Land tenure and cost inefficiency: the case of rice (*Oryza sativa* L.) cultivation in Chile

Tenencia de tierra y costo ineficiencia: el caso del cultivo de arroz (*Oryza sativa* L.) en Chile

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Abstract

This study aims to examine the impact of land tenure arrangements on production costs in a sample of rice farmers in Ñuble Region, Chile. A stochastic frontier model was estimated using the primal approach on a panel of 107 farmers in 2014-2015. Production cost was broken down into frontier costs and inefficiency. According to findings, economic inefficiency raises rice production costs by 82%. Technical inefficiency accounts for a 61% increase, while allocative inefficiency accounts for 21%. Across tenure types, land is the input with the highest misallocation, accounting for 93% of allocative inefficiency costs. Sharecropping is the arrangement allocating inputs most efficiently, producing significant differences in production costs relative to leasing and ownership. This finding suggests that before designing a policy to induce a tenure system, it is necessary to evaluate specific cases as there is no system superior to another, strictly speaking.

Keywords
rice production • land tenure • stochastic model • cost inefficiency • misallocation

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Resumen

El propósito de este trabajo es analizar el impacto del acuerdo de tenencia de tierra sobre los costos de producción, en una muestra de productores de arroz en la Región de Ñuble, Chile. Usando un panel de 107 agricultores para los años 2014 y 2015, se estimó un modelo de frontera estocástica, mediante el enfoque primal, y descompuso el costo de producción en costos de frontera e ineficiencia. Los resultados muestran que la ineficiencia económica incrementa en 82% los costos de producción de arroz. Un 61% del incremento se debe a ineficiencia técnica y 21% a ineficiencia en asignación. Transversal al tipo de tenencia, tierra es el factor de producción que presenta la peor asignación, contribuyendo en un 93% a los costos por este tipo de ineficiencia. Mediería, es el acuerdo que asigna los factores con mayor eficiencia, produciendo diferencias significativas en los costos de producción en relación con arriendo y propiedad. Este hallazgo, sugiere que antes de diseñar una política para inducir un sistema de tenencia, es necesario evaluar casos específicos, ya que no existe un sistema que en estricto rigor sea superior a otro.

Palabras clave

producción de arroz • tenencia de la tierra • modelo estocástico • ineficiencia de costos • mala asignación

Introduction

Rice is a staple food for half of the world's population and the third most-produced cereal after maize and wheat on a world basis. More than 90% of total production is concentrated in Asian regions, primarily in China, India, and Indonesia, where local production accounts for 66% of global output (14, 45). In Chile, production is concentrated in Maule and Ñuble regions, with an average of 83,368 tons of rice available for human consumption from 2012 to 2022. Historically, this volume has been insufficient to meet 40% - 45% of the domestic demand, with the remainder imported primarily from Argentina, Uruguay, and Paraguay (36). National output has dropped by 30.4% over the last decade, due not only to adverse climatic factors such as frost and water scarcity, but also to current high input prices for fertilizers and pesticides, high land prices, labor shortages, and low market prices, which have significantly reduced output (35). These factors put farmers under pressure to become more efficient in rice production and input utilization to avoid additional costs and make farms profitable. This raises several questions. One of them refers to the study of the characteristics, unique to the farmer, the farm, and the environment, which help understand why one farmer is more cost-efficient than another and, particularly, what role tenure arrangements to exploit the land play. The latter is the focus of this study.

Tenure arrangements, which govern land exploitation, can have an impact on production and cost efficiency. Landlord, fixed rent, and sharecropping are the most common land tenure systems documented in the literature (1). A large body of literature discusses the factors influencing agricultural production efficiency. However, studies on the impact of various types of land tenure arrangements on production costs are scarce. Works such as Ackerberg and Botticini (2000), Alem *et al.* (2018) and Islam (2018), conclude that land tenure, either leased or owned, favors technical efficiency levels, but they do not break down production costs into technical inefficiency and input misallocation inefficiency cost. Other papers, decompose and analyze the determinants of technical and allocative efficiencies, but they do not estimate the costs of these inefficiencies, nor analyze differences between land tenure arrangements or the degree of input misallocation and its impact on costs (13, 19, 26, 37, 44).

