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Technical efficiency and marketing channels among small-scale farmers: evidence for raspberry production in Chile

RESEARCH ARTICLE

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Abstract

This study analyses technical efficiency (TE) levels among small-scale raspberry producers in Central Chile. Special attention is given in to investigate the impact of the marketing channel used by the farmers on their technical performance. The data used in this study were obtained from a farm-level survey of 139 small-scale raspberry farmers. A stochastic production frontier model was used to evaluate the association between TE, extension, training and farmers' decisions to sell their production directly to the agro-industry or indirectly through an informal middleman. The empirical results show that the decision to sell raspberries using informal channels is negatively associated with farm productivity and revenues. The analysis also reveals a positive relationship between TE and income among experienced and trained farmers. Implementing food quality and safety standards was also found decisive in increasing farm income. Policy implications stemming from these results are also discussed.

Keywords: marketing channels, stochastic production frontiers, technical efficiency, small-scale farmers, raspberry, productivity
JEL code: D24, F63, Q13, O13

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1. Introduction

Since the 1960s, Chile has promoted non-traditional exports as part of a general outward-looking economic strategy (Barham *et al.*, 1992; Melo *et al.*, 2014). During the last 10 years, the value of fruit exports has increased at annual averages close to 13%. In the 2015 season, more than 50% of the fruit production was exported, representing over US $4.4 billion in sales (ODEPA, 2017a). Raspberry production represents approximately 3% of total fruit exports. However, this is an important economic enterprise for a large number of small-scale farmers, and thus has a substantial implication for the economic wellbeing of many rural families and their communities (Domínguez, 2012).

Raspberries have shown high volatility in real prices over time. Real prices can fluctuate by as much as 300% from one season to the next, making raspberry a very risky endeavor with the potential for high profits, but also for high losses (Challies and Murray, 2011). Figure 1 shows the average price per kilogram received by Chilean farmers. Lower prices during 2005 and 2012 can be explained by high levels of global production especially in Poland, Serbia and USA (the three top raspberry producers in the world, Chile ranks fourth). On the contrary, in 2008 and 2014 global output decreased due to adverse climatic conditions in many countries resulting in higher prices and revenues for Chilean producers (Fedefruta, 2016). This variability in revenues combined with high labor costs has forced medium-to-large producers in Chile to exit the market, and has allowed small-scale farmers, mostly family operations, to expand their participation in raspberry production.

Chile currently has over 21,000 farmers growing raspberries on 16,000 hectares, which results in an average farm size equal to 0.76 hectares. Raspberry production is concentrated in the Maule Region (67% of the total land and 77% of farmers) with an average farm size below of the national average at 0.66 hectares. The Bio-Bio and Los Lagos regions account for 20 and 10% of the total land, respectively (SAG, 2016).

Raspberries are highly susceptible to physical damage and bruising; therefore, harvest and post-harvest grading and packing require intensive use of well-trained workers to handle these activities. Mechanical harvesting saves a significant amount of labor, an increasingly scarce resource in Chilean agriculture; however, the initial capital outlay and maintenance costs of mechanized systems are substantial, making them financially feasible only for large-scale operations. Moreover, the overall farm architecture (i.e. spacing and layout of

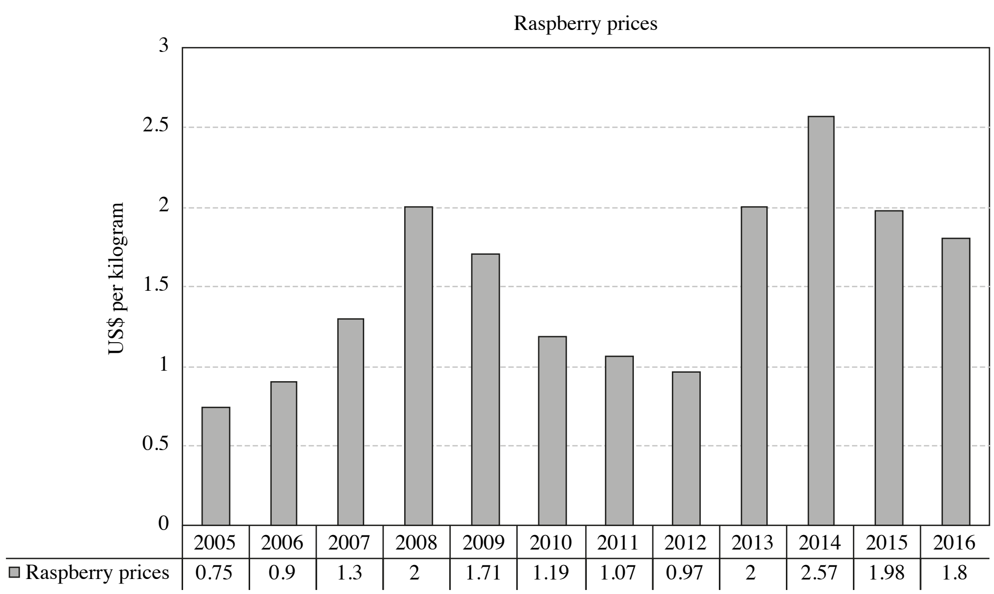

Figure 1. Average prices received by farmers in US$ per kilogram, 2005-2016 (adapted from ODEPA, 2017b).

hedgerows, trellises and irrigation systems) must be redesigned to accommodate mechanical harvesting and the initial capital required for such farm transformation is considerable (Strik, 2007). Cultivars suitable for mechanical harvesting are also required. Thus, the innovation process requires high levels of investment but lack of funds among small-scale farmers is a significant constraint for the Chilean raspberry sector (Challies and Murray, 2011).

