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Abstract

The influence on technical efficiency of access to credit and public support policies is studied for two groups of specialized small farmers in Chile. Using 2004 data, translog stochastic frontier production functions for 109 livestock and 342 crop producers are estimated. Mean technical efficiency is 89% and 78% for crop and livestock producers, respectively. Technical efficiency increases with decreasing use of inputs, dependence on on-farm income, farmer education, family size and the age of the family head. Extension services do not appear to help farms become more efficient, and even reduce efficiency among specialised crop producers. The volume of credit increases efficiency in crop production and reduces it in livestock production. Correspondingly, credit constrained farmers are less efficient in crop production and more efficient in livestock. These results may reflect the fact that investments in livestock production can involve considerable adjustment costs in the short run. For livestock producers, credit volume and credit constraints are found to be endogenous to technical efficiency. A possible explanation is the organisation of public support for small livestock producers in Chile, which provides lenders with information about individual livestock producers. This might enable lenders to target loans on the basis of efficiency. Correcting for this endogeneity does not lead to qualitatively different results, but does influence point estimates of parameters in the production function and inefficiency models. This highlights the importance of testing for endogeneity in the variables used to model inefficiency effects.

1 Introduction

Since Chile opened its economy at the end of the 1970s, the agricultural sector has experienced rapid growth and changes in land use. Driven by export demand, the production of fruits, vegetables and forestry products has increased relative to livestock and field crop production. Today, the perception of Chilean agriculture abroad is dominated by large export-oriented farms producing fruits, vegetables and wine. From a domestic policy perspective, however, the over 278,000 small farms in Chile are also of great importance. Operating on an average of 14 hectares each, these farms account for 85% of all farms and over 40% of the

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areas dedicated to crop, vegetable and grape production, and of the numbers of dairy cows and beef cattle in Chile.

Access to technology and credit are critical determinants of competitiveness in agriculture. The Chilean government implements policies that are intended to support small farms by increasing their access to technology (via extension services) and credit (via credit provision). Since 1978, state subsidies have supported the provision by private agencies of extension services to small farms. INDAP (*Instituto de Desarollo Agropecuario*), a public institution that promotes the agricultural development of small farmers, defines overall policy orientations, manages funds, conducts monitoring and evaluation, and provides training to the staff of the private companies that provide extension services to small farmers in Chile.

Furthermore, although the financing of Chilean agriculture is mainly based on private sector funds (such as farmer's own resources, formal and informal capital markets, and loans from agribusiness firms and export companies), INDAP also provides credit to a large number of small farmers who have difficulty securing loans on formal credit markets. Quiroz (2002) argues that banks in Chile are often unfamiliar with the unique characteristics and requirements of agriculture, and are correspondingly wary of lending especially to medium- and small-sized farmers. Credit markets for livestock producers are particularly underdeveloped. Discussions with lenders suggest that it is more difficult to establish creditworthiness in livestock than in crop production because livestock producers tend to have less collateral and weaker relations with up- and downstream agribusiness, and because the relationship between credit use and improvements in profitability is more tenuous and slower to unfold in livestock production. INDAP and the public Banco Estado, the main providers of credit to agriculture, have responded by designing special credit channels for livestock producers.

In general, little is known about the impact of access to extension and credit on the efficiency of small farms. The purpose of this study is to cast light on the impact of extension services and credit on the technical efficiency of specialised smallholder crop and livestock farms in Chile. Using detailed cross-section data from 2004 we address the following questions:

- Is there evidence that extension services increases technical efficiency?
- Are specialised smallholder farms credit constrained?
- Does access to credit influence technical efficiency?
- Do the answers to these questions differ between smallholders specialising in crop production and those specialising in livestock?

We focus on specialised smallholders because these non-subsistence operations are potential crystallisation points around which future viable farm units might form. This focus also enables us to avoid problems associated with adequately modelling multiple-output technology and comparing efficiency across technologies.

This paper makes four main contributions. *First*, it provides the first estimates of technical efficiency for small farmers in Chile based on a country-wide sample. Despite the importance and growth of agriculture in Chile in recent decades, we are aware of only two other studies of the efficiency of Chilean agricultural production. Santos at el. (2006) studies technical efficiency in potato production in the country's central zone, and Moreira et al. (2006) studies technical efficiency and technological change for a sample of small dairy farmers in the south zone. *Second*, we model not only the level of technical efficiency, but also the factors that influence its variability across farms in a stochastic frontier setting. To our knowledge this has not been done at all for Chile so far, and only infrequently for small farmers in other settings. Most published studies (e.g. Brümmer and Loy, 2000; Hadri et al., 2003; Curtiss and Brümmer, 2005) that explicitly model the determinants of inefficiency consider much larger farms than we do here. *Third*, we estimate separate impacts of credit volumes and credit constraints on technical efficiency. The relationship between credit and technical efficiency is complex, and theoretical explanations have been proposed for positive and for negative impacts (e.g. Hadley et al., 2001; Davidova and Latruffe, 2003). By estimating separate impacts of credit volumes and credit constraints on technical efficiency, and by doing so for separate samples of crop and livestock producers, we are able to cast light on the relative merits of these theories under the conditions confronting specialised smallholders in Chile. *Fourth*, our analysis explicitly accounts for the possible endogeneity of access to credit. Endogeneity can arise if, for example, farms that are more efficient enjoy easier access to credit. While many authors have studied the impact of financial variables on efficiency, only Davidova and Latruffe (2003) and Liu and Zhuang (2000) address the potential endogeneity of the financial variables that they consider. However, these studies employ different financial variables and empirical methods in settings that differ considerably from ours.

The rest of this paper is structured as follows. In section 2 we briefly review the literature on the impacts of access to extension services and credit on technical efficiency. Empirical methods and data are discussed in section 3. Section 4 present estimation results and section 5 closes with a discussion of conclusions and implications.

2. Review of the literature on the impacts of extension and access to credit on efficiency

Extension can increase farmers' awareness of new technologies (e.g. new varieties, optimal input use, marketing strategies) and impart or improve the management skills that are needed to implement these technologies effectively. There is a broad empirical literature on the impact of extension on efficiency, and in general analysts have found this impact to be positive (Dinar et al., 2007, and citations therein).

As mentioned above, the provision of extension services to small farms by private agencies is subsidised by the state in Chile. Assessments of the performance of these extension services diverge. The Chilean government has contracted its own evaluations (e.g. Berdegué, 1998), and finds that extension has played a positive role in supporting the development of a more competitive, diversified and productive small scale agriculture in Chile, and in alleviating rural poverty. However, Lopez (1996) finds that participation in extension programs does not significantly increase the income of small farmers, although it does increase production (via greater use of inputs rather than improvements in productivity). Bebbington and Sotomayor (1998) argue that the poor performance of extension programs is due to the low quality of the services provided, in particular the limited market orientation and rigour of the technical assistance that has been provided to small farmers in the past. However, Berdegué and Marchant (2000) claim that the evolution of the extension system has solved many earlier problems such as excessive politicization and inefficient field operations. None of these studies explicitly models the impact of extension on technical efficiency.

