Latin American Economic Review (2022), volume 31, article 8
https://doi.org/10.47872/laer.v31.63

LATIN AMERICAN ECONOMIC REVIEW
CIDE

RESEARCH ARTICLE

Technical efficiency, production risk, and sharecropping: the case of rice farming in Chile

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Submission received: September 7, 2021
Final version received: June 16, 2022
Accepted: June 20, 2022
Published: December 26, 2022

Abstract

Contractual relationships regarding land tenure in agriculture are diverse. From formal systems such as landowner and fixed rent, sharecropping emerges as an alternative in which the owner of the land shares the benefits and risks of the results with tenants. Therefore, land tenure systems differ in terms of the incentives that the landowner offers to workers, which can have an impact on productivity and production risk. The purpose of this work is to analyze the effect of sharecropping on the mean and variance of technical efficiency for a sample of rice producers in the Ñuble Region, Chile. Using panel data of 109 farmers for the years 2014-2015, we estimate a stochastic frontier model that allows heteroskedasticity in both the general and inefficiency-specific error components. The results show that farmers cultivating under sharecropping show higher levels of technical efficiency while those cultivating land by the fixed rental system reveals an increase in the variance of technical efficiency compared to landowners. Explanations based on moral hazard problems and risk-sharing mechanisms are discussed.

Keywords: technical efficiency; production risk; sharecropping; rice farming.
JEL codes: Q12, Q15, C01.

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1. Introduction

Agriculture is one of the key pillars for economic growth and people's well-being in most economies in the world (FOA, 2020). A limited land supply has led to the growth of the sector being highly conditioned on productivity gains. However, a global decrease in production yields has been observed in agriculture. To illustrate, between 1965 and 1985, global crop yields increased by 56%, while between 1985 and 2005, yields only increase by 47%, a clear indication that agricultural productivity is increasing slower than before (Foley et al., 2011). This decreasing trend is also observed in Chilean agriculture (INE, 2007; Namdar-Irani et al., 2020). In addition, agriculture is a risky activity as constantly threatened by a series of uncontrollable factors, mainly coming from climate. The risks associated with climate play an important role in decisions about the use of inputs and production in agriculture, influencing farmers' strategies to mitigate the impact that these risks could have on crop farming (Kumbhakar, 2002; Zúñiga et al., 2021). In other words, yield variability could be reduced through an appropriate combination of inputs and efficient management practices (Yang et al., 2016). Thus, the adoption of productivity-enhancing, and risk management strategies are crucial to boost food production and mitigate agricultural risks.

Tenancy contracts through which the land is exploited can have implications on yield and yield variability. The most common system of land tenancy documented in the literature are landowner, fixed rents, and sharecropping (Ackerberg and Botticini, 2000), being the latter the focus of this research. Sharecropping has established itself as a solid farming system whose adoption has been uneven across regions around the world (Pi, 2013).). In China, sharecropping was the dominant tenure system for agriculture in the past, which has gradually been decreasing for some crops. For example, sharecropping in rice farming is being replaced by the land rental system due to more favorable conditions (Yang, 2014). In India, sharecropping has emerged as the dominant land tenure system, reaching almost 100% in some regions (Deb et al., 2016). In Indonesia, shared contracts have coexisted with the rest of the alternatives since the feudal era (Sulistyowati et al., 2019). In Bangladesh, the most common form is sharecropping, although a large part of farmers carries out their activity in the informal market (Ahmed, 2011). In Chile, sharecropping has been crucial for the preparation of land for agriculture in southern regions, due to the more extreme geographical conditions observed in these zones. Sharecropping has also allowed farmers in Chile to supplement incomes from their main activity (Robles-Ortiz, 2020). A common feature in all developing countries is that the adoption of sharecropping reflects the concern to share risk in the absence of agricultural insurance or a developed financial market (Nabi, 1986). According to (Nabi, 1986) when a farmer chooses to cultivate his land on his own account or as a tenant paying a fixed rent he expects to receive higher average returns by fully assuming the existing risk (Carmona and Simpson, 2012; Michler and Shively, 2015; Almeida and Buainain, 2016). Sharecropping allows risk sharing, so rewards for the owner and farmer will be among those of the two mentioned contracts (Nabi, 1986). In the sharecropping system, farmers´ incentives are strengthened to exert a higher effort and contribute with their own skills to increase yield and/or quality of production, since they will be paid by a share of total profits, and additional efforts will be reflected in the final distribution. In this sense, farmers' skills play a key role in sharecropping systems, which translates into a greater valuation of peasant labor.