In Chile, the National Institute for Agricultural Development (INDAP, its official acronym in Spanish) is the main agency providing support to small-scale agriculture, with the aim of improving the competitiveness and market orientation of small-scale farmers. INDAP also finances technical assistance and management programs, and implements general assistance for low-income farmers (OECD, 2008). The agricultural extension assistance for raspberry farmers is mainly focused on various aspects of production and on helping farmers to comply with regulations focusing on Good Agricultural Practices (GAP). A total of 280,000 small-scale farmers cultivate four million hectares, almost 25% of the agricultural land in Chile. These farmers produce roughly 45% of the annual crops (317,058 hectares), vegetables (31,342 hectares), wine grapes (56,250 hectares) and livestock in the country, and 29% (86,143 hectares) of the major fruit crops (apples, avocados, and table grapes). More importantly, in the context of this study, small-scale farmers account for 96% of all raspberries grown in the country (SAG, 2016).

Considering that raspberry production is an important cash crop for small-scale producers and that the lack of funds is one of the main barriers to improve production levels, Domínguez (2012) describes a set of priorities that must be addressed to increase the competitiveness and productivity of this sector. These priories include: (1) establishment of plant breeding programs to develop higher yielding varieties; (2) streamlining marketing channels; (3) greater focus on Individually Quick Frozen (IQF) products rather than block pack products to generate higher farm revenues; and (4) adaptation to climate fluctuations, particularly through the adoption of improved irrigation technologies. These are important priorities but the work required to develop and promote the adoption of innovations is a lengthy process especially for small-scale farmers. Consequently, in the short run, it is critical that farmers make the best use of their current technologies in order to enhance their competitiveness. In this context, understanding the efficiency gaps that might exist in the utilization of the available technology is an important endeavor.

Numerous empirical studies had estimated productivity and efficiency gaps in agriculture, focusing mainly on annual crops, dairy or livestock sectors (Elasraag and Alarcón, 2015). However, empirical studies centering on the productivity of the fruit sector, especially among small-scale farmers, are scarce. The few exceptions are Plénet *et al.* (2009), who measured efficiency in peach and nectarine production in France, and Henriques *et al.* (2009) and Moreira *et al.* (2011) who studied the TE of vineyards for wine production. There is also some work on table grapes (Ma *et al.*, 2012), olives (Lachaal *et al.*, 2005), and citrus (Lambarraa *et al.*, 2007); but, to our knowledge, the present article is the first to study farm level TE for raspberry production.

The main goal of this article is to describe the production technology of small-scale raspberry farmers and analyze prevailing TE levels in the Maule region of Chile. Studying the sources of efficiency in agriculture is important because it allows farmers and policy makers to identify and target private and public resources in the most appropriate manner to improve agricultural production, productivity and agricultural incomes (Bravo-Ureta *et al.* 2007; Ogundari 2014). Our study also adds to the literature by explicitly analyzing the relationship between technical efficiency and the marketing channel used.

2. Overview of the raspberry agricultural chain sector.

Around 80% of the Chilean raspberry agricultural chain is export-oriented, berries are processed as frozen and the rest are exported as pulp or juice (Challies and Murray, 2011). Exports of fresh raspberries were interrupted in 2010 when Serbia and Mexico started to provide fresh fruit to Europe and USA at lower prices than Chile (Domínguez, 2012) and, as a result, production is currently marketed almost exclusively as processed fruit (Fedefruta, 2016).

The international market for fresh fruit is regulated by different standards and norms, some of which are mandatory and enforced by public entities. Other standards are voluntary, developed by global food distribution chains, such as GlobalGap (Neven and Reardon, 2004). In developed countries, mandatory private food safety and quality standards govern the importation of fresh fruits. These norms are also becoming increasingly important in the domestic markets of many non-OECD countries in Africa, Latin America and East Asia due to the expansion of supermarket chains (Henson and Humphrey, 2009).