While extension is generally found to have a positive impact on efficiency, and debates largely revolve around the ability of different modes of delivery (e.g. public vs. private) to tap its potential, the relationship between credit and technical efficiency is more complex. Theoretical explanations for both positive and negative impacts have been proposed (e.g. Hadley et al., 2001; Davidova and Latruffe, 2003). Explanations that point to a positive impact include the theory of *credit evaluation*, according to which lenders may partly base their credit evaluations on a firm's performance. In this case there will be a positive correlation between credit and technical efficiency as inefficient firms will be less likely to receive credit. Of course, this explanation reverses the direction of causality between credit and efficiency, and thus raises the possibility of endogeneity in econometric analysis, as is discussed below. The theory of *free cash flow* asserts that large asset holdings and excess cash flow can encourage a lack of discipline in management, leading to technical inefficiency compared with a situation in which a firm depends on credit (Jensen, 1986). This theory is presumably of limited applicability to smallholder agriculture in Chile. The *embodied capital* approach stresses the importance of credit as a means of making investments that are required to 'keep up' with the production frontier as it shifts upwards over time, and thus to maintain or improve efficiency. Finally, Liu and Zhuang (2000), based on Mukesh and Ashok (1989), argue that credit can *mitigate consumption risk* and thus encourage investment by risk-averse small farmers, promoting technical efficiency.

Explanations for a negative relation between credit and technical efficiency include *agency cost* theory which asserts that lenders deal with the asymmetric distribution of information between themselves and borrowers by transferring higher costs to borrowers in the form of higher interest rates, higher collateral requirements, etc. As a result, more indebted farmers will bear higher costs and be less inefficient, all other things being equal. According to the theory of *adjustment*, changing competitive environments, for example due to trade liberalisation, oblige farms to become more efficient in order to survive. However, since the ability to adjust is negatively related to indebtedness, farms with lower credit burdens are able to adjust more easily and will thus be more efficient.

The empirical evidence on the impact of access to credit on efficiency reflects this heterogeneity. Appendix 1 provides an overview of empirical studies of the relation between credit and technical efficiency, distinguishing between non-parametric and parametric approaches. As illustrated in Appendix 1, most studies analyze the impact of financial exposure, measured as the debt-asset ratio, on technical efficiency. These studies reach varied conclusions, with some finding a significant positive impact of credit on technical efficiency, and others finding a significant negative impact. No studies consider the impact of credit constraints and credit volumes on technical efficiency simultaneously, and only three consider the impact of credit constraints alone. Of these three, Battese and Broca (1997), in an investigation of the importance of the choice of functional forms in parametric efficiency analysis, find a negative relation between credit constraints and efficiency. However, both Liu (2005) and Hazarika and Alwang (2003) find no significant relation. We propose to consider both credit volumes and credit constraints, first because these two dimensions of a farm's credit situation might affect efficiency via different pathways (e.g. *agency cost* theory is especially relevant for farms with large credit volumes, while the theory of adjustment will apply especially to credit constrained farms). Second, credit volumes and credit constraints might interact (e.g. the impact of a given volume of credit will differ according to whether the farm in question is credit constrained or not).

The literature has given only limited attention to the possible endogeneity of access to credit in studies of their impacts on technical efficiency. As mentioned above, *credit evaluation* theory suggests that farms that are more efficient will enjoy easier access to credit because they are perceived by lenders as being more creditworthy. If this is true, estimates of the impact of credit and extension on efficiency will be biased. While many authors have studied the impact of financial variables on efficiency (see Appendix 1), only Davidova and Latruffe (2003) and Liu and Zhuang (2000) address the potential endogeneity of the financial variables that they consider. However, these studies employ different financial variables and empirical methods in settings that differ considerably from ours. Davidova and Latruffe's (2003) analysis is based on non-parametric efficiency measures for large farms in the transition economies of Central and Eastern Europe. Liu and Zhuang (2000) study the impact of liquidity, measured as the sum of available financial resources, on the technical efficiency of very small farms in China using stochastic frontier methods. Liu and Zhuang (2000) do not test endogeneity explicitly, but they do replace their liquidity variable – which is much broader than the credit volume and credit constraint variables considered here – with predicted values obtained from an auxiliary regression on a set of instruments.

3 Empirical methods and data

3.1 Stochastic frontier analysis

Since Farrell's (1957) seminal work, parametric and non-parametric methods for analysing efficiency have been developed.[2] We follow the parametric approach known as stochastic frontier analysis. This approach explicitly allows for measurement error as well as random factors that are not under a farmer's control, such as weather and disease. It also permits testing hypotheses about a farm's production technology, and the imposition of corresponding restrictions. As stochastic frontier techniques are well-established in the literature, the following overview is brief.

A simple representation of the stochastic frontier model is:

$$y_i = f(\mathbf{x}_i)\, exp(w_i), \qquad (1)$$

[2] Kalirajan and Shand (1999) and Murillo-Zamorano (2004) provide reviews; more advanced treatment is provided by Coelli, Rao and Battese (1998) and Kumbhakar and Lovell (2000).

where y_i denotes the level of output for observation (farm) i, $\mathbf{x}_i$ is a vector of the levels of k inputs for that farm, $f(\cdot)$ is the frontier production function and $w_i = v_i - u_i$ is a composite error. The error component v_i is a pure random (white noise) component that accounts for factors, such as weather, that are beyond farmers' control, as well as omitted variables and measurement error. u_i is a systematic, nonnegative component that accounts for inefficiency. The corresponding output-oriented technical efficiency measure, $TE_i = exp(-u_i) \in [0,1]$, indicates by how much farm i could increase its output given the technology and the input levels it employs. An output-oriented approach is appropriate in agricultural settings since input choices are made at the beginning of the production period and input levels can therefore be considered predetermined (Griliches, 1963). In this case there is no correlation between the stochastic error and the predetermined input variables in the production function, and direct estimation of equation (1) will not suffer from simultaneous equation bias (Zellner et al., 1966; Dinar et al., 2007). Since only w_i is observed, distributional assumptions for v_i and u_i must be made. In most applications it is assumed that v_i follows a normal and u_i a half-normal distribution, and that $\mathrm{cov}(v_i,u_i) = 0$.

Based on this model, many empirical analyses have proceeded in two steps. In the first step the stochastic frontier model is estimated, and in the second step estimated TE_i is regressed on a vector of variables $\mathbf{z}_i$ (that may overlap with $\mathbf{x}_i$) that are hypothesised to explain differences in efficiency across farms. However, it can be demonstrated that this procedure leads to biased estimators (Caudill and Ford, 1993; Wang and Schmidt, 2002). An alternative based on pioneering papers by Kumbhakar at el. (1991), Huang and Liu (1994) and Battese and Coelli (1995) is to estimate a full model,

$$y_i = f(\mathbf{x}_i)\ exp(v_i - u_i(\mathbf{z}_i)), \tag{2}$$

in a single step using maximum likelihood methods. We follow this approach using a translog specification of (2):

$$ln(y_i) = \beta_0 + \Sigma\beta_k ln(x_{ki}) + 0.5\Sigma\Sigma\beta_{lp} ln(x_{li}) ln(x_{pi}) + v_i - u_i \tag{3}$$

and incorporating the following assumptions:

a) symmetry ($\beta_{lp} = \beta_{pl}$);

b) v_i is an i.i.d. normal random variable with constant variance σ_v^2; and

c) following to Caudill at el. (1995) and Brümmer and Loy (2000), systematic deviations from the frontier u_i are assumed to be i.i.d. half-normal random disturbances uncorrelated with v, with mean zero and a heteroscedastic (i.e., farm-specific) variance σ_{ui}^2 such that $ln(\sigma_{ui}^2) = \sigma_0 + \Sigma\phi_j z_j + \xi_i$, where ϕ_j are parameters to be estimated that measure the influence of variables in **z** on efficiency, and ξ_i is assumed to be an i.i.d. normal random disturbance.