This article aims to analyze the differences in production efficiency and variability associated with inefficiency across the type of land tenure contracts. The hypothesis of this study is that the sharecropping system increases average efficiency and reduces production variability associated with inefficiencies. The literature discussing the factors underlying agricultural contract choices is well-documented, but studies examining the effect of different types of land tenure systems on technical efficiency and its variability are less common. A recent exception is Sulistyowati et al. (2019), who used a stochastic frontier analysis to explore the effect of sharecropping contracts on technical efficiency in Indonesia, concluding no major differences among land tenure systems. However, this study does not explore further the effect of sharecropping on the variability of production associated with inefficiency, which, according to our knowledge, has not been explored in the literature before.

For this purpose, we estimate a stochastic frontier model with production risk, in which marginal effects of the use of inputs on production risk are allowed by incorporating the approach proposed by Just-Pope (Jaenicke et al., 2003). This model also incorporates heteroskedasticity in both the general and inefficiency-specific error components to study differences in the variance of the efficiency across land tenancy contracts. Similar approaches have previously been applied in different countries and crop sectors (Jaenicke et al., 2003; Kumbhakar, 2002; Tiedemann and Latacz-Lohmann, 2013; Yang et al., 2016), but none of the previous studies has incorporated the type of tenancy contract as a determining factor explaining technical efficiency and its variability. The model is applied to a panel data of rice farmers in the Ñuble Region, Chile, collected during the years 2014 and 2015.

This article is organized as follows: in the second part, we present the characteristics of the agriculture sector, rice production, and land tenancy systems in Chile. In the third section, we discuss farmers' motivations for choosing one contract over another and its potential impact on productivity and production risk. In section 4, we discuss the data used and, in section 5, the methodology applied in this study. In section 6, we discuss the results and present the main conclusions.

2. Agriculture and Land Tenure Contracts in Chile

During the first decade of the XX century, Chilean agriculture was characterized by a hierarchical social structure, with large portions of land owned by few people. This unequal distribution was a limitation for production expansion and one of the main causes behind the deterioration in peasants' working conditions, creating important concerns for the rural sector (ODEPA, 2017a). Under this context, and influenced by the social pressure and economic crisis at that time, an agrarian reform aimed at improving land distribution was promulgated. Years later, with the end of the military government, a process of economic liberation and commercial opening drives rapid growth in the sector, creating an important source of employment for rural populations. To illustrate, the Agricultural GDP has almost quintupled since the agrarian reform, according to the last agricultural census (ODEPA, 2017b).

In addition, agriculture represents 25% of the total exports of the country, being fruits the main traded product (DIRECON, 2018). The contribution of agriculture to total employment is also relevant, reaching 8% of the national employment. This value increases up to 20% in some regions in central-south in Chile (ODEPA, 2020a).

Chile is the southernmost place in the world where rice is grown, with varieties developed exclusively in the country to resist low temperatures (Gonzalez et al., 2020). This could be considered a competitive advantage over the rest of rice producers in the world (Becerra et al., 2015). Despite this potential advantage, Chile is not a relevant actor in the international rice market (FOA, 2018; Gonzalez et al., 2020). However, rice farming is quite important for local consumption, meeting 60% of the national consumption (Paredes et al., 2015). Rice farming mainly concentrates in central-south in Chile, being Maule and Ñuble regions the most relevant production zones (Gonzalez et al., 2020; ODEPA, 2020b). In addition, more than 70% of rice producers are family farmers, with an average land size of no more than 15 hectares (Gonzalez et al., 2020). This segment owns about 90% of productive units of the agriculture sector (Berdegué and Rojas, 2014), and plays an important role in the social and economic development of rural communities in Chile.

In Chile, while share contracts are the dominant remuneration system in artisanal fisheries (Salazar, 2015), several land tenure systems coexist in agriculture, which vary in terms of the degree of formality in contracts. According to the last agricultural Census (INE, 2007), the most common forms of land tenure in Chile are landowners (self-cultivated land), rental contracts (land available to the producer in exchange for a fixed rent payment), sharecropping (called mediaría in Spanish), land received in a royalty (land used by a producer that received it as part of a payment for administrative services, effort or other relationships), given land (land used by a producer that was voluntarily given to him), and occupied land (public or private land used without the consent of landowners).