The market exclusion of small-scale farmers due to lack of funds is a concern, and strategies that encourage the implementation of stringent requirements pose major challenges for policymakers in providing opportunities for small-scale farmers to upgrade their operations (Asfaw *et al.*, 2009). In Chile, since 2000, there have been several initiatives to support the certification of private GAP such as GlobalGAP or TESCO, which are standards to facilitate access to the most competitive and demanding markets. The results have been successful especially for medium and large farmers (Cofré *et al.*, 2012). In the case of small-scale farmers, INDAP has promoted GAP practices among small-scale famers since 2005 with mixed results. Handschuch *et al.* (2013) show that the main barriers to implementing GAP certification among raspberry farmers are low educational levels, limited volumes and poor quality of the fruit sold. However, once farmers adopt GAP certification, a positive effect has been observed on the quality of their fruit as well as on their net raspberry income. Small-scale production and low levels of formal education are major challenges to meet any type of certification process (Handschuch *et al.*, 2013). Therefore, small-scale farmers are highly dependent on the technical support provided by extension agents contracted by INDAP, such as Technical Assistance Service (SAT) and Local Development Program (PRODESAL), to guide farm management and fruit marketing, and to help comply with standards. SAT includes extension support, as well as the design, financing, monitoring and evaluation of technical assistance projects that are implemented in the field by external contractors (Apey and Barril, 2006). The aim of SAT is to increase the competitiveness of peasant enterprises in national and international markets. In contrast, PRODESAL aims to build technical and productive capacity among low-income, small-scale farmers and their families, with the goal of increasing their share of value added along the production process. PRODESAL is implemented at the local level through agreements between INDAP and municipal governments (Challies and Murray, 2011). Likewise INDAP provides financial capital exclusively for small-scale farmers such as credits (short or long run) and investment projects. The Investment Development Program (PDI) is an initiative that co-finances investment projects that enable the modernization of production processes, and provides support for project design and implementation. The difference with credit is that PDI is a non-refundable benefit.

In Chile, raspberry farmers have two alternative marketing channels: direct sale to the agro-industry; and the use of an informal trader (Challies, 2010). Formal channels include sending the fruit to raspberry collection centers located near the raspberry fields, from where the fruit is transported to agro-industry firms. Formal channels also include the possibility of sending the fruit directly to agro-industry firms. Usually the fruit is sent to collection centers or agro-industry in trays (not pre-packed). Under both modalities, the payment conditions are 30 to 60 days from the date of the invoice. The agro-industry firms export the raspberries directly or sell them to domestic wholesalers.

An alternative trading system includes transient intermediary traders, known colloquially (and slightly derogatorily) as *conchenchos,* which are common players in the informal trade business (Challies and Murray, 2011). *Conchenchos* generally buy raspberries by the tray for as low a cash price as possible, and then transport the fruit and sell it to agro-industry firms. Also there is a strong connection among low prices and low quality of the fruit. Despite the low prices they pay, these informal traders solve several problems especially for disadvantaged farmers: (1) they provide transportation for those producers who have no private means and cannot deliver their produce directly to an agro-industrial market; (2) provide immediate cash for farmers' operational and living expenses; and (3) make it possible to have transactions without formal invoicing, thus avoiding tax payments.

3. Material and methods

3.1 Methodological approach

In this study, we employ Stochastic Production Frontier (SPF) methodology to measure farm level TE. Following Battese and Coelli (1995), the general model can be depicted as:

$$Y_i = \exp(\chi_i\beta + v_i - \mu_i) \quad (1)$$

where Y_i is the value of the raspberries produced by the i^{th} farmer, x are inputs, β is a vector of unknown parameters, and $v–\mu=\varepsilon$ is the composed error term. The term v represents a two-sided random error with a normal distribution (v~N $[0, \sigma_v^2]$) that captures stochastic factors beyond the farmer's control (e.g. climate, luck, etc.) and statistical noise. The term μ is a one-sided non-negative component that captures the TE of the producer. In other words, μ measures the gap between observed and maximum output that could be produced if the farm operated on the frontier, given the technology, inputs and the production environment. TE for the i^{th} farm can be measured as:

$$TE_i = \exp(-\mu_i) \quad (2)$$

where μ is the efficiency term as defined above. TE for each farm is calculated using the conditional mean of *exp*(–μ), given the composed error term for the stochastic frontier model (Battese and Coelli, 1988). TE ranges between 0 and 100%, where a value of 100% denotes full efficiency.

The maximum-likelihood method developed by Battese and Coelli (1995) makes it possible to estimate the determinants of farm technical inefficiency (TI) in a one-step procedure. Thus, TI can be estimated by incorporating the following expression in the frontier model shown in Equation 1:

$$\mu_j = \delta_0 + \sum_{n=1}^{k} \delta_n z_{nj} + \omega_j \quad (3)$$

where μ_j is technical inefficiency, z_{nj} are variables that affect efficiency, δ_n are unknown parameters to be estimated, and ω_j is an error term.

3.2 Data, study area and empirical model

This study was undertaken in the North Maule Basin, Province of Curicó, in Central Chile (Figure 2). The data used were obtained from a farm-level survey of 139 small-scale farmers, carried out between July and September of 2011. The questionnaire was divided into the following six sections: (1) human capital; (2) crops and land use; (3) inputs and infrastructure; (4) credit and incentives; (5) social capital; and (6) perceptions[1].