This paper aims to analyze differences in production costs, particularly those due to technical and allocative inefficiencies between ownership, leasing, and mediation arrangements among rice producers in Chile. No other studies deal with this relationship on a cost basis, nor estimate input allocation problems among small rice farmers in Chile. For this purpose, a stochastic frontier model was implemented. Using the primal approach, the degree of input misallocation was estimated and the cost of production was broken down into frontier costs and technical and allocative inefficiencies on a farm basis. The model is applied to a panel data of rice farmers in the Ñuble Region, Chile, collected during the years 2014 and 2015.

This paper is structured as follows: The second part concisely describes rice cultivation and its production chain in Chile. The third section briefly describes the agricultural land tenure system in the country and analyzes its evolution over time. The fourth section introduces the theoretical model and explains the methodology used for this study. The fifth section discusses the data used in the research. In the sixth section, the results obtained are presented and analyzed. Finally, in the seventh section, the main conclusions derived from this study are summarized.

Rice cultivation and value chain in Chile

Rice cultivation in Chile dates back to 1925, although it only acquired commercial relevance a few decades later. The introduction of this crop made it possible to take advantage of an extensive area of soils previously considered marginal, as they lacked viable alternatives for agriculture. This allowed a more intensive use of these soils and offered a more favorable economic option (17, 33). Currently, the national area dedicated to rice cultivation is concentrated in the central-south zone of Chile, with Maule and Ñuble being the most relevant regions. In the last decade, the cultivated area has oscillated around 24,000 hectares, with a peak of 29,500 hectares in the 2017/18 season and a minimum of 20,700 hectares recorded in the 2021/22 season. This has resulted in an average of 83,368 tons of rice available for human consumption and yields of 53% for milled rice or rice available for human consumption.

The internal value chain comprises producers, processors, importers/distributors, and retailers. Producers or farmers are concentrated mainly in the Maule and Ñuble Regions. According to the 2007 Agricultural Census, there are about 1,500 farms dedicated to rice cultivation, with slightly fewer farmers involved in this activity. Notably, most of these farms, specifically more than 70%, have cultivation areas that do not exceed 50 hectares. This reflects that rice production in Chile mainly comprises small and medium-scale farmers.

On the other hand, only a small percentage, approximately 1.6%, has a farm size that exceeds 500 hectares (33). The national processing industry comprises companies that acquire raw materials through long-term contracts or spot purchases directly from farmers. These companies usually have reception, storage, and processing plants located in the communes of the Maule and Ñuble regions, where rice production in the country is concentrated. Some of these companies also play an essential role as importers and wholesale distributors in the Chilean rice market. The rice importing and distributing sector in Chile comprises companies that play a crucial role in the supply chain of this product in the country. These companies import rice from countries such as Argentina, Uruguay, and Paraguay to meet domestic demand (36). In addition to importing, these companies handle the wholesale distribution of processed rice ready for consumption in the Chilean market. The retail sector in the rice supply chain in Chile is composed of companies engaged in the retail marketing of rice products directly to consumers. Approximately 70% of rice sales in Chile are estimated to be concentrated in these retail companies, including supermarket chains, hypermarkets, and convenience stores (33).

It investigates the differences in production costs, particularly those due to technical and allocative inefficiencies between ownership, leasing, and mediation regimes among rice producers in Chile. In the next section, a brief description of Chile's agricultural land tenure system will be provided, and its evolution over time will be analyzed. This will serve as a context for understanding how different ownership regimes can influence production costs and efficiency in rice cultivation in the country.

Agricultural land tenure in Chile

Before the 1967-1973 agrarian reform, the predominant tenure structure in Chile was the latifundio-minifundio system, constituted by relations of dependence between landowners and peasants and characterized by a strong hierarchy and coercion, like the European manorial system, but lacking legal ties over land ownership (16). The tenancy relationship was the main link between an employer and his workers. It consisted of a contract through which the employer ensured stable labor in exchange for meeting the basic needs of his tenants. This contract passed from generation to generation, along with the inheritance of the land from the master to his relatives. The precarious working conditions at the time caused a massive exodus of workers to cities in search of better opportunities. This, together with the unequal distribution of land, which limited the productive expansion of the sector, and the social pressure and economic crisis at the time triggered the agrarian reform, aiming to improve land distribution and put an end to the latifundio-minifundio system. Thus, in 1962, the first agricultural reform law was passed, which made it possible to redistribute state lands among peasants and organize fiscal institutions to reform the countryside (16). This process was further intensified during the Popular Unity (Spanish: Unidad Popular, UP)[1] government from 1970 to 1973. It represented the massive redistribution of 9 million hectares of land to peasants, on legal and institutionally backed conditions (46). However, in 1973, the military government initiated the gradual restitution of a portion of the confiscated lands and the sale of some of the properties with legal problems through the so-called agrarian counter-reform. This process was not free of political, civil, and economic tensions.