3.2 The variables employed

We next describe the variables used to estimate equation (3) before describing the survey data employed and how it was processed.

The dependent variable y_i is defined as farm income measured in thousands of pesos. The vector ***x*** comprises four inputs: land (*L*, in hectares); working capital (*WC*, in thousand pesos) as a proxy for intermediate inputs; the market value of livestock (*AV*, in thousand pesos) evaluated at sample average as a proxy for capital stock; and estimated labour input (*T*, in hours per week based on reported shares of time spent by the members of the household in farm and off-farm activities). The share of irrigated land (*ShIL*) is introduced as an additional input that captures differences in land quality, and dummy variables (*DZ3*, *DZ4*, and *DZ5*) capture whether the farm in question in located in geographic zone 3, 4 or 5, respectively (zone 2 is the reference).[3] Some crop producers have no animals, so following Battese (1997) an additional dummy variable ($Dav = 1$ if $AV > 0$) is used to avoid biased parameter estimates.

Drawing on the literature (e.g. Bravo-Ureta and Evenson, 1994; Dinar et al., 2007) and plausibility considerations, we specify a vector **z** that includes the following six categories of possible determinants of efficiency:

i) Three variables account for socioeconomic characteristics of the farm household. These are the age and education of the household head (*Age* and *Edu*, both in years), and the size of the household (*HS*, number of members).

ii) One variable (*ShOL*, the share of farmed land that is owned by the household) reflects land tenure conditions.

iii) One variable measures access to markets (*Acc*, the distance in km to the main road).

iv) Eight variables capture management decisions. These include, in addition to the four input variables listed above (*L*, *WC*, *AV* and *T*), a dummy that equals one if the farmer has

[3] Chile is divided into six zones. Little crop and livestock production takes place in zones 1 (northernmost; largely desert) and 6 (southernmost; windy and cold), and 97% of Chile's small farmers are located in zones 2 through 5.

spent money on management training (e.g. attending a training course) or services (e.g. bookkeeping) in the course of the year (*Dmanag*). The dummy *Dex* equals one if the farmer has received assistance from extension services, and the dummy *DVet* equals one if the farmer has spent money on veterinary services. Finally, *ShFI* is defined as the share of farm income in total income.

v) *Dindap* is a dummy variable that equals one if the farm in question participates in any INDAP programs.

vi) Finally, two variables measure various dimensions of a farm's access to credit. The first is total credit used (*Cred*) in millions of Pesos. The second is a dummy that equals one if the head of the farm households reports being credit constrained (*Dcc*).

Table 1 presents descriptive statistics for these variables in each of the two sub-sets of data (crop producers and livestock producers) that will be analysed below, together with an indication of the expected influence of each variable on production and efficiency in equation (3). Beginning with the production function variables in $\boldsymbol{x}$, the elasticities of the production factors and the proportion of irrigated land (*ShIL*) are expected to be positive. The location dummies (*DZ3*, *DZ4* and *DZ5*) will have positive or negative impacts as geographic zones are better- or worse-suited to production; for example, moving south from the reference zone 2 into colder and wetter zones, crop production is expected to fall, all other things being equal. The sign of the coefficient on *Dav*, which accounts for crop producers who have no animals ($AV = 0$) is indeterminate *a priori*.

Table 1: Definition and descriptive statistics for the variables employed in the analysis

Turning to the determinants of efficiency in $\mathbf{z}$, inefficiency is expected to decrease with increasing age (*Age*) and education (*Edu*) of the household head. Inefficiency is also expected to decrease with increasing household size (*HS*) and the associated timeliness and variety (children, youngsters, adults, elderly) of available labour (e.g. Abdulai and Eberlin, 2001; Coelli et al., 2002; Hazarika and Alwang, 2003). The share of own land farmed (*ShOL*) is important in Chile as in much of Latin America because it is linked to tenure and land reform issues. Farms that own higher shares of the land they farm are expected to be less inefficient *ceteris paribus* because they will have stronger incentives to use better management practices, and because they will be able to use land as collateral to secure credit at more advantageous conditions (e.g. Wu et al., 2003; Karagiannis and Sarris, 2005; and Chavas et al., 2005). Access to markets (*Acc*) provides advantages in marketing and can be expected to increase a farm's awareness of and access to best practice methods, thus reducing inefficiency. Inefficiency is expected to fall with increasing values of the management variables *Dmanage*, *DVet* and *Dex*. As the share of on-farm income in total income (*ShFI*) increases, the time and attention dedicated to running the farm operation efficiently can be expected to increase as well, also reducing inefficiency. If public assistance is effective, then *Dindap* will have a negative impact on inefficiency. Finally, as outlined in section 1, the sign of the relation between credit and technical efficiency is ambiguous. We therefore formulate no *a priori* expectations for the variables *Cred* and *Dcc*.

3.3 Data

In 2004 INDAP conducted an extensive, representative survey of 2,024 small farms across all six zones in Chile. Since zones 1 and 6 contain very few small farmers, we do not use the data collected there, and focus instead on the 1,931 surveys from zones 2 through 5. In the course of the survey, farmers were asked a total of 105 questions covering all aspects of their agricultural activities.[4]

A number of procedures are used to identify the specialised operations among the 1,931 surveyed farms, and to eliminate inconsistencies. First, the Herfindahl index (sum of squared revenue shares across different agricultural products) is used to identify the specialised small farms. Second, only households with a minimum of 185 US$ of farm income, and for which farm income amounts to at least 1% of total income, are considered. Third, farms are only considered if their working capital is greater than zero and greater than or equal to the total cost of farm production. Fourth, to be considered, a farm must report a positive amount of land and labour used in farm production. Finally, consistency checks are applied to eliminate, for example, farms that claimed to produce crops but reported no income from sales of crop products, or that reported land use that could not be reconciled with reported volumes of crop production. The result is 342 specialized crop and 109 specialized livestock farms.

81% of the specialised livestock producers identified in this manner are located in the south-central zones 4 and 5, while 72% of the specialised crop producers are located in the north-central zones 2 and 3. Specialised crop production concentrates on four crops (wheat, maize, potatoes and rice) that account for 90% of land use on the corresponding farms. Specialized livestock production encompasses cattle, sheep and goats, but cattle (milk and beef) account for 70% of the farm revenue on these farms. The descriptive statistics in Table 1 illustrate that

[4] A copy of the (Spanish) survey questionnaire is available from the authors upon request.

one third of those farmers have access to credit of short-term, financed by INDAP (75%), Banco Estado (13%) and Department Stores (9%), with an average credit of 1,300,000 pesos (US$2,400) which accounts for 54% of their working capital (appendix 3). On average, a 41% of the sample faces credit constraint and a 66% of the total surface has irrigation. Additionally, crop production is concentrated in the macro zones 2 and 3, accounting for 70% of the total production sampled. Only a 27% of livestock farmers received credit from INDAP (68%), Banco Estado (20%) and BCI Bank (12%). The cattle production was the activity that received more financing and for who received credit its average amount was 535,000 pesos (US$1,000), which financed the 48% of its working capital (appendix 3). On average, a 43% of the sample faces credit constraint, the irrigated surface reaches only the 20% and the activity is concentrated in the macro zones 4 and 5, accounting for 80% of the total production sampled.