In the past, sharecropping was popularly known only as a verbal agreement, so that the government decided to regulate this contract by the Decree Law 993 of 1975 (MINAGRI, 1975). This law defines the conditions of sharecropping no matter whether the contract is written or not. As written, the core clauses are land description and contributions of the parties, allowed crops, profit distribution, and land restitution date, among others. When the contract is only verbal, it will be assumed that the landowner is obligated to contribute at least the land and water, half of the seeds, and two-thirds of fertilizers, while sharecroppers must contribute with their labor and the rest of the inputs needed for farming. In this case, it will be understood that rewards will be shared equally.

According to the last census in 2007, only 1% of agricultural farms are under sharecropping, a fraction that reduced from a 5% observed in 1976. However, sharecropping is relevant in some regions. For example, out of 2,000 farms reporting the use of share contracts, 60% of them are located in Maule, Ñuble, and Biobío Regions (INE, 2007). There are several reasons why sharecropping can be more prevalent in these regions. First, Ñuble and Maule's Regions are two of the main agricultural production areas in the country, which influence the number of sharecroppers in absolute terms (INE, 2021). Second, there could be structural reasons that explain this regularity. Small-scale farmers are relatively more important in central-southern regions of Chile, including the region of interest, Ñuble (ODEPA, 2019). Sharecropping is more likely to emerge as land is relatively more scarce to labor and capital and as agricultural risk is substantial. Given the limited access to the financial market and lower bargaining power, small-scale farmers are more likely to experience resource constraints and suffer from market and climate fluctuations. In the face of these limitations, sharecropping emerges as the more efficient tenancy system among small-scale farmers to cope with this higher risk or for compensate the lack of resources (Posada, 1995).

3. Farming Contract, Productivity, and Risk

In order to prevent disagreements and establish in advance the terms that concern parties, land tenure contracts are common institutional arrangements in agriculture. They mainly coincide in the way in which capital and labor efforts are rewarded. The most common contractual forms in agriculture are landowners, rental contracts, and sharecropping. Reid's (1975) seminal article on the history of sharecropping, stated that the main difference between the types of contracts in agriculture is given by the degree of mutual cooperation between landowner and tenants. Regarding landowners, it is a form of exploitation referring to an owner who does not transfer the rights to use his land to a third party, being able to cultivate it himself or hire workers to do so in exchange of a fixed salary. This arrangement is more likely to emerge when the owner has enough experience to cultivate his own plot, and has the means (assets) to do so. Fixed rent is a contractual form in which a landlord rents his land in exchange for a fixed rental fee. The similarity with landowners is that high skilled tenants will have the ability to independently work on their plot.

Sharecropping is a contractual form that requires the cession of the land, promoting an association between two actors. The agents involved in this contract are the owner and tenant, who commonly is in agreement to share the benefits and costs of the harvest, where the owner generally contributes with his land, half of the seeds and equipment for harvesting, while the tenant contributes with specialized labor (Codoceo Tapia, 2019; Robles-Ortiz, 2020). This allows to share production risk between landowners and tenants. Furthermore, given tenants' skills are not perfectly observed by landowners, and monitoring relevant costs, sharecropping can help to deal with potential adverse selection and moral hazard problems in the owner-tenant relationship (Agrawal, 1999; Das et al., 2019).

In practice, sharing fifty percent of the results is a common reference in sharecropping, however, it will depend on the contributions provided by each party (Pi, 2013). Sharecropping is usually carried out informally and is very popular among family farmers (Codoceo Tapia, 2019), not only because it lacks a written contract (Arimoto et al., 2010), but also because agricultural activity takes place in an informal market. From a social perspective, sharecropping is widely accepted by farmers for being considered fair as incomes are linked to efforts and productivity improvements, providing an important source of income for a large fraction of farmers that do not own land (Wells, 1984; Nabi, 1986).

There is a vast literature devoted to empirically studying the factors underlying agricultural contract choices, with variables related to farmers' skills and experience, type of crop, assets value, gender, income from other sources, and monitoring costs being the most relevant ones (see for example: Ackerberg and Botticini, 2000, 2002; Jacoby and Mansuri, 2009; Ahmed, 2011; Gebregziabher and Holden, 2011; Carmona and Simpson, 2012; Almeida and Buainain, 2016). There is also a well-documented debate on potential differences in productivity across agricultural contracts from a historical and theoretical perspective. Historians describe sharecropping as a poor farming system, developed in depleted soils and small crops (Reid, 1975). Theoretical contributions suggest that productivity may significantly differ across types of agricultural contracts under certain conditions. For example, Agrawal (1999) states that when both parties are monitored jointly, sharecropping would be as efficient as a rental contract or own cultivation, since it reduces the incentives to provide less effort and asset mismanagement. Pi (2013) proves that equal division between the landowner and tenant is an efficient contractual arrangement regardless of the land's fertility, and At and Thomas (2019) argue that optimal agricultural contracts will be conditioned on tenants' outside options.