[1] The Unidad Popular was a left-leaning political coalition in Chile that supported the successful candidacy of Salvador Allende in the 1970 presidential elections.

Currently, several agricultural land tenure systems coexist in Chile, varying in contract formality. According to the latest Agricultural Census, the most common forms of land tenure in Chile are:

- Ownership with a registered title: Land over which the producer has possession and is covered by a title registered in the Real Estate Registry.

- Ownership without title (irregular): Land the farmer exploits as owner without a registered title deed. It includes those coming from de facto divided inheritances, irregular sales without being adequately registered, those obtained de facto by exchange with irregular title, those assigned by public entities without regularizing their title, etc.

- Royalty: Land the farmer uses as payment for services rendered as manager, laborer, or other employment relationship.

- Leased: Land available to the farmer for use in his operation under a lease contract. As agreed with the landowner, he pays an annual rent for the land in cash, agricultural products, or a combination of both.

- Sharecropping: Land used by the producer - independent mediator - in which the owner is remunerated with part of the production obtained, either in kind or its equivalent in money, following the conditions established by the parties.

- Ceded: Land used by the producer, which was voluntarily given to him by some person and for the use of which he makes no payment.

- Occupied: Public or private land used by a producer without the consent of the legitimate possessor and payment.

As agreed with the landowner, he pays an annual rent for the land in cash, agricultural products, or a combination of both; sharecropping, land received as a royalty, ceded land, and occupied land, the latter corresponding to public or private land used without owners' consent. According to the share of owned, leased, and sharecropped land in the national total, 65.4% of agricultural land is owned, 8.5% is leased, and only 1.5% is sharecropped. Despite the low national share of the latter, both arrangements are relevant in some regions. For example, 24.3% of the leased properties and 43.5% of the properties under mediation are located in Maule, Ñuble, and Bíobío regions (20). This is due to different reasons: first, Maule and Ñuble Regions are two of the country's main agricultural production areas, strongly influencing the number of leasing and sharecropping contracts (21) and second, landholdings in these regions, mainly Ñuble, the region of interest, are smaller relative to the national average (34).

Due to the inherent nature of farming, access to finance is often linked to the use of land as collateral. In this context, farmers operating smaller farms often face limitations in accessing financial resources. This suggests the need to consider more efficient alternatives, such as tenure systems based on leases and sharecropping, specially designed for small farmers, to compensate for the scarcity of resources (40, 41). The latter makes up the focus of this study, *i.e.*, analyzing the differences in farm efficiency levels, according to the type of tenure arrangement.

Model

This study uses the primal system approach proposed by Schmidt *et al.* (1979) and extended by Kumbhakar *et al.* (2006) to identify and measure technical and allocative inefficiencies for a sample of Chilean producers. This approach consists of a production function and first-order conditions of the cost minimization problem. It is algebraically equivalent to the cost system of the self-dual production function (27), but it starts from a parametric production function rather than a cost function.

Consider a Cobb-Douglas production frontier with j inputs, as proposed by Battese *et al.* (1988).

$$\ln y = \alpha_0 + \sum_{j}^{J} \alpha_j \ln x_j + v - u \qquad (1)$$

where:

y = denotes output

x_j = jth input

α_j = are technology parameters to be estimated

v = a random error term capturing events beyo nd farmers' control, which is independently and identically distributed.

u= a non-negative term capturing persistent technical production inefficiency, independently and identically distributed as $N^+(0, \sigma_u^2)$.

Expressing equation (1) in terms of In x_1 we obtain,

$$\ln x_1 = \frac{1}{r}\left[-\alpha_0 + \ln y - \sum_{j=2}^{J} \alpha_j \ln \frac{x_j}{x_1} - (v-u)\right] \qquad (2)$$

where:

$r = \sum_{j=1}^{J} \alpha_j$ are the returns to scale. Equation (2) can be seen as a function of input distance. Following to Kumbhakar *et al.* (2020); Musau *et al.* (2021) and Schmidt and Lovell (1979), the first order conditions of the cost minimization problem are [2]:

[2] Input ratios can be treated as exogenous since they are a function of prices (exogenously given).