4 Estimation and results

Maximum Likelihood (ML) estimations of equation (3) are performed in Ox 3.40 (Doornik, 2002) using the package SFAMB (Stochastic Frontier Analysis using ModelBase). The one-step estimation procedure follows Battese and Coelli (1995). On-farm income and production input variables are divided by their arithmetic means so that parameter estimates can be directly interpreted as production elasticities evaluated at sample means. Regularity conditions are tested.[5] Monotonicity in the variable inputs land, labour and working capital is found to hold for 100% of the observations in both the crop and livestock samples, while quasi-concavity holds for 100% and 99% of the crop and livestock observations, respectively. An overview of the literature shows that regularity conditions are rarely fulfilled globally in empirical work; however since they are met overwhelmingly in our samples, we conclude that the estimated production function is interpretable (Berndt and Christensen, 1973).

4.1 Results for specialised small crop producers

According to LR tests (Table 2), the best model for specialised crop producers does not include animal market value (*AV*) and the corresponding dummy (*Dav*) in the production function, and the share of own land farmed (*ShOL*) in the inefficiency model. The first results suggests that either the capital stock does not play an important role in smallholder crop production in Chile, or the market value of animals is not an appropriate proxy for the relevant

[5] See for example Thijssen (1992). Results are available from the authors.

capital stock. The insignificance of *ShOL* indicates that land tenure is not a determinant of technical efficiency for small crop producers in Chile. Table 2 also shows that the Cobb Douglas restriction of the translog production function is rejected by the crop production data. The null hypothesis that there is no inefficiency in crop production (u_i = 0 for all farms) is rejected (χ^2 = 69.4, critical value = 23.7)[6], as is the hypothesis that the variables in the vector ***z*** make no significant contribution to explaining inefficiency (χ^2 = 57.0, critical value = 22.4).

Table 2: Likelihood ratio tests for the crop production frontier model

Estimates of equation (3) for crop producers are presented in Table 3. The regional dummy variables have a significant impact and indicate, as expected, that crop production is lower, *ceteris paribus*, in Chile's southern regions. The partial elasticities of land, labour force and working capital, at sample mean levels, are significant with values of 0.33, 0.37 and 0.57, respectively. Constant returns to scale are not rejected for crop production (χ^2 = 2.5 compared with a 5% critical value of 3.8). The results indicate that irrigated land is more than 7 times more productive than land without irrigation[7], and that irrigation increases the production elasticity of working capital from 0.57 to 0.69.[8]

Table 3: Stochastic production frontier results for specialised small crop producers in Chile

The estimated mean technical inefficiency in the sample of crop producers is 11% and the distribution of inefficiency is highly concentrated around farms with scores in the 90-100% range (Figure 1). The variables used to explain efficiency are jointly significant as illustrated above, and most of them are individually significant. Since inefficiency is modelled in equation (3), a negative coefficient indicates that the variable in question reduces inefficiency, or increases efficiency. The specification employed allows us to interpret the individual coeffi-

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[6] Under the null hypothesis of no inefficiency, a parameter of interest takes on a boundary value (Dinar et al., 2007, p. 141). In this case, the LR statistic follows an equally weighted mixture of a degenerate $\chi^2(0)$ and $\chi^2(1)$ distribution (Self and Liang, 1987). Koddle and Palm (1986) provide critical values.

[7] Following Battese at el. (1989) we consider land as a weighted average of irrigated (*IL*) and non-irrigated land (*nIL*). The production function is then $y = \alpha_0(\alpha_1 nIL + (1\text{-}\alpha_1)IL)^{\beta_1}$. This can expressed in term of total land (L = $IL + nIL$) and the ratio of irrigated to total land (IL/L) as $y = \alpha_0\alpha_1^{\beta_1}L^{\beta_1}[1 + (\phi - 1)(IL/L)]^{\beta_1}$, where $\phi = (1 - \alpha_1)/\alpha_1$ is the productivity of one hectare of irrigated land relative to non-irrigated land. Taking logarithms and a Taylor series approximation gives ln$y$ = *constant* + $\beta_1$ln$L$ + $\beta_2$ln(IL/L), where $\beta_2 = \beta_1(\phi - 1)$. Using our estimates of β_1 (the coefficient on ln$L$) and β_2 (the coefficient on $ShIL$=IL/L), $\phi = (\beta_2 + \beta_1)/\beta_1$ = (2.12 + 0.33)/0.33 = 7.42 (Table 3). These calculations ignore the insignificant estimate of the coefficient on the interaction term (ln$A$ * $ShIL$).

[8] The elasticity of working capital is: $e_{wc} = \partial \text{n}y/\partial \text{n}WC = \beta_{wc} + \Sigma\beta_{ij}\ln x_j + \omega_{wc}ShIL$. Evaluated at samples means this becomes: $e_{wc} = \partial \text{n}y/\partial \text{n}WC = \beta_{wc} + \omega_{wc}ShIL$. Since ω_{wc}, the estimate of the parameter on the interaction term (*lnWC* * *ShIL*), is significant (Table 3), the elasticity of working capital for specialized crop producers with irrigation is: $e_{wc} = \partial \text{n}y/\partial \text{n}WC$ = 0.5695 + (0.1777 * 0.66) = 0.6868.

cients in the inefficiency model as the marginal effects of the corresponding variables. As expected, results indicate that there is a positive relation between efficiency and the education of head family (*Edu*), the age of the head family (*Age*), family size (*HS*) and the share of on-farm income in the total income (*ShFI*). Technical efficiency decreases with increasing use of land, labour and working capital (*L*, *T* and *WC*). Extension services (*Dex*) and distance to main road are significant (*Acc*), but their signs are unexpected. Thus, farmers who receive extension and are located closer to main road are less efficient. The former result supports those earlier studies that argue that extension efforts in Chile have not been effective (Lopez, 1996; Bebbington and Sotomayor, 1998). The latter result could be due to a conflation of the effects of market access and input use, as more remote farms tend to be smaller and hence use fewer inputs. It might also be that distance from the main road is a poor measure of remoteness, as a farm might be close to a main road but nevertheless quite far from the relevant markets.

The variables that measure access to credit have a significant impact on technical efficiency. The volume of credit (*Cred*) has a positive influence on technical efficiency, and farms that consider themselves credit constrained (*Dcc*) are significantly less efficient than others. The results in Table 3 can be used to demonstrate that the mean technical inefficiency of the credit constrained crop farmers is 16%, while that of the unconstrained farmers is 7%. These results are in line with the *free cash flow*, *credit evaluation*, *embodied capital* and *credit as insurance* theories that explain a positive impact of credit on efficiency. Participation in INDAP programs (*Dindap*) has no significant impact on technical efficiency, and neither does the variable related to management efforts (*Dmanag*).

Figure 1: Distribution of efficiency scores for specialised small crop producers in Chile

4.2 Results for specialised small livestock producers

The best model for the specialised livestock producers does not include the variables land (*L*), labour force (*T*) and localization (DZ_i) in the production function (Table 4). However, the estimated coefficients on land and labour, while insignificant, have the expected positive signs.[9] Furthermore, the insignificance of land in the livestock production function is not surprising and has been reported in several other empirical applications (e.g. Kumbhakar et al., 1991; Bravo-Ureta et al., 2006; Tauer and Mishra, 2006). As is the case for specialised crop

[9] The estimates of these coefficients are 0.15 and 0.21, respectively. Detailed results are available from the authors.

producers, the land tenure variable (*ShOL*) is insignificant in the inefficiency model for specialised livestock producers (Table 4).