To estimate TE levels and its determinants we used the following Cobb-Douglas (CD) stochastic production frontier:

$$\begin{aligned} \ln Raspberry_i = {} & \alpha_i + \beta_1 \ln Land_i + \beta_2 \ln Pinputs_i + \beta_3 \ln Labor_i + \beta_4 \ln Channel_i \\ & + \beta_5 \ln Plants_i + v_i - \mu_i\,[\delta_0 + \delta_1\, Age_i + \delta_2\, Education_i + \delta_3\, Experiencie_i \\ & + \delta_4\, Extension_i + \delta_5\, Training_i + \omega_i] \end{aligned} \quad (4)$$

where *Raspberry* represents the value of the raspberry production of the i^{th} farm; *Land* is the number of hectares devoted to raspberry production; *Pinputs* represents expenses on purchased inputs used for raspberries

[1] A copy of the questionnaire can be found in Supplementary materials S1.

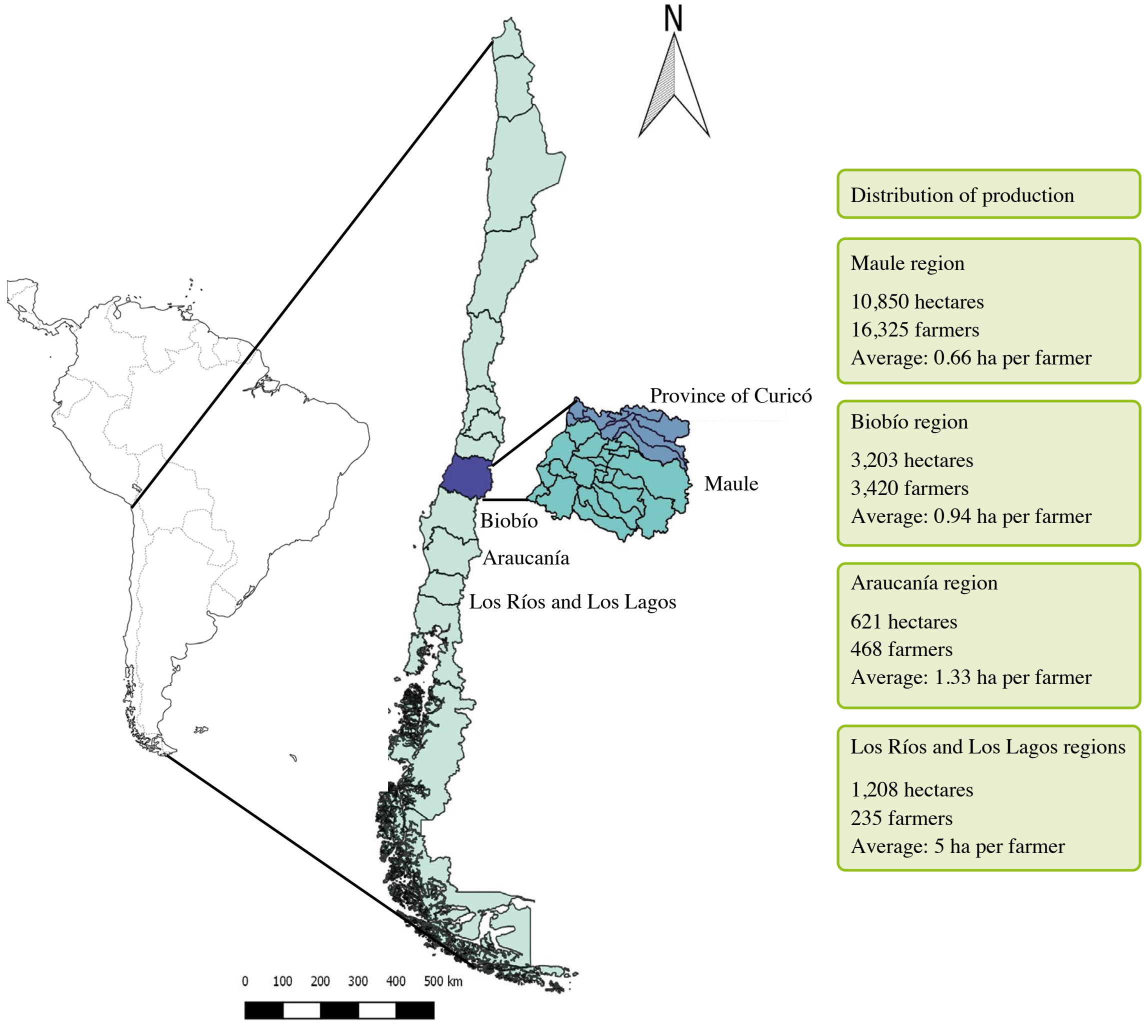

Figure 2. Study area and raspberry statistics.