$$\frac{PM_{x_j}}{PM_{x_1}} = \frac{\alpha_j x_1}{\alpha_1 x_j} = \frac{w_j}{w_1} e^{\xi_j} \Longrightarrow x_1 = \frac{w_j}{w_1} \cdot \frac{\alpha_1}{\alpha_j} x_j e^{\xi_j} \qquad (3)$$

where:

PM_{xj} = the marginal product of x_j and w_j is the price of input j. The term $e^{\xi_j} \neq 1$ represents the inefficient allocation of input j relative to input 1, the numeraire. Given linear price homogeneity, it is only possible to estimate negative inefficiency. So, input must be numeraire to identify (6). Then, if $\xi_j > 0\left(e^{\xi_j} > 1\right)$ there will be an underutilization of input j relative to input 1, while if $\xi_j < 0\ \left(e^{\xi_j} < 1\right)$ will be overused relative to input 1.

Using logarithms for the first-order condition (3),

$$\ln\left(\frac{\alpha_j}{\alpha_1}\right) - \ln\left(\frac{w_j}{w_1}\right) - \ln x_j + \ln x_1 = \xi_j \qquad (4)$$

Then, using the distance function (2), equations (3, 4) derived from the first-order conditions, and solving for x_j, the following input demand functions can be obtained logarithmically.

$$\ln x_j = a_j + \frac{1}{r}\sum_{j=1}^{J} \alpha_i \ln w_j - \ln w_j + \frac{1}{r}\ln y + \frac{1}{r}\sum_{i=2}^{J} \alpha_i \xi_i - \xi_j - \frac{1}{r}[v-\mu] \qquad (5)$$

$$\ln x_1 = a_1 + \frac{1}{r}\sum_{i=1}^{J} \alpha_i \ln w_i - \ln w_1 + \frac{1}{r}\ln y + \frac{1}{r}\sum_{i=2}^{J} \alpha_i \xi_i - \frac{1}{r}(v-u) \qquad (6)$$

where:

$$a_j = \ln \alpha_j - \frac{1}{r}\left[\alpha_0 + \sum_{i=1}^{J} \alpha_i \ln \alpha_i\right]$$

The production cost function can be obtained from the input demands, taking the following form

$$\ln C = a_0 + \frac{1}{r}\ln y + \frac{1}{r}\sum_{i=1}^{J} \alpha_i \ln \omega_i - \frac{1}{r}(\nu - u) + (E - \ln r) \tag{7}$$

where:

$$a_0 = \ln r - \frac{\alpha_0}{r} - \frac{1}{r}\left[\sum_i \alpha_i \ln \alpha_i\right] yE = \frac{1}{r}\sum_{j=2}^{J} \alpha_j \xi_j + \ln\left[\alpha_1 + \sum_{j=2}^{J} \alpha_j e^{-\xi_j}\right]$$

As pointed out by Kumbhakar *et al.* (2006), Musau *et al.* (2021) and Vasconcelos (2020), the impact of technical and allocative inefficiency on production costs can be obtained by comparing the cost function with and without inefficiencies. In the cost function, technical inefficiency increases costs by $100\frac{1}{r}u\%$, while allocative inefficiency increases them by $100(E - \ln r)\%$. When there is no inefficient input allocation, *i.e.*, when $e^{\xi_j} = 1$, the E and In r terms are equal. Moreover, there is an inverse relationship between the firm's returns to scale (r) and both inefficiencies. More productive firms should also be more efficient in production and input allocation.

Data

This study uses a balanced panel of 107 rice producers from Ñiquén and San Carlos communes in Ñuble Region, Chile. Data were collected by the Agricultural and Livestock Research Institute (INIA for its acronym in Spanish), particularly, the Technical Assistance Program (SAT, for its acronym in Spanish) from 2014 to 2015. They provide information on yield (kg), output value (CL$), land use (ha), production costs (CL$), public and private infrastructure, and farmer characteristics. Following the methodology described by Alem *et al.* (2018) and Henderson (2015), the prices of the inputs used in this study were collected from secondary sources. Prices per man-day (MD) reflect wages for hired labor, the machinery cost is measured in CLP per hectare, and the price of land (ha) corresponds to the equivalent lease's market value, representing the opportunity cost. These price data were obtained from the Chilean Ministry of Agriculture's Office of Agricultural Studies and Policies (ODEPA, for its acronym in Spanish), guaranteeing their reliability and relevance to the country's agricultural context. For other inputs (seeds, fertilizers, and pesticides), the Consumer Price Index (CPI) was used, as suggested by Musau *et al.* (2021). Prices are expressed in Chilean pesos (CL$) for 2014.