Table 4: Likelihood ratio tests for the livestock production frontier model

As is the case for crop production, the Cobb Douglas specification is rejected by the livestock production data. Constant returns to scale are rejected for specialised livestock production (χ^2 = 12.2, critical value = 3.8), and at sample means returns to scale are increasing (1.35). This suggests that the livestock producers in the sample are operating at a sub-optimal size, and is interesting in light of the discussion about the optimal size of cattle production that has emerged during the last years in Chile as a consequence of strong competition with imported meat from other MERCOSUR countries. The null hypothesis that there is no inefficiency in crop production (u_i = 0 for all farms) is rejected (χ^2 = 44.1, critical value = 23.7), as is the hypothesis that the variables in the vector **z** make no significant contribution to explaining inefficiency (χ^2 = 40.9, critical value = 22.4).

The first three columns of Table 5 present the parameter estimates for the specialised livestock producers. The partial elasticities of working capital and animal market value, evaluated at sample means, have significant values of 0.51 and 0.84, respectively. The share of irrigated land (*ShIL*) is not significant, which is not surprising for livestock production. However, the coefficient on the interaction term between *ShIL* and the working capital input (ln*WC* * *ShIL*) is significant. As a result, the production elasticity of working capital is slightly higher on irrigated than on non-irregated land (0.55 rather than 0.51).

Table 5: Stochastic production frontier results for specialised small livestock producers in Chile

The mean inefficiency is 22% in the sample of specialised livestock producers, and the distribution of efficiency scores for these producers in Figure 2 is less concentrated than that for crop producers in Figure 1. Most of the variables used to explain efficiency in specialised livestock production are significant. As is the case for crop production, the technical efficiency of specialised livestock production increases with the age and education of the household head, and with increasing share of on-farm income in total income. The hypothesis that the credit variables are jointly insignificant is rejected (Table 4). Inefficiency increases with increasing volume of credit (*Cred*), and is lower for farms that perceive themselves to be credit constrained (*Dcc*) (Table 5). In other words, given two otherwise identical farms with equal credit volumes, the one that is credit constrained will be more efficient; given two otherwise identical farms that are both credit constrained, the one that has a larger volume of credit will be less efficient. These results support the *agency cost* and *adjustment* theories outlined above. They might also reflect longer gestation periods for investments in livestock production (e.g. genetic improvements) and possible temporary reductions in efficiency that result while farmers are learning to implement new technologies.

Receiving support from INDAP increases the technical efficiency of specialised livestock farms. Recall that this effect was insignificant for specialised crop production. The implication is that the special efforts undertaken to support livestock production in recent years have had a noticable impact. A surprising result is that farmers who report spending money on management training and services (*Dmanage* = 1) are significantly less efficient than those who do not.

Figure 2: Distribution of efficiency scores for specialised small livestock producers in Chile

4.3 Testing for the endogeneity of the credit variables

The possible endogeneity of the variables that measure access to credit and technical efficiency was identified above as an important but seldom studied issue. We use the Durbin-Wu-Hausman test (Davidson and MacKinnon, 1993) to test endogeneity. First, we run an auxiliary regression of the possibly endogenous variable on all other right-hand-side (RHS) variables of the original efficiency model, plus a set of instrument variables. The instruments are chosen to be highly correlated with the possibly endogenous variable, but not with the term error of the original efficiency model. Second, we re-estimate equation 3 including the residuals of the auxiliary regression as an additional RHS variable in the inefficiency model. Under the null hypothesis of no endogeneity, the coefficient on this additional residual term equals zero. If this null hypothesis is rejected (i.e. the coefficient on the auxiliary residuals differs significantly from zero), we re-estimate equation (3) once more, this time replacing the variable that has been found to be endogenous with its fitted values from the auxiliary regression.

This procedure is carried out for both the *Cred* (credit volume) and *Dcc* (credit constraint dummy) variables. The same instruments are used in both auxiliary regressions. These instruments (descriptive statistics are presented in Table 1) include:

- The logarithm of on-farm income per hectare (ln*(Y/L)*) a proxy for household wealth.
- The quantity of own land (*OL*) as a proxy of a farmer's collateral.

- A dummy variable (*Dporg*) that equals one if the farmer is a member in a producers organisation as a proxy for social capital.
- An indicator (*Dcworth*) that ranks the lender's perception of the borrower's creditworthiness. This variable ranges from 0 (most) to 4 (least), and it is calculated as the average of several subjective evaluations (each on a scale of 1 to 4) of the general cleanliness and order of the household's dwelling and farm. This admittedly rough method of assessing creditworthiness is similar to methods that the Banco Estado has implemented in recent years in an attempt to reduce the administrative costs of delivering small rural credits.
- An indicator that ranks a farm's past repayment behaviour for loans from INDAP (*Drepay*). This categorical variable takes values of 1, 2 and 3, with 1 being the best category and 3 the worst.

We estimate a Tobit auxiliary regression for the credit volume variable (*Cred*) and a Probit auxiliary regression for the credit constraint variable (*Dcc*)[10]. The resulting residuals are added to the RHS of equation (3). For crop production we find that the null hypothesis that these residuals are jointly insignificant is not rejected ($\chi^2 = 1.4$, critical value = 5.99). However, for livestock production this null hypothesis is rejected ($\chi^2 = 13.2$, critical value = 5.99), indicating that the credit variables are endogenous.

What might explain this difference in results between crop and livestock production? Recall that *credit evaluation* theory provides a plausible explanation for causality from technical efficiency to credit access. In the sample of farms analysed here, the main lenders are INDAP and the Banco Estado, two institutions with a long tradition of providing support to smallholders. Since beginning of this decade, INDAP and to a lesser extent the Banco Estado have been supporting the creation of information centres for livestock producers in Chile's southern regions where production is concentrated. These centres, for which there is no equivalent in crop production, serve as forums for the exchange of information on market perspectives and who is who in terms of productivity, cost and reputation. The endogeneity of access to credit by livestock producers might reflect knowledge of farms on the part of lenders, knowledge that has been become better and more readily available as a result of the information centres.

[10] Results are available from the authors.

The final three columns of Table 5 present corrected estimates of equation (3) for livestock production, using the fitted values of the auxiliary *Tobit* and *Probit* models as instruments for *Cred* and *Dcc*. Comparing the estimated coefficients with and without the correction for endogeneity reveals few major changes. Most coefficients retain their original signs, magnitudes and levels of significance. The coefficients of the access to credit variables *Cred* and *Dcc* themselves are important exceptions to this rule; they increase by factors of roughly 4 and 5, respectively. This indicates that failure to account for endogeneity would lead to considerable underestimation of the (negative) impact of access to credit on technical efficiency in specialised smallholder livestock production in Chile.

5 Discussion and implications

Using a parametric approach, we estimate stochastic production functions for 109 small specialised livestock and 342 small specialised crop producers in Chile. The results show that crop production follows constant returns to scale at sample means. The inputs land, labour and working capital are significant in the crop production function, but the proxy for capital stock (market value of animals) is not. Geographic location and land quality, measured as the share of irrigated land that is farmed, contribute significantly to the explanation of differences in crop production. The production elasticity of intermediate inputs, proxied by working capital, is 0.57, and increases to 0.69 for farms with irrigated land. We find that irrigated land is over 7 times more productive than land without irrigation.

The results for livestock production differ in several respects. Livestock production is characterised by increasing return to scale at sample means. This result corresponds well with recent discussions about the need to increase the size of cattle production units in Chile as a consequence of strong competition from MERCOSUR countries. Geographic location is not a significant factor in the production function for livestock, and irrigation has no significant impact except for a small augmentation of the production elasticity of intermediate inputs (working capital). At sample mean level, the elasticities of intermediate inputs (working capital) and capital (animal market value) are significant with values of 0.51 and 0.84, respectively. However, labour and land inputs have no significant impact, which is not unusual for livestock production.