The empirical literature exploring yield or efficiency differences across agricultural contracts is less common. Jacoby and Mansuri (2009) find that on average, sharecropping contracts underperform, with a production yield 18% lower than landowners or rental contracts. However, this difference vanishes as supervision is exerted. Jamal and Dewi (2009) examine technical efficiency differences for a set of tenancy contracts among rice farmers in Indonesia. The authors find that while sharecropping is less efficient compared to owner-cultivated plots, fixed-rental arrangements show higher technical efficiencies. Differences in efficiency are lower in cases where there are no alternative employment opportunities for the tenants. Arimoto et al. (2010) studied the association between contract choices and their implication for productivity in rice farming in Japan. The authors find a lower average rice yield in prefectures with a higher prevalence of tenancy, and a stronger negative effect in prefectures with a greater proportion of share tenancy. The authors explain this result on the basis of a potential disincentive in share contracts, differences in production ability or financial ability to purchase sufficient inputs by owners and tenants. Michler and Shively (2015) test the effects of land tenure arrangements on farm efficiency by estimating a stochastic production function among rice farms in the Philippines. The authors find that farmers showed greater technical efficiencies under a fixed rental contract than in formalized property rights arrangements, revealing allocative inefficiency in the market for land. In a recent article, Sulistyowati et al. (2019) also analyze the empirical evidence from rice farming in Indonesia on the use of sharecropping contracts and their impact on economic efficiency. The authors find that landowners show higher economic efficiency levels compared to sharecroppers, and economic efficiency analysis is in line with allocative efficiency results. In spite of that, the authors conclude that the evidence in unclear to support significant differences in terms of economic efficiency between these forms of tenancy contracts, arguing that tenancy systems may be profitable for both landowners and tenants. To our knowledge, there are no empirical studies exploring the effect of agricultural contracts on production risk from an efficiency perspective.

4. Empirical Strategy

In this study, a stochastic frontier production function is estimated for a sample of rice farmers. The Stochastic Frontier Analysis (SFA), has been introduced simultaneously by Aigner et al. (1977) and Meeusen and van Den Broeck (1977). This parametric technique allows distinguishing between the inefficiency term and the random noise error, this term captures random factors beyond the producer's control, such as weather, as well as measurement errors and omissions. The model used in the literature to describe a panel data frontier production function can be written as follows:

$$
\begin{aligned}
y_{it} &= f(x_{it};\beta) + \epsilon_{it} \\
\epsilon_{it} &= v_{it} - u_{it} \\
v_{it} &\; N(0,\sigma_v^2) \\
u_{it} &\; N(0,\sigma_v^2)
\end{aligned} \tag{1}
$$

where y_it is the log of output for the ith sample farm $(i = 1, ..., N)$ and $t(t = 1, ..., N)$ the time period; $f(x_it;\beta)$ is a linear function of the variables in the vector x_it; β is a vector of unknown parameters to be estimated and ϵ_it is the composed error term and consists of v_it and u_it. The former v_it, accounts for statistical noise and follows a normal distribution with zero mean and variance σ_v^2. The latter $u_it \geq 0$ represents the inefficiency component of the composed error term, and it is assumed to have a truncated-normal or a half-normal distribution, although gamma and exponential distribution are also possible.

Rice production like other crops is inherently risky affecting yield due to uncertainty of weather conditions, diseases and inputs (Villano and Fleming, 2006; Yang et al., 2016). In order to examine production risk, the stochastic production function developed by Just and Pope (1978), allows for the estimation of the impacts of an input variable on expected output and its variance (production risk). The general form of the Just-Pope production function can be defined as follows:

$$
y = f(x;\beta) + \epsilon = f(x;\beta) + g(z;\gamma)v \tag{2}
$$

where $f(x;\beta)$ is the mean function relating x to average yield; $g(z;\gamma)$ is the variance function (risk function) that relates the effects of z inputs on the variance of output with γ as the vector of variance-related parameters to be estimated and v is an error term that is independent and identically distributed