(new vegetative material, fertilizers, pesticides); *Labor* is the value of both unpaid (family) and hired labor. The value of unpaid labor was computed as kilograms harvested by family members times the price paid to hired workers per kilogram; *Plants* is a continuous variable that specifies the age of the canes in years and controls for the productive potential of the raspberry plants (younger plants are expected to produce more than older ones). *Channel* is a dummy variable equal to 1 if the fruit is marketed directly and zero if a trader is used. It is important to indicate that the decision to sell the production directly or indirectly is made post hoc, i.e. at harvest time. Therefore, the type of trade system selected does not affect the production decisions implemented by the farmer. This issue is important because it avoids any potential endogeneity problems in our estimations shown in Section 3. We should also mention that the raspberry producers in our data do not have pre-production contracts.

The inefficiency term μ_i is explained by the following variables: *Age* and *Education* of the household head, both in years; *Experience* or knowledge of raspberry production of the household head; *Extension* (if the household head received extension); and *Training* (if the household head participated in training courses). The βs and δs are the parameters to be estimated; v_i is the stochastic noise; and ω_j is an error term. Table 1 shows a definition of variables used included in Equation 4.

Table 1. Definitions of variables used in the econometric model.

Variable	Type	Definition
Raspberry	continuous	raspberry production value in US$
Land	continuous	hectares worked
Inputs	continuous	expense in plants, fertilizers, and pesticides in US$
Labor	continuous	value of total labor in US$
Channel	dummy	1 if the farmer sold his produce to an informal trader; 0 if the produce is sold in the agri-industry
Plants	continuous	age of the raspberry plants, in years
Age	continuous	age of the farmer, in years
Education	continuous	education of the farmer, in years
Experience	continuous	farmer's experience in raspberry production, in years
Extension	dummy	1 if the producer has received technical assistance by INDAP; 0 otherwise
Training	dummy	1 if the producer has participated in training courses in raspberry production; 0 otherwise

4. Results and discussion

Table 2 presents descriptive statistics for the sample. On average, the annual value of raspberry production is US $3,760 per farm, with a standard deviation of US$ 3,286. On average, the amount of *Land* devoted to raspberry production in our sample is one hectare, and the average expenditure in fertilizers and pesticides (*Pinputs*) is US$ 148. The amount spent on new plants is nearly zero, despite the fact that young plants and improved varieties are crucial to increase the productivity and competitiveness of the sector. *Labor* represents the major expense in raspberry production and has an average value, including unpaid family labor, of US$ 2,246. Direct costs, the sum of the expenditures on *Labor* and *Pinput,* reach US$ 2,494 on average. There is no official statistics for small-scale raspberry producers in Chile, but for medium and large-scale farmers the average direct cost is approximately US$ 6,800 (ODEPA, 2016). This difference is not surprising given the higher labor and overhead costs that lager farmers encounter in comparison to family farms.

The average age of the head of household is 52 years, which is consistent with other studies focusing on small-scale farmers in Chile (Jara-Rojas *et al.*, 2012a, 2013). The level of education of the household head in the sample is low with only 7.8 years of schooling. On average, household heads have 13.4 years of experience in raspberry production. Many (42.5%) of the farmers have contacts with extension from SAT or PRODESAL, and 40.3% have received training in topics related to raspberry production and GAP.

Table 2. Descriptive statistics of the variables included in the econometric model.

Variable	Units	Mean	Std. dev.	Max.	Min.
Raspberry	US$	3,760	3,286	17,272	136
Land	hectares	1.0	0.7	5.0	0.1
Pinputs	US$	148	182	1,515	5.3
Labor	US$	2,246	1,941	10,850	60
Channel	%	74.1	–	–	–
Plants	years	5.7	2.6	11.0	2.0
Age	years	51.5	8.7	76.0	24.0
Education	years	7.8	3.2	14.0	2.0
Experience	years	13.4	5.6	22.0	2.0
Extension	%	42.5	–	–	–
Training	%	40.3	–	–	–

Table 3 presents the maximum likelihood estimates for the SPF model. The null hypothesis that γ=0 is rejected at the 1% significance level, which lends support to the SPF model, i.e. the SPF model is superior to an average production function resulting from estimation using ordinary least squares. Moreover, the value for γ is statistically significant, with a value of 0.78, which indicates that inefficiency is an important contributor to observed output variability (Battese and Coelli, 1995). The function coefficient is 0.922, revealing decreasing returns to scale.

The parameters for the three inputs in the CD production frontier, which can be interpreted as partial production elasticities, are statistically significant at the 5% level or better. Typically, *Land* exhibits the largest elasticity in studies analyzing small-scale agriculture (Jaime and Salazar, 2011). However, our study suggests that *Labor* is the most significant input, with a partial elasticity equal to 0.62. This value indicates that a 10% increase in the value of *Labor* results in a 6.2% increase in the value of production revealing the importance of labor in raspberry farming. According to our survey data, harvest labor accounts for roughly 95% of labor costs and 93% of total operating costs. Other TE studies dealing with fruit production report higher levels of elasticity for land (Coelli and Sanders, 2013; Guesmi *et al.*, 2012; Moreira *et al.*, 2011).