The mean efficiency of the crop producers is 89%, while that of the livestock producers is 78%. In general, technical efficiency falls with input use and increases with the share of farm income in total income, the age and education of the farm head, and farm household size. Participation in INDAP programs has no significant influence on the technical efficiency of crop production, but it does increase the efficiency of livestock production, suggesting that special support in the form of direct subsidies for improving grasslands and animal stocks has been effective. Of course, this does not necessarily imply that this support has been economically efficient. Extension services appear to be performing poorly, even reducing the technical efficiency of specialised small crop production. This result is disappointing because it suggests that the quality of the provided services is low, or that farms are not following the recommendations they receive.

41% of the crop farmers and 43% of the livestock farmers in the sample are credit constrained, and credit accounts for 15% of the working capital of those farms that are constrained as opposed to 45% for those that are not. The results for crop producers indicate that credit volume has a positive impact on efficiency, supporting the free cash flow, credit evaluation, and embodied capital theories that have been proposed in the literature. It may also be that the link between the more readily available short-term credits and improvements in technical efficiency is more pronounced in crop production. In livestock production credit volume is found to have a negative impact on efficiency, supporting agency cost and adjustment theories. The relative scarcity of long-term credit may be precluding the long-term investments that are needed to improve technical efficiency in livestock production.

We find that credit constrained farmers are less efficient in crop production and more efficient in livestock production. This reinforces our results on the impact of credit volumes on efficiency. While credit volumes increase the technical efficiency of crop producers, for example, given two farms that are identical in all other respects including credit volume, the one that is not credit constrained will be more efficient. In livestock the opposite is true; efficiency falls with increasing credit volume, and all other things including credit volume being equal, credit constrained farms will be more efficient. This suggests that livestock farmers are over-using credit from a technical efficiency perspective, and that credit constraints actually limit this 'error'. In crop production, credit constraints limit the ability of some farms to put credit to an efficiency enhancing use. Note, this is only technical efficiency, however, and not allocative efficiency...

Additionally, we checked the possibility of simultaneity between technical efficiency and the variables related to the credit market in our results. Using the Durbin-Wu-Hausman test, we can not reject the hypothesis of no simultaneity in the crop production, but we can do it in livestock production, suggesting any kind of feedback from the levels of efficiency to the variables related to the credit market. We justify this finding from an institutional perspective; lenders would have more information and knowledge of farmers in livestock production. This situation has been the result of a public policy oriented to sectors with a more direct exporting orientation.

The livestock estimation was corrected by taking the fitted values from the Tobit and probit models as instruments of the financial variables. Those estimations confirm our previous results; however, this procedure affected other parameters both in the production function and the inefficiency model. Basically, the elasticity of capital (measured as the variable animal market value) increased, the elasticity of intermediate inputs (measured as the variable working capital) decreased and the proportion of irrigated land was no longer significant. The interaction between the two inputs considered is significant and positive, suggesting a complementary between them. This finding is interesting and stresses the necessity of checking endogeneity in the variables used to model the inefficiency effects.

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Table 1: Definition and descriptive statistics for the variables employed in the analysis

		Crop producers (n = 342)				Livestock producers (n = 109)				Expected
Variable (description)	**Units**	**Min.**	**Mean**	**Max.**	**Std.dv.**	**Min.**	**Mean**	**Max.**	**Std.dv.**	**sign (+, –, ?)**
Production function										
Y (farm income)	'000 Pesos	100	2,842	50,400	5,932	100	797	10,600	1,365	+
L (agricultural land used)	hectares	0.05	3.39	50.00	4.98	0.75	20.16	200.00	25.53	+
ShIL (share of irrigated land)	share	0	0.66	1	0.45	0	0.20	1	0.37	+
WC (working capital)	'000 Pesos	40	2,103	40,000	4,587	24	1,365	9,500	2,104	+
T (labour input)	hrs/week	6.52	93.16	289.62	43.44	2.94	82.54	200.31	40.96	+
Av (value of the livestock on the farm)	'000 Pesos	0	184	1,280	280	176	2,299	16,040	2,166	+
Dav (=1 if Av > 0)	dummy	0	0.43	1	0.49					?
DZ3 (=1 if farm in macro-zone 3, reference is 2)	dummy	0	0.47	1	0.49	0	0.06	1	0.24	?
DZ4 (=1 if farm in macro-zone 4, reference is 2)	dummy	0	0.19	1	0.39	0	0.23	1	0.42	?
DZ5 (=1 if farm in macro-zone 5, reference is 2)	dummy	0	0.09	1	0.29	0	0.56	1	0.49	?
Determinants of inefficiency: Socioeconomic characteristics										
HS (number of household members)	number	1	3.98	13	1.64	1	3.47	8	1.65	–
Age (age of household head)	years	24	51.10	84	13.62	31	53.30	86	12.57	–
Edu (years of education of household head)	years	1	7.80	26	5.83	1	7.47	25	4.80	–
Determinants of inefficiency: Land tenure										
ShOL (share of farmland that is owned)	share	0	0.45	1	0.46	0	0.66	1	0.44	–
Determinants of inefficiency: Access to market										
Acc (distance to nearest main road)	km	0	1.91	48.00	4.37	0	1.81	35.00	5.92	+
Determinants of inefficiency: Management										
Dvet (=1 if farm spends on animal health)	dummy	0	0.10	1	0.30	0	0.63	1	0.48	–
ShFI (share of farm income in total income)	share	0.02	0.59	1	0.34	0.01	0.42	1	0.32	–
Dmanag (=1 if farm spends on management)	dummy	0	0.32	1	0.46	0	0.49	1	0.49	–
Dex (=1 if farm receives extension services)	dummy	0	0.15	1	0.36	0	0.22	1	0.42	–
Determinants of inefficiency: Public support										
Dindap (=1 if farm gets assistance from INDAP)	dummy	0	0.54	1	0.49	0	0.56	1	0.49	–
Determinants of inefficiency: Access to credit										
Dcc (=1 if farmer feels credit constrained)	dummy	0	0.41	1	0.49	0	0.43	1	0.49	?
Cred (total credit used)	'000 Pesos	0	0.43	24.00	1.70	0	0.14	4.00	0.45	?
Instruments for endogeneity tests										
ln(Y/L) (on-farm income per hectare)	ln(Pesos/ha)	3.17	6.22	9.55	0.99	1.05	3.59	6.50	1.15	
OL (quantity of own land)	hectares	0	3.02	35	5.36	0	13.64	110	19.99	
Dporg (=1 if member of producers organisation)	dummy	0	0.06	1	0.24	0	0.25	1	0.43	
Dcworth (1=most, 4=least creditworthiness)	dummy	1	1.25	4	0.46	1	1.32	4	0.64	
Drepay (1=best, 3=worst repayment history)	dummy	1	2.40	3	0.83	1	2.01	3	1.21	

Table 2: Likelihood ratio tests for the crop production frontier model

Null hypothesis	Log likeli-hood	Number of parameters in model	Number of restrictions	LR statistic (critical value)	Decision
Full model	-270.1	42	-	-	-
No animal market value (all terms in-volving *AV* and *Dav* = 0)	-275.3	34	8	10.4 (15.5)	accept
As above, and no effect of land tenure (the term involving *ShOL* = 0)*	-275.5	33	1	0.4 (3.8)	accept
As above, and no effect of credit markets (terms involving *Cred* and *Dcc* = 0)	-281.1	31	2	11.2 (6.0)	reject
Production function in Cobb Douglas (all cross-effect terms = 0)	-294.1	23	10	37.2 (18.3)	reject
No inefficiency (σ_0 and all ϕ_j = 0)	-310.9	20	14	69.4 (23.1)	reject
Variables in **z** do not explain inefficiency (all ϕ_j = 0)	-304.0	18	13	57.0 (22.4)	reject