Table 1 (page 67), shows summarized statistics of the production cost structure and factor prices per kg of output. Labor costs are the lowest and fluctuate between $5.84 and $70.60, with an average of $20.80. Machinery, other inputs, and land average about $40 and $43 per kg of rice, dominating 86% of the overall cost structure. As expected, the price per hectare of land is the highest, followed by the price per hectare of agricultural machinery and the price per man-day.

For estimating the stochastic production frontier, one output and four input variables were used. Total output was measured in kilograms of rice, land in hectares, labor in MD, machinery in hectares, and the other inputs (seeds, fertilizers, and pesticides) in thousands of Chilean pesos as of 2014.

Table 1. Descriptive statistics of production costs and input prices.
Tabla 1. Estadísticas descriptivas de costos de producción y precios de insumos.

	Mean	Std. Dev.	Min	Max
Production cost for kg rice				
Labor cost ($/kg)	20.80	7.77	5.84	70.60
Machinery cost ($/kg)	42.60	16.30	25.40	170
Other inputs cost ($/kg)	40.70	10.70	14.30	104
Land cost ($/kg)	43.40	7.86	27.70	77.10
Input price				
Labor price ($/jh)	12,800	274.0	12,500	13,000
Machinery price ($/ha)	47,500	1,020.0	46,500	48,500
Other inputs price (IPC)	1.02	0.02	1.00	1.04
Land price ($/ha)	274,000	5,890	268,000	280,000

Table 2 shows the summarized statistics of the variables used in the production function. In terms of output, the maximum production level reached 141 tons in 2015, representing a 68% drop, compared to the maximum in 2014. On average, there was also a significant drop, albeit less pronounced, in the production level, falling back by 9.1%, compared to the previous figure. This result is in line with the decrease in the total area cultivated with rice in Ñuble Region, which fell by 18% in 2015, compared to 2014 (32). Land use and agricultural machinery also show significant drops of 9.1% and 37.5% on average between periods, respectively. The decrease in machinery use may reflect a capital investment drop, which is in line with the decline in the rice area. In contrast, the number of man-days and the cost of other inputs, considering expenditure on seeds, fertilizers, and pesticides, increased by about 3% in 2015.

Table 2. Descriptive statistics of output and inputs.
Tabla 2. Estadísticos descriptivos de productos e insumos.

Variables	2014				2015			
	Mean	Std. Dev.	Min	Max	Mean	Std. Dev.	Min	Max
Output(kg)	49,300	31,700	13,300	237,000	44,800	25,800	8,700	141,000
Land (ha)	7.66	4.39	2	32	6.96	4.17	1.50	20
Labor (jh)	71.80	43.30	15.60	225	74	44.20	7.34	247
Machinery (ha)	52.60	42.30	10.70	347	32.90	19.70	6.74	101
Other inputs (1,000 CL $)	1,860	1,120	438	7,760	1,930	1,280	336	6,490

Regarding technical and allocative inefficiency cost determinants, annual averages were calculated for each determinant as a model was estimated by assuming persistent technical inefficiency. This arrangement makes sense because the panel is small and few observations demonstrate variation between the relevant years. The estimations were adjusted to account for these observations (41). Table 3 (page 68), shows descriptive statistics for variables related to farmers' characteristics, public agricultural infrastructure, and land tenure systems. Educational level was represented by a categorical variable, as follows: No education (0), incomplete primary education (1), complete primary education (2), incomplete secondary education (3), complete secondary education (4), incomplete tertiary education (5), and complete tertiary education (6). Only one farmer claimed to have completed college education, whereas more than 75% of the farmers said they had only completed their primary education. The difference between the administration date of the survey and the start of business operations in the rice industry served as the unit of measurement for farmer experience, which was expressed in years. Farmers said they had been producing rice for an average of 12 years; the farmer with the least experience said they had been doing it for two years, while the farmer with the most said they had been doing it for 35 years. The percentage of total agricultural land set aside for rice farming reflects specialization. Farmers in the study devote an average of 50.8% of the land to this crop. Concerning access to water, a dummy variable was created, assuming a value of 1 when the farm is supplied from a rainwater reservoir and 0 otherwise. On average, 43% reported access to water from a pool. Finally, on land tenure systems, 44% of the farmers report working the land by sharecropping and just under 20% report renting the land.

