 ***	0.11 **	0.41 ***
r^2	0.91	0.95	0.68
Breusch-Pagan test of independence: $chi^2(3) = 282.41$, $p < 0.0000$			

Statistically significant at 0.01 (***), 0.05 (**) and 0.1 (*) level of confidence.

First at all it is important to note that Total Revenue, Direct Cost and Profit are significantly correlated with the planted area with estimated elasticities of 1.00, 1.05, and 0.95, respectively. These coefficients were tested to be different from the unit in order to validate constant economies of scale. Only in the case of Direct Cost was possible to reject the null hypothesis, indicating that there are increasing cost to scale ($p<0.01$). However, this result is not surprising since it is expected that larger vineyards address production more intensively. On the other hand, specialization in variety is not relevant on Revenue nor Profit but significant on Direct Cost, where a positive change of 1% reduces costs by 0.15% ($p<0.01$). This may be because specialization has the possibility of reducing unit costs and structure of expenditures by limiting complexity in management (Czyżewski y Smędzik-Ambroży, 2015).

Other variables that were included as control variables were valley and water availability for irrigation. Regarding the latter, lower Revenue and Profit are observed when vineyards face scarcity of water resources ($p<0.05$), which is understandable as it result in a productive limitation. As for the production valley, we can see that Rapel's winegrowers have larger Profit than in other valleys, 41% higher than in Curicó and even more high compared to Maule, last place where winegrowers present lesser Revenue and Direct Cost ($p<0.01$).

Of the three agricultural technologies evaluated, we can observe that each one has different implications in the economic performance of winegrowers. For example, producers with pressurized irrigation versus those irrigating in a gravitational manner, have significantly higher Revenue (17%) but no higher Direct Cost, resulting in 43% higher Profit ($p<0.01$). However, with respect to have instruments that measure meteorological conditions to schedule irrigation, there is no evidence that they affect statistically neither Revenue, Direct Cost nor Profit. As for mechanization, the result is significantly increases in Revenue and Direct Cost ($p <0.05$); although the effect is not transferred to the margins due they are counteracted.

Finally, in terms of production approaches interesting results were obtained, since basically all have a significant impact on the economic performance of the vineyards. When the main variety grown is red grape compared to white grape, Revenue is 37% lower and Direct Cost are not significantly different, which translates into 75% lower Profits. On the other hand, the vine training system is key along the three equations, since conducting the vines as Tendone or Pergola, versus vertical systems, increases 58% the Revenue, 30% the Direct Cost and therefore, 92% the Profit ($p<0.01$). Regarding grape destination, when vineyard produces reserve grapes of higher quality than varietals, the Revenue is 22% higher and Direct Cost 11% higher, resulting also in 41% higher Profit ($p<0.01$). The above indicates that choosing a production approach may be associated with higher Direct Costs, however, this fact is compensated by obtaining a greater Revenue that also lead to higher Profit. That is, there is a prize for the effort made, which clearly makes sense from the economic point of view.

Conclusions

The economic performance analysis carried out in this study showed how vineyards could improve their profits by adopting different production approaches or technologies, and also to understand their effect on revenues and direct cost. In this sense, it has been demonstrated that managerial performance, quality product and productivity is essential to be profitable within the bounds that winegrowers face. The above is relevant in terms of agricultural policy to the extent that efficiency at the vineyard level can have an impact on the commercial success of a whole industry.

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Annex 1

Geographical characterization of Rapel, Curicó and Maule valleys.

Valley	Surveyed producers	Characteristics
Rapel	164	Composed by the sub-valleys Cachapoal and Colchagua, both are located in the O'Higgins region of Chile and are characterized by their sub-humid, Mediterranean temperate climate, ideal for the production of red varieties. The hours of light, high thermal oscillation, and the existence of various microclimates allow for growing different wine strains. This region has a pronounced seasonality, where winter concentrates the most of annual rainfall. It has an average temperature of 22° C and precipitation around 600 mm. The soils are alluvial in origin. These valleys are located north of the Curicó and Maule valleys.
Curicó	91	Located in the Maule region of Chile. Curicó valley is considered the center of the Chilean wine growing because of its high concentration of vineyards. It has a temperate Mediterranean climate with a dry period five months a year, precipitation around 700 mm, and an average temperature of 20° C. White varieties are best grown in coolest areas of the valley. It has numerous water sources and the soil is alluvial and volcanic in origin.
Maule	181	Located in the Maule region of Chile south of Curicó valley and considered the "Cradle of Chilean wine" because of its origin during the time of Spanish colonization. It has a temperate Mediterranean climate with rainy winters. The soils are acids and clayed, which partially reduces productivity to benefit the quality of the grapes. It has many rivers that also exert influence on the quality of their wines.
Total	436	