** This model without animal market values and the land tenure variable is the 'best model' against which the ensuing hypotheses are tested. Source: Own calculations.*

Table 3: Stochastic production frontier results for specialised small crop producers in Chile

	Coefficient	Robust standard error	t-value
Constant	-0.1068	0.1644	-0.65
*ln*L	0.3341	0.1162	2.88**
*ln*WC	0.5696	0.09729	5.85***
*ln*T	0.3659	0.1334	2.74***
ShIL	2.1283	0.5455	3.90***
DZ3	-0.2325	0.08454	-2.75***
DZ4	-0.4940	0.1119	-4.42***
DZ5	-0.3825	0.1854	-2.06**
0.5 * *ln*L²	-0.0950	0.06836	-1.39
0.5 * *ln*WC²	-0.0377	0.04983	-0.76
0.5 * *ln*T²	-0.1042	0.1105	-0.94
0.5 * ShIL²	-3.5245	0.9606	-3.67***
*ln*L * *ln*WC	0.1058	0.04814	2.20**
*ln*L * *ln*T	-0.0147	0.08097	-0.18
*ln*L * ShIL	-0.0603	0.1209	-0.50
*ln*WC * *ln*T	0.1395	0.05394	2.59***
*ln*WC * ShIL	0.1777	0.08227	2.16**
*ln*T * ShIL	-0.3304	0.1432	-2.31**
$ln(\sigma_v)$	-0.6664	0.04674	-14.30***
Constant	3.3650	0.9897	3.40***
Age	0.01284	0.007147	1.80*
Edu	-0.1026	0.03805	-2.70***
HS	-0.2604	0.1021	-2.55**
Acc	-0.1072	0.04722	-2.27**
*ln*L	0.5232	0.1897	2.76***
*ln*WC	0.7617	0.2012	3.79***
*ln*T	0.5230	0.2367	2.21**
Dmanag	-0.0734	0.2308	-0.32
Dex	1.0935	0.3987	2.74***
ShFI	-7.1318	0.9562	-7.46***
Dindap	-0.3329	0.2523	-1.32
Cred	-0.5894	0.1570	-3.75***
Dcc	0.8113	0.2563	3.17***

****, ** and * refer to significance at the 1%, 5% and 10% levels, respectively. Source: Own calculations.*

Table 4: Likelihood ratio tests for the livestock production frontier model

Null hypothesis	Log like-lihood	Number of parameters in model	Number of restrictions	LR statistic	Critical value
Full model	-54.0	42	-	-	-
No labour and land inputs, no regional effects (all terms involving *L*, *T* and DZ_i = 0)	-65.2	26	16	22.4	26.3
As above, and no effect of land tenure (the term involving *ShOL* = 0)*	-65.6	25	1	0.9	3.8
No effect of credit markets (terms involving *Cred* and *Dcc* = 0)	-70.4	23	2	9.7	6.0
Production function in Cobb Douglas (all cross effect terms = 0)	-78.1	19	6	25.0	12.6
No inefficiency (σ_0 and all $\phi_j = 0$)	-87.6	10	14	44.1	23.1
Variables in **z** do not explain inefficiency (all $\phi_i = 0$)	-86.0	12	13	40.9	22.4

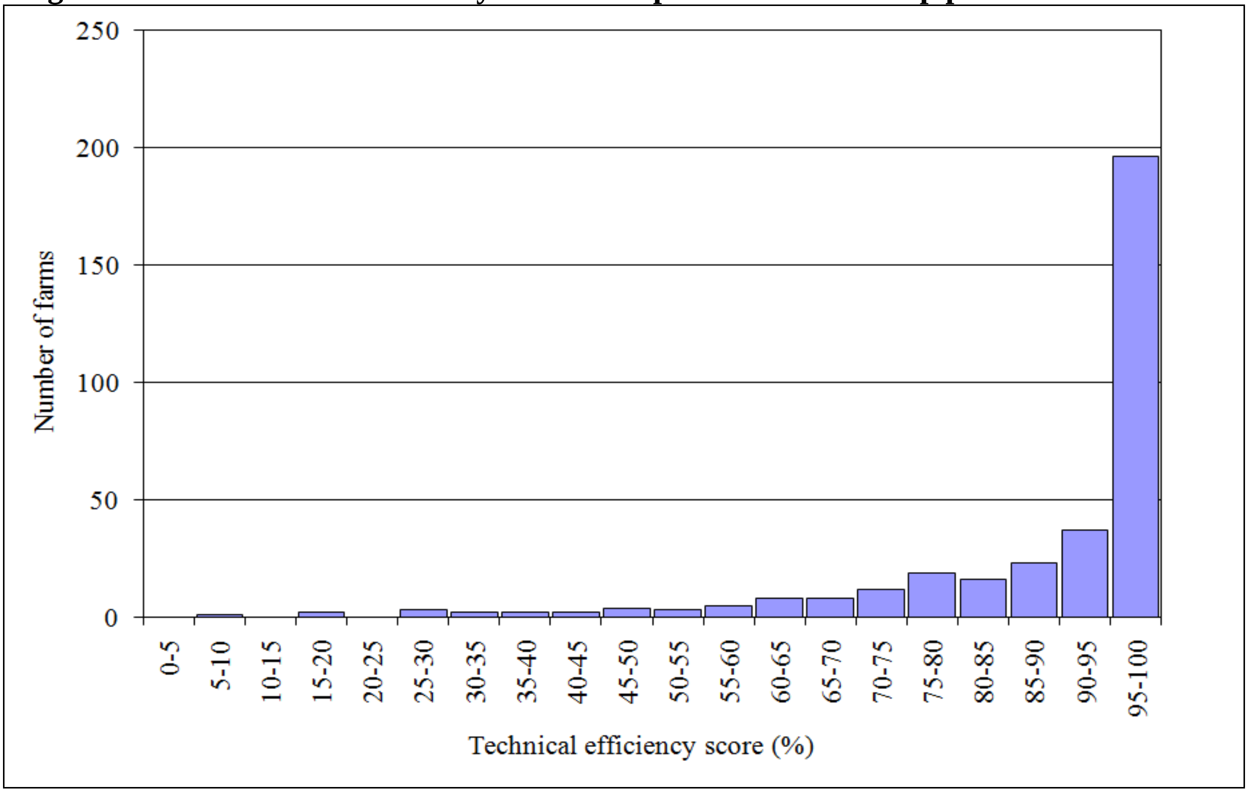
** This model without land and labour inputs, regional dummies and the land tenure variable is the 'best model' against which the ensuing hypotheses are tested. Source: Own calculations.*

Table 5: Stochastic production frontier results for specialised small livestock producers in Chile