$N(0,1)$. Thus, the variance of error is not constant (heteroskedastic) and the marginal risk production (the partial derivative of the variance with respect to the input z_i) can be positive, negative or zero:

$$\frac{\partial var(y)}{\partial z_i} < or = or > 0 \tag{3}$$

If the marginal production risk is positive, the input is risk increasing (increase variance of output), while a negative sign implies a risk decreasing input by this output. The combination of efficiency analysis (SFA) with the Just Pope approach has been presented in several papers. Examples include Kumbhakar (1993, 2002); Battese et al. (1997); Wang (2002); Hadri et al. (2003); Jaenicke et al. (2003); Villano and Fleming (2006); Ogundari and Akinbogun (2010); Tiedemann and Latacz-Lohmann (2013); Badunenko and Kumbhakar (2016); Cagdas et al. (2016); Yang et al. (2016); Wang et al. (2020).

The interest is exploring the variance of inefficiency. Based on the Cagdas et al. (2016), for panel data, we use the following model for our analysis:

$$\begin{aligned} y_i t &= f(x_{it};\beta) + \epsilon_{it} \\ \epsilon_{it} &= v_{it} - u_i \\ v_{it} &\sim N(0,\sigma_v^2) \\ \sigma_v^2 &= exp(x_{it}^v \gamma^v) \\ u_i &\sim N^+(\mu,\sigma_u^2) \\ \mu_i &= z_i^u \delta^u \\ \sigma_u^2 &= exp(z_i^u \alpha^u) \end{aligned} \tag{4}$$

This expression corresponds to the general stochastic frontier analysis model for panel data with heteroskedasticity in v_{it} and u_i. The later following a truncated-normal distribution with mean μ_i and variance σ_u^2, which allow us not only to analyze the mean of efficiency but also the variance of production associated with efficiency. Thus, the expression of the inefficiencies mean μ_i and variance σ_u^2 are added, as functions of z_i^u, a vector of explanatory variables, and δ^u and α^u the vectors of parameters. The Just & Pope approach (risk production) is incorporated through the specification of variance γ_v^v.

A maximum likelihood random effects time-invariant model is employed for the estimation. We assume constant inefficiencies over time because our panel is short with only two periods.

5. Data

This article uses data of a random sample of rice farmers from Ñuble region in Chile between 2014 and 2015. Data collection was conducted by the National Institute of Agrarian Research (INIA by its Spanish acronym), specifically by the Technical Advisory Service Program (SAT by its Spanish acronym). Our samples comprise 109 rice farmers from Ñiquen and San Carlos communes in the region. In terms of surface area, the sample represented at that time approximately 22% of the total rice area of the Ñuble

Table 1: Descriptive statistics of production and input variables.

	2014				2015			
Variable	Mean	SD	Max	Min	Mean	SD	Max	Min
Output (Kg)	49,332	31,388	237,184	13,250	44,821	25,599	141,480	8,700
Land (hectares)	7.650	4.350	32.000	2.000	6.960	4.130	20.000	1.500
Labor (CL$)	901,961	537,660	2,816,000	195,000	1,010,820	599,963	3,360,000	100,000
Capital (CL$)	2,429,430	1,949,463	16,112,523	498,600	1,664,634	989,266	5,094,160	341,300
Other inputs (CL$)	1,859,371	1,108,602	7,762,286	438,000	2,010,014	1,327,181	6,774,000	350,700

Source: Own elaboration. The monetary variables are in real terms.

region. Table 1 shows input and output variables used in the estimation of the stochastic production frontier.

While output is measured by kilos of rice, and land by hectares, inputs are valued in Chilean pesos (CL$). Regarding outputs, the maximum value was observed in 2014, when production reached around 237 tons, as in 2015 production fluctuates between 8 and 141 tons. On average, production decreases a 9% in 2015 compared to 2014. This was in line with a general decrease in the total rice cultivated area in the Ñuble region, which reduced by 18% in 2015 compared to the previous year (ODEPA, 2015). The farmer who allocated more land to rice production in 2014 used 32 hectares while in 2015 the maximum only reached 20 hectares. Nevertheless, average land fell 9% between periods from 7.650 to 6.960 hectares. In particular, labor costs [1] accounted for CL$ 901,961 in 2014, experiencing an increase of 12.1% between periods. Capital inputs are proxied for the use of machinery and capital services in the agricultural production process. These input costs are relevant, and account for investment decisions among farmers. This item experienced a decrease of 31.5% between the years. The reduction in capital costs may reflect a drop in machine investment, which is in line with the decrease in rice area. Finally, other inputs consider the value spent in seeds, fertilizers and pesticides. The average cost of these inputs reached around CL$ 1,859,371 in 2014, with a maximum of CL$ 7,762,286. This input cost also experienced an increase between 2014 and 2015, reaching a value close to CL$ 2,000,000. These higher input costs in the second year may have influenced the reduction in the rice cultivated area in the short-term.