The parameter of the variable *Plants* is negative and significant, which confirms the fact that raspberry plants produce less as they age. Raspberry plants have their best yields in the first six years, but many farmers keep their plants for more than 10 years. Although the *Plants* parameter does not capture the possible effect of different raspberry varieties, this is a matter that should be considered by farmers, consultants, and policy makers. In our study, 99% of the farmers grow the 'Heritage' variety, but it is likely that using improved varieties could increase yields and fruit quality. Figure 3 shows the decreasing association between yield and years of the plants of our sample. Usually small-scale farmers producing own plants and thus the potential yields are lower than certified nursery plants.

Of particular importance in this study is the parameter for the dichotomous variable *Channel*, which equals 1 if the fruit is marketed directly and zero if a trader is used. Our estimates show that the parameter for *Channel* is negative and significant with a value of -0.156. This result suggests that farmers who sell their

Table 3. Stochastic production frontier results.[1]

Variable	Coefficients	Standard error
Constant	5.715***	0.905
Land	0.214***	0.069
Purchased inputs	0.086**	0.047
Labor	0.622***	0.061
Channel	-0.156*	0.100
Plants	-0.099***	0.020
Inefficiency model		
Constant	4.925***	1.690
Age	-0.050***	0.022
Education	-0.057	0.066
Experience	-0.287***	0.068
Extension	-0.559	0.696
Training	-1.569***	0.783
Returns to scale	0.922	
Log likelihood function	80.47	
$\sigma^2 = \sigma_v^2 + \sigma_u^2$	0.690***	0.105
$\gamma = \sigma_u^2 / \sigma^2$	0.780***	0.079
Average TE	81.0%	

[1] *** = significant at 1%; TE = technical efficiency.

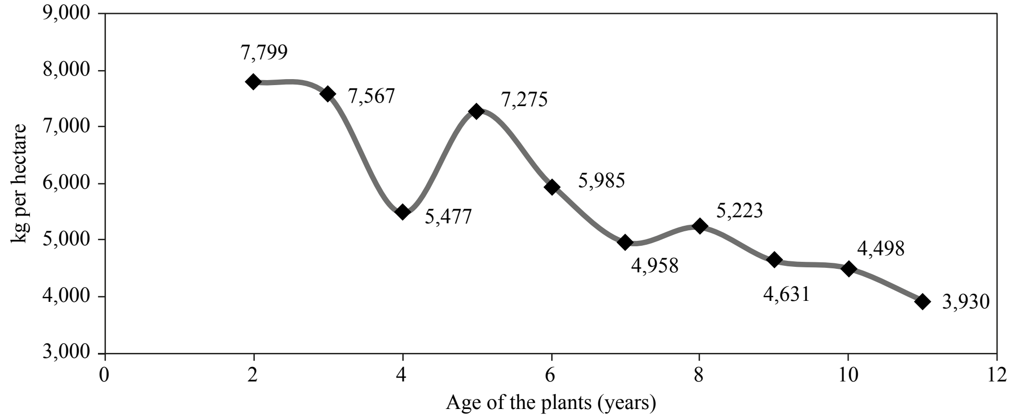

Figure 3. Production in kilograms per hectare and age of the plants.

production using an informal trader (or *conchencho*) have a value of output that is 25% lower (US$ 3,463 vs 4,613)[2], *ceteris paribus*, than those who sell directly to the market. As mentioned, *Channel* is related to the quality of the fruit. Farmers who can meet high quality standards can sell to the markets for fresh or frozen IQF raspberries; thus, getting a higher price compared to those with lower quality fruit who must sell the berries to juice or marmalade factories or to an informal trader.

Our results also show a strong relationship between the level of GAP practices employed in the farm and the use of formal trade (Table 4). Farmers in our sample use 12 different GAP practices. Specifically, most of the farmers (82.6%) with lower level of GAP (1 to 3 practices) sell their production to informal traders. This percentage decreases to less than 50% for those farmers with 6 GAP practices. On average, farmers in our sample have implemented 5 of the 12 recommended practices and the most adopted is 'Fruit storage', which is a place where farmers select, classify and pack the fruit prior to transportation to the agro-industry. Table 4 also shows a positive trend between the number of GAPs implemented and income. Ten farmers had implemented 10-12 GAP practices and their average income was US$ 7,554, while the income for those farmers with 1-3 was US$ 1,288. Handschuch *et al.* (2013) show that Chilean small-scale raspberry farmers benefit from the implementation of food quality and safety standards through better farming and higher management skills. Our findings reveal a direct link between GAP practices, higher volume and better quality. Gains in fruit quality also facilitate the access to formal markets and thus higher income.