Table 3. Descriptive statistics determining allocative and technical inefficiency costs.
Tabla 3. Estadísticas descriptivas determinantes de los costos de ineficiencia técnica y de asignación.

Variable	Mean	Std. Dev.	Min	Max
Education	2.24	1.19	0	6
Experience (years)	12.1	8.64	2	35
Specialization (%)	0.508	0.247	0.049	1
Reservoir (1=Yes, 0 = No)	0.43	0.497	0	1
Land tenure type				
Rental (1=Yes, 0 = No)	0.196	0.399	0	1
Sharecropping (1=Yes, 0 = No)	0.439	0.499	0	1
Landowner (1=Yes, 0 = No)	0.364	0.484	0	1

Results and discussion

Table 4 (page 69) shows inefficient allocation parameters (e^{ξ_j}) for land, labor, and other inputs relative to machinery by land tenure type. Results suggest that, on average, none of the inputs is used optimally and there is inefficient allocation. On an input basis, land shows the highest inefficiency level, with an (e^{ξ_j}) three times higher than optimal across all tenure types, revealing a high degree of under-utilization, relative to $e^{\xi_j} = 1$, thus indicating efficient input allocation. In labor, this situation is also observed, but to a lesser extent, fluctuating between 23% and 33%. On the other hand, other inputs are the only over-utilized factor, with a parameter between 0.617 and 0.638. This result may be associated with the high fertilizer and soil preparation costs incurred by farmers to mitigate the impact on productivity due to weed proliferation. Assessments in the Ñuble Region determined average yield losses of up to 30% due to poor weed control (38).

Concerning land tenure, on average, landlords are the most inefficient input allocators, while sharecroppers are the least inefficient. This finding is generally not supported by empirical literature. Bolhuis *et al.* (2021), Chen (2017) and Chen *et al.* (2022), found that greater access to land rental markets via land titling programs would significantly contribute to reducing the inefficient allocation of productive factors. However, some theoretical and empirical contributions provide insights that may aid in explaining this result. Authors such as At *et al.* (2019), Jacoby *et al.* (2009), Jamal *et al.* (2009), Pi (2013), argue that sharecropping efficiency, compared to other land tenure arrangements, can be conditioned by the landowner's monitoring efforts, benefits division, and landholders' external choices. In other words, sharecropping can be expected to be more efficient because the interests of both sides in sharing benefits make monitoring closer and more effective. These two characteristics are not observed in the sample, but there is educational information from the farmers that could be associated with access to external options for income generation. In our sample, sharecroppers have, on average, a lower schooling level (incomplete secondary) than tenant farmers (complete secondary). This characteristic may be a sign of greater dependence on rice cultivation for income generation, fewer external options, and, thus, greater commitment to devote more time and effort to rice production. This effect does not necessarily hold for other tenure modalities. For example, in cases of lease or land ownership, when the farmer needs to hire workers at a fixed rent, regardless of performance, there may be less incentive for productivity as wage needs to be indexed to performance. This is not the case in a sharecropping arrangement as each party's income is a fraction of the total benefits, a function of their effort.

Table 4. Estimates of inefficient allocation by inputs and tenure.

Tabla 4. Estimaciones de asignación ineficiente por insumos y tenencia.

Inputs	Mean	Std. dev.	Min	Max
Machinery/land				
Tenant	3.410	0.179	3.080	3.790
Sharecropper	3.080	0.156	2.780	3.420
Landowner	3.240	0.163	2.790	3.570
Machinery/labour				
Tenant	1.330	0.069	1.210	1.480
Sharecropper	1.230	0.076	1.110	1.420
Landowner	1.240	0.062	1.050	1.370
Machinery/other inputs				
Tenant	0.638	0.011	0.618	0.660
Sharecropper	0.626	0.010	0.605	0.647
Landowner	0.617	0.010	0.590	0.639

From equation (7), it is evident that inefficient input allocation will negatively impact production costs. This impact was estimated using these results and technical inefficiency estimates from the input distance function (2). Table 5 (page 70), shows the average cost to produce 1 kg of rice under different inefficiency constraints. As expected, sharecropping farms show the lowest production costs on average, *i.e.*, 13.5% lower than leased farms and 3.4% lower than owned farms. Using totelling's Generalised T-squared tests of means, both the cost of technical inefficiency and allocative inefficiency were found to be significantly different than zero at 1%. Ignoring these costs could lead to underestimating actual farm production costs, regardless of tenure arrangement. Results indicate that economic inefficiency costs exceed