Table 2: shows the descriptive statistics of variables related to farmers' characteristics and land tenancy systems. They are represented as the vector z in our model.

Variable	Mean	SD	Max	Min
Education	2.229	1.181	6.000	0
Farmer Experience (years)	11.826	8.411	35.000	1.000
Rice specialization (% of total land)	0.512	0.281	1.000	0.042
Storage warehouse (1= yes, 0=no)	0.775	0.418	1.000	0
Type of land tenancy				
Landowners (1= yes, 0=no)	0.362	0.482	1.000	0
Sharecropping (1= yes, 0= no)	0.427	0.496	1.000	0
Fixed rents (1=yes, 0= no)	0.211	0.409	1.000	0

Source: Own preparation.

Given the assumption of persistent inefficiency, we used the average of these variables to explain the mean and variance of technical efficiency. This arrangement is reasonable due to the short panel data, and just few observations presenting some variation between years of interest. These observations were removed from estimations.

[1]The labor variable is defined as the total labor cost. This is a value in Chilean pesos reported by the farmer, including the cost of both own and hired labor.

To proxy for education, we use a categorical variable as follows: No education (0), incomplete elementary education (1), complete elementary education (2), incomplete secondary education (3), complete secondary education (4), incomplete tertiary education (5), and complete tertiary education (6). More than 75% of farmers in our sample report to have completed elementary education or have a lower level, with just one farmer revealing to have completed his tertiary education. Farmer experience is measured in years and calculated as the difference between the starting date of the rice business and the survey date. Farmers in our sample report having, on average, 12 years of experience farming rice. Rice specialization is calculated as the share of total agricultural land that is allocated to rice farming. Data shows that farmers do not only produce rice, allocating, on average, 51% of this land to rice cultivation. In addition, we add a dummy variable informing on the presence of a storage warehouse in the plot, where 76% of farmers report to have this infrastructure in the farm. Finally, data confirms the coexistence of the three main land tenure systems, where sharecropping comprises 43% of farmers.

6. Results

We estimated the stochastic production frontier model with random-effects and time-invariant covariates. This model specifies the variance and mean equations of the inefficiencies as functions of time-invariant variables, which fit better our data structure with key time-invariant variables such as land tenancy contracts. [2]

Table 3 shows the estimated coefficients after estimating our Frontier Stochastic Production model in which heteroskedasticity is permitted in the inefficiency component. The latter allows to explain not only differences among farmers associated with the mean of inefficiency, but also heterogeneity in production associated with inefficiency. Results are presented by the estimation of four equations: production mean, production variance, inefficiency mean, and inefficiency variance equations. Production and variance equations are controlled by year and locality. This last control is a dummy variable that takes the value of 1 if farmer belongs to San Carlos, and cero otherwise (Ñiquen). In stochastic frontier efficiency models, it is common to perform a likelihood ratio test (LR test) to check if adding the efficiency term significantly improves the goodness-of-fit of the analysis. Basically, the LR test compares the stochastic frontier model with the corresponding OLS model. We reject the null hypothesis of no efficiencies showing that the OLS model is rejected in favor of the stochastic frontier model. That is, there are significant technical inefficiencies and it is justified to use a stochastic frontier approximation [3].

Results show that efficiency levels in rice farming in Chile are quite high, reaching an average of 90.67%. This result is comparable with those obtained by Aung (2011) in Myanmar, Nargis et al. (2013) in Bangladesh, Sirikanchanarak et al. (2017) in India and Wagan et al. (2019) in Pakistan with values of technical efficiency of 84%, 93%, 96% and 96% respectively. Figure 1 shows the distribution of efficiency scores by land tenancy. The resulting distribution reveals that efficiency scores for each type of land contract are left-skewed. This is confirmed by the skewness values -0.5503035, -1.686499 and

[2] Alternatively, and given no variation in land tenancy contracts across years, we estimate a stochastic frontier model for cross-section data for each year separately (Battese et al., 1997). Although the results are something different, these do not contradict our main findings. While sharecropping significantly reduces inefficiency means in the estimations as using 2014 data, this is not statically significant to explain the efficiency mean in 2015, although the coefficient remains negative. However, we argue that that the stochastic frontier model with panel data has some advantages compared with the cross-sectional versions, in spite of being a very short panel. According to Gujarati and Porter (2004), panel data provides, among other things, a greater amount of informative data, more degrees of freedom and greater variability. Results from cross-sectional models are provided upon request.