Figure 4 shows the distribution of TE levels among our studied sample. The average TE level is 81% indicating that, an average farm in the sample could, in principle, increase its level of production by 19% using the current input quantities and technology. Figure 4 also shows that more than 50% of producers attain TE in the 70-79% range; and 22% of farmers reach a TE of 90% or higher. The average TE value is consistent with other studies focused on Latin America. Jara-Rojas *et al.* (2012b) reported an average level of TE of 80%, Solís *et al.* (2009) 78%, and Bravo-Ureta *et al.* (2007) found an average TE of 78% in their meta-analysis.

The bottom of Table 3 presents the parameters of the determinants of inefficiency. Following the usual practice, the interpretation is in terms of TE (instead of inefficiency). Frequently, the variable *Age* is used as a proxy for household experience. However, the literature shows mixed results with respect to the relationship between *Age* and TE. For example, young farmers can be relatively more efficient because they are more educated (Mariano *et al.*, 2010); yet, older farmers can exhibit higher efficient due to more experience (Jaime and Salazar, 2011). Following Bozoğlu and Ceyhan (2007), we include the variables *Age* and *Experience* separately. Our results indicate that younger farmers are more efficient, but the parameter is

[2] In terms of value per hectare, the average production value for those farmers that sell directly to the market is US$ 4,075/ha, and for those farmers using an informal trader is US$ 3,017/ha.

Table 4. Good Agricultural Practices (GAP) practices and raspberry income.

Type of GAP practices			**Number of GAP**		
	N° of farmers	% of total	Frequency	N° of farmers	% of total
Input warehouse	78	56.1	1	4	2.88
Harvest tools warehouse	84	60.4	2	5	3.60
Packing	7	5.0	3	14	10.07
Fruit storage	114	82.0	4	20	14.39
Latrines	94	67.6	5	37	26.62
Fence	42	30.2	6	29	20.86
Signs	38	27.3	7	9	6.47
Workers dining	18	12.9	8	7	5.04
SAG[1] records	57	41.0	9	4	2.88
Input applications records	124	89.2	10	4	2.88
Harvest records	50	36.0	11	1	0.72
Formal business	48	34.5	12	5	3.60

	Informal channel sales?		
Number of GAP practices	Yes	No	Raspberry income[2]
1-3	n=19 (82.6%)	n=4 (17.4%)	US$ 1,288[a]
4-6	n=73 (76.8%)	n=22 (23.2%)	US$ 3,317[b]
7-9	n=6 (54.5%)	n=5 (45.5%)	US$ 4,017[b]
10-12	n=5 (50.0%)	n=5 (50.0%)	US$ 7,554[c]

[1] The Chilean Agriculture and Livestock Service (SAG) is the institution in charge of record of raspberry farmers and other value chain participants (e.g. traders, packing). Also SAG is in charge of monitoring GAP norms for farmers (food safety norm 341).
[2] Different letters indicate significant differences (Tukey's test, P<0.05) in raspberry income among different groups of GAP practices.

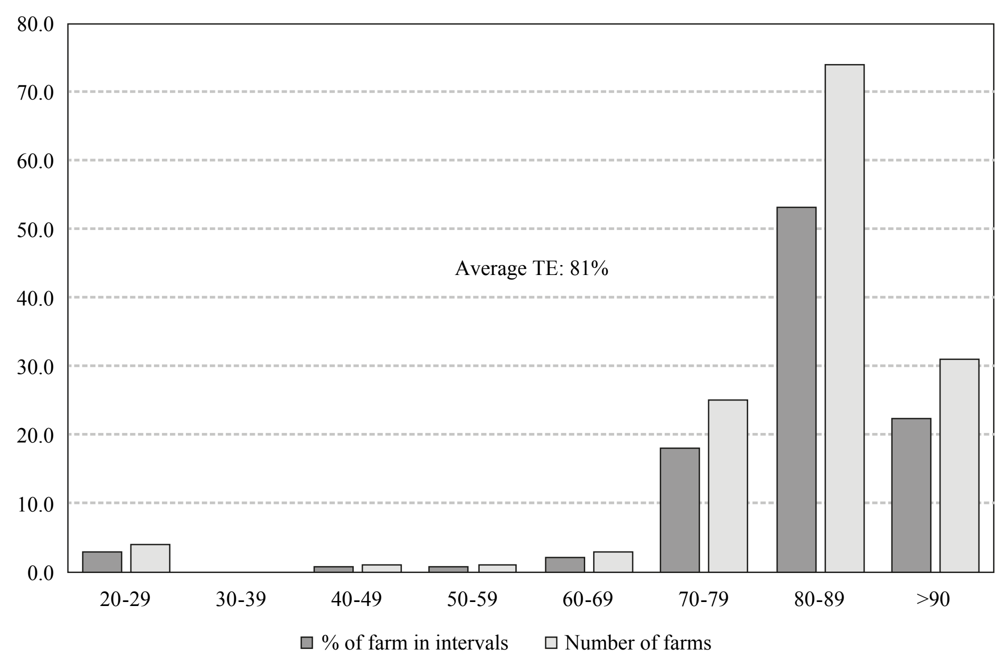

Figure 4. Distribution of technical efficiency (TE) scores.

not significant, while *Experience* in raspberry production is positively and significantly associated with TE. This result is in line with Rao *et al.* (2012) that analyze the participation in supermarket channels among vegetable producers in Kenya.