Explanatory variable	Initial model			Model corrected for endogeneity (*Cred* and *Dcc* replaced by fitted values from Tobit and Probit regressions, respectively)		
	Coefficient	Robust st. err.	t-value	Coefficient	Robust st. err.	t-value
Constant	0.1207	0.0900	1.34	0.0272	0.09797	0.28
*ln*WC	0.5152	0.0780	6.61***	0.4266	0.06878	6.20***
*ln*AV	0.8487	0.1260	6.74***	0.9836	0.1158	8.49***
ShIL	-0.1869	0.9893	-0.19	0.1429	0.9394	0.15
0.5 * *ln*WC²	0.0863	0.0460	1.87*	0.0333	0.04723	0.71
0.5 * *ln*AV²	0.2925	0.1115	2.62***	0.2679	0.1206	2.22**
0.5 * ShIL²	0.6326	2.0380	0.31	-0.2360	1.9580	-0.12
*ln*WC * *ln*AV	0.0492	0.0558	0.88	0.1176	0.06273	1.87*
*ln*WC * ShIL	0.1649	0.0796	2.07**	0.1156	0.08792	1.31
*ln*AV * ShIL	-0.2414	0.2174	-1.11	-0.0959	0.1746	-0.55
$ln(\sigma_v)$	-1.0100	0.0789	-12.8***	-0.9445	0.0721	13.10***
Constant	1.6201	0.9506	1.70*	532.2710	2.4220	2.20**
Age	-0.0225	0.0113	-1.98*	-0.0502	0.0224	-2.25**
Edu	-0.0276	0.0255	-1.08	-0.0412	0.0348	-1.19
HS	0.0543	0.1338	0.41	0.2131	0.1854	1.15
Acc	-0.0424	0.0384	-1.10	0.0110	0.0568	0.19
*ln*WC	0.3948	0.1762	2.24**	0.0185	0.2032	0.09
*ln*AV	0.6643	0.2607	2.55**	1.5311	0.6873	2.23**
Dmanag	0.8710	0.2725	3.20***	2.4669	0.9277	2.66***
Dindap	-0.7284	0.2543	-2.86***	-1.8455	0.6715	-2.75***
Dex	0.3454	0.2695	1.28	-0.5301	0.6291	-0.84
Dvet	-0.1454	0.2782	-0.52	0.0033	0.3461	0.01
ShFI	-2.0985	0.7935	-2.64***	-3.8181	1.4110	-2.78***
Cred	0.2368	0.1147	2.06**	0.9902	0.4682	2.11**
Dcc	-1.1054	0.3468	-3.19***	-5.6272	2.2480	-2.50**

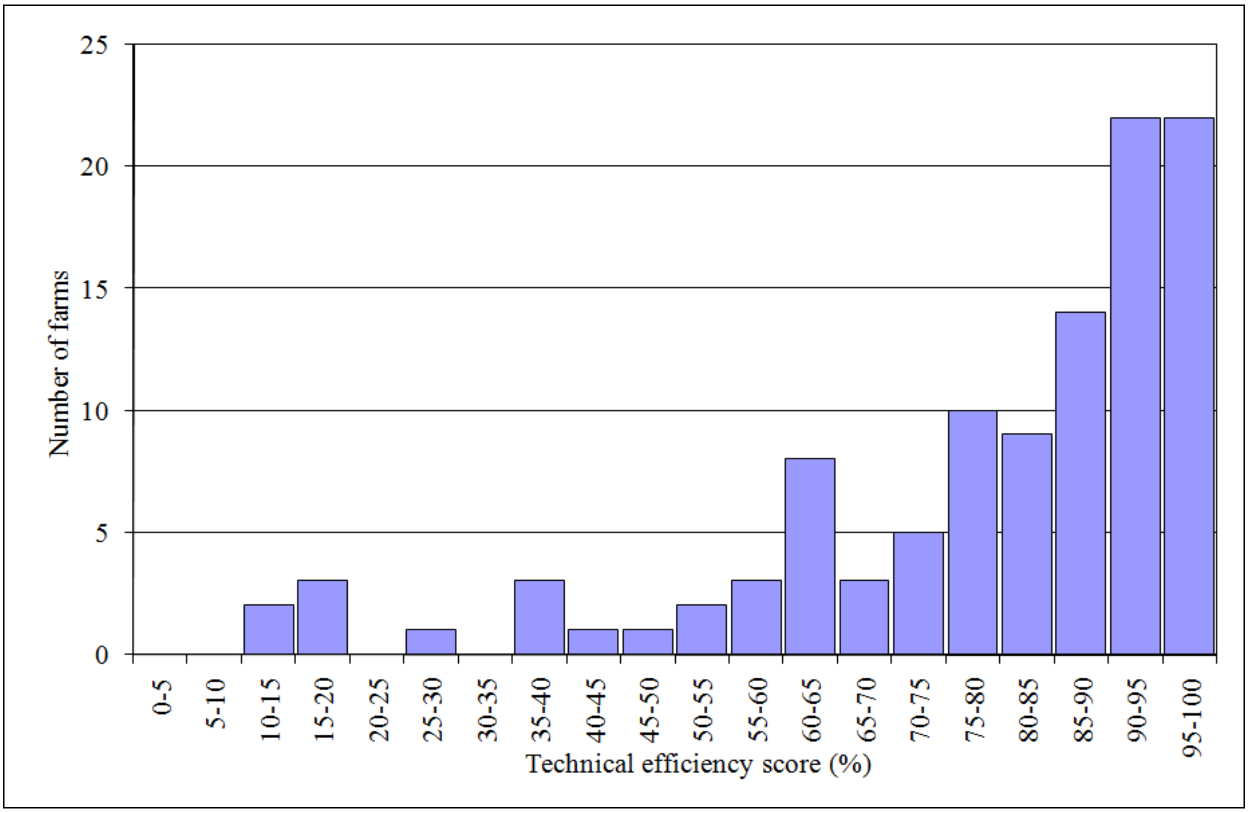
Source: Own calculations.

Figure 1: Distribution of efficiency scores for specialised small crop producers in Chile



Source: Own calculations.

Figure 2: Distribution of efficiency scores for specialised small livestock producers in Chile



Source: Own calculations.

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Die Wurzeln der **Fakultät für Agrarwissenschaften** reichen in das 19. Jahrhundert zurück. Mit Ausgang des Wintersemesters 1951/52 wurde sie als siebente Fakultät an der Georgia-Augusta-Universität durch Ausgliederung bereits existierender landwirtschaftlicher Disziplinen aus der Mathematisch-Naturwissenschaftlichen Fakultät etabliert.

1969/70 wurde durch Zusammenschluss mehrerer bis dahin selbständiger Institute das **Institut für Agrarökonomie** gegründet. Im Jahr 2006 wurden das Institut für Agrarökonomie und das Institut für Rurale Entwicklung zum heutigen **Department für Agrarökonomie und Rurale Entwicklung** zusammengeführt.

Das Department für Agrarökonomie und Rurale Entwicklung besteht aus insgesamt neun Lehrstühlen zu den folgenden Themenschwerpunkten:

- Agrarpolitik
- Betriebswirtschaftslehre des Agribusiness
- Internationale Agrarökonomie
- Landwirtschaftliche Betriebslehre
- Landwirtschaftliche Marktlehre
- Marketing für Lebensmittel und Agrarprodukte
- Soziologie Ländlicher Räume
- Umwelt- und Ressourcenökonomik
- Welternährung und rurale Entwicklung

In der Lehre ist das Department für Agrarökonomie und Rurale Entwicklung führend für die Studienrichtung Wirtschafts- und Sozialwissenschaften des Landbaus sowie maßgeblich eingebunden in die Studienrichtungen Agribusiness und Ressourcenmanagement. Das Forschungsspektrum des Departments ist breit gefächert. Schwerpunkte liegen sowohl in der Grundlagenforschung als auch in angewandten Forschungsbereichen. Das Department bildet heute eine schlagkräftige Einheit mit international beachteten Forschungsleistungen.

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