[3] The chi-square test of the likelihood ratio is 26.683, which is sufficient evidence to reject the estimation of the the Ordinary Least Square (OLS) model.

Table 3: Results from Frontier Stochastic Production estimations.

Variables	Coefficient		SE
Production mean equation			
Land	0.265	***	0.047
Labor	0.109	***	0.023
Capital	0.403	***	0.055
Other inputs	0.198	***	0.035
Year	0.003		0.017
Locality	-0.026		0.019
Constant	0.150		0.639
Production variance equation			
Land	-3.791	***	0.780
Labor	-0.463		0.332
Capital	3.395	***	0.633
Other inputs	1.436	**	0.624
Locality	-0.832	***	0.293
Year	0.801	**	0.369
Constant	-60.450	***	9.839
Inefficiency mean equation			
Education	-0.019		0.012
Rice experience	-0.004	*	0.002
Rice specialization	-0.126	**	0.056
Storage warehouse	0.103		0.101
Sharecropping	-0.057	*	0.034
Fixed rent	-0.054		0.067
Constant	0.160		0.101
Inefficiency variance equation			
Education	0.463		0.295
Rice experience	0.095		0.061
Rice specialization	2.448	*	1.356
Storage warehouse	-2.579	***	0.869
Sharecropping	-0.305		0.973
Fixed rent	1.935	*	1.067
Constant	-7.498	***	2.063

Source: Own elaboration. *, ** and *** denote statistical significance at 10%, 5% and 1% levels, respectively.

-0.6995606 for sharecropping, fixed rent, and landowner contracts, respectively. The red line shows the mean efficiency for each type of contract. On average, sharecropping show larger efficiency levels than the landowner, and in turn, landowner reports larger efficiency scores than fixed rent contract.

Regarding the production mean equation, al inputs are statistically significant at 1% to explain production and have the expected sign, that is, land, labor, capital and other inputs, are positively and significantly related with rice production.

In terms of the production variance equation, we found that capital and other inputs are risk increasing. Capital increasing production variance is in line with a potential higher risk of assets losses, which may drive larger fluctuations in yield production (Yang et al., 2016). A positive and significant coefficient in the production variance equation for other inputs has been also found in the literature before for the case of fertilizers, for instance (Cagdas et al., 2016). We found too that labor and land decrease production risk (negative coefficient) but only land is statistically significant. A negative coefficient for land can be associated with differences between larger and smaller farmers, where the formers should be in better conditions to cope with production risk.

In the inefficiency mean equation, we found that sharecropping, rice experience and rice specialization are negatively and significantly related to technical inefficiency (negative coefficient). More experienced farmers have spent more time in the sector, learning from practices, which should improve their skills and knowledge of the field. Our results suggest that rice experience in relevant to boost technical efficiency. This finding is common in the literature (Külekçi, 2010; Mariano et al., 2011). Farmers with a larger fraction of rice over the total cultivated land also show higher levels of technical efficiency. These results mean that farmers that specialized in rice farming have some advantages in terms of productivity compared to farmers who diversify and devote their land to other crops (Jaime and Salazar, 2011).

Finally, sharecropping is positively associated with technical efficiency, having as baseline landowners. This finding is not generally supported by the empirical literature. However, theoretical contributions and some empirical works provide some insights that help us with a possible explanation for this result. Some authors argue that the efficiency of sharecropping compared to other land tenancy arrangements will be conditioned on characteristics such as monitoring efforts, division of benefits, and tenants' outside options (Jacoby and Mansuri, 2009; Jamal and Dewi, 2009; Pi, 2013; At and Thomas, 2019). In other words, it is expected that sharecropping works relatively better as the tenant´s efforts can be properly supervised, tenants face fewer alternative employment opportunities, and benefits are distributed more equally. Unfortunately, the first two characteristics are not observed in our data. Notwithstanding, we do observe the level of specialization in rice farming by the fraction of the total area that is devoted to rice farming. This feature reveals that the level of specialization in rice farming is larger in sharecropping compared to other land tenancy systems (0.56 versus 0.51). We believe that this is can be a signal of a higher dependence on rice farming to generate income, fewer outside options, and therefore a higher commitment to devote more time and effort to rice production. Thus, the incentive-mechanism embedded in share contracts on the basis of tenants' rewards being more closely related to their economic performance will be more likely to activate in our setting. This is not necessarily true for alternative land tenancy systems. For example, under landowner and fixed rental mechanisms, workers are hired for a fixed salary that is paid regardless of their performance, giving rise to opportunistic behavior, and then reducing incentives to enhance labor effort. In contrast, under a sharecropping arrangement, tenants act as workers whose payment will be a share of total benefits, which is a function of their own effort.