The parameter for *Education* shows a positive but non-significant relationship with TE. Abdulai and Huffman (2000) found that education has a positive and significant effect on TE, and suggested that an appropriate response to changes in market prices requires management skills acquired through education and access to information. Also, Asfaw *et al.* (2009) identify the lack of human and physical capital as major factors that limit the adoption of safety standards by small-scale farmers. The same authors add that public investment designed to promote farmers' productivity and connectivity to markets, and the promotion of collaborative action among producers are crucial policies to build the technical capacity of farmers.

Consistent with Feder *et al.* (2004), the variable *Extension* shows a positive but non-significant relationship with TE. The *Extension* services provided by the PRODESAL and SAT programs focus on various aspects of production, such as fertilization and crop protection, but do not address issues related to marketing channels that could explain this result. Extension services showed a positive association with TE in Lindara *et al.* (2006). The parameter for the variable *Training* is significant and reveals a positive effect on TE. Training is defined as short courses taken by farmers, usually related to raspberry production and GAP topics. This result suggests that training courses that help farmers develop GAP help boost TE and this finding is consistent with those of Li and Sicular (2013).

Table 5 shows mean values for TE, Raspberry Income (RI) and Gross Margin (GM) among farmers in the sample for several variables. For example, TE, RI and GM for farmers who sold their produce to an informal trader (captured by the variable *Channel*) are significantly lower than for those farmers who sold to the agro-industry. Similar significant differences are exhibited when comparing farmers with training who had an average TE of 84% and an average RI of US$ 4,676, while those without training had an average TE of 80% and an average RI of US$ 3,176. Challies (2010) also found that training courses are highly beneficial in helping small-scale farmers become successful raspberry producers. In addition, we include the variable *Project*, which captures the effect of the PDI program and the results show that participants reach significantly higher levels of TE (84%), RI (US$ 5,497) and GM (US$ 4,596) compared to farmers

Table 5. Differences in technical efficiency (TE), income and gross margin.

Variable	N (%)	TE (%)	Raspberry income[1]	Gross margin[2]
Channel				
Informal trade	74	81.6	3,463	1,059
Formal trade	26	83.1	4,613*	2,247*
Projects				
Without PDI[3]	81	81.2	3,361	4,485
With PDI	19	85.3*	5,497*	4,596
Training				
No	60	80.7	3,176	4,485
Yes	40	84.0*	4,676*	4,596*
Credit by INDAP				
No	57	81.5	3,994	4,441
Yes	43	82.6	3,573	4,743

[1] Total raspberry income in US$.

[2] The gross margin (*GM*) is computed as Raspberry Income (*RI*) less expenditures on Purchased Inputs (*PI*) and Labor Cost (*LC*): $GM = RI - (PI + LC)$

[3] PDI = Investment Development Program.

* Indicates significant differences at 5% confidence level (*t*-test)

without such projects (TE=81.2%; RI=US$ 3,361; and GM=US$ 4,485, respectively). By contrast, credit provided by INDAP exhibits no significant effects on TE, RI and GM. Usually credit is used to cover direct costs and not for investment.

5. Summary and conclusions

This study analyzed the determinants of TE for a sample of small-scale raspberry farmers in central Chile. The empirical results suggest that the marketing channel used by farmers to sell their production plays an important role on the productivity and TE estimates. The empirical results also showed that human capital, in terms of *Age*, *Experience* and *Training*, is a crucial factor associated with higher levels of TE, where the latter is a proxy for managerial performance.

The Chilean Government is directly involved in supporting small-scale raspberry producers and the overall agricultural chain through SAG and INDAP, two leading governmental agencies within the Ministry of Agriculture (Challies and Murray, 2011). While SAG has a regulatory function, INDAP is the main agency that provides support to small-scale farmers and its mission is to increase the competitiveness of such farmers.

Given that raspberry production is an important source of income for small-scale farmers in Chile, this article has some policy implications that can be of significance to this vulnerable sector of producers. First, to increase the profitability and farm income of the raspberry sector, it is imperative to improve the managerial ability of small-scale farmers. The ability to produce and market high-quality fruit has a major impact on farm profitability particularly when output prices are low as was the case in the 2011-2012 seasons (50% lower than the 2008-2010 period). Thus, training programs provided by INDAP should be designed to promote technical capabilities and compliance with required quality standards. Second, INDAP should improve the targeting of incentive programs that help to acquire new and better varieties of raspberries so as to enhance the productivity of the sector. Finally, now that small-scale farmers have been working on raspberry production for more than 15 years, it is important to strengthen technical assistance focusing on managerial topics in order to improve TE and to enhance farm income and profitability among poor rural households.

Supplementary material

Supplementary material can be found online at https://doi.org/10.22434/IFAMR2016.0168.

Materials S1. Questionnaire.

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