For the variance of production associated with inefficiency, results show an increase in the variance among more specialized farmers, and those with fixed rent contracts, while farmers having storage warehouse exhibit a reduction in the variance associated with inefficiency. Farmers devoting a larger fraction of their land to rice cultivation could be at a higher risk as diversifying less and putting most of their resources in just one activity. Thus, more specialized rice farmers will have less options to mitigate potential negative effects from uncontrolled events. A higher efficiency average and a higher variance in this inefficiency observed in farmers that are more dependent on rice production is consistent with economic rationale that suggests that higher returns come to the expense of bearing higher risks. We also found that farmers with storage warehouse show a lower production variability associated with inefficiency. Warehouse facilities are crucial infrastructure to face fluctuations in rice markets by storing part of the production as market supply is high or demand is insufficient. Storage also permits reduce the humidity level and keeps the cereal clean, mitigating the risk of pest problems commonly observed in cereals. Finally, results reveal that farmers with land fixed rent contracts show a higher production variance associated with inefficiency compared with landowners. One clear distinction between the landowner and fixed-rent contracts has to do with an opportunistic behavior related to asset mismanagement. Fixed rent tenants have fewer incentives to invest in productive asset maintenance relative to landowners (Platteau and Nugent, 1992). For example, some farmers with fixed rent contracts may be less likely to carry out efforts to enhance land quality (Jacoby and Mansuri, 2009), which can increase dispersion in agricultural productivity. Moreover, farmers renting land from a third party have limited information on farm characteristics (fertility, humidity, etc.), which becomes an extra risk that tenants must assume. Consequently, inefficiency variance may be relatively larger among farmers with fixed-rent contracts.

7. Conclusions

This research aims to contribute empirically to the discussion of productivity differences across land tenancy systems. Sharecropping is an informal and poorly regulated type of contract, which has made it an object of interest among scholars to explore its choice and performance in relation to alternative land tenure contracts. The objective of this work was to estimate the effect of the type of contract on technical efficiency and the risk of production associated with efficiency. To achieve this objective, we estimated a stochastic production frontier with an approximation to the Just-Pope model that allows heteroskedasticity in both the general and inefficiency-specific error components. We applied this model to a sample of rice farmers in the Ñuble region in Chile.

Our analysis supported productivity-enhancing characteristics of share contracts in rice farming. We found that sharecroppers perform better than landowners in technical efficiency, which may be proof of the benefits of collaboration included in this contract. In this sense, results could be in line with larger incentives for sharecroppers to contribute with their knowledge and skills to improve technical efficiency in production, motivated by a closer association between efforts and rewards. We did not find a significant relationship between sharecropping and inefficiency variance. However, results revealed that rice farmers renting land could exhibit a larger variability of production associated with technical inefficiency in relation to landowners. A lack of associativity inherent in this type of contract and the most probable emergence of information asymmetries in the relationship landowner-tenant may be behind this higher risk.

Our results have important policy implications. First, sharecropping emerges as a development opportunity for those who do not have land. Therefore, this type of contract is an important income generating activity for who have knowledge and skills to perform well in agricultural activities, but at the same time did not have the resources and access to land to farm, or to fully cover the cost of inputs. Thereby, as returns increase, sharecroppers will rise their participation in the contract and will receive larger benefits. Second, results support larger efforts for public policy design aimed at supporting and promoting sharecropping among small-scale farmers. To increase commercial and entrepreneurial capacity in these contracts, it is essential to generate instances that promote investments by sharecroppers to increase their participation, training programs that improve sharecroppers' knowledge and skills, as well as projects aimed at incentivizing associativity between landowners and tenants to complement resources, share risk and enhance joint capacities to increase the competitiveness of the sector.

Funding Information

We acknowledge financial support from the Office of Research (Dirección de Investigación y Creación Artística) at University of Bio-Bio, Chile, under the research project "Shock de sequías e integración espacial en los mercados agrícolas en Chile" [2030341 IF/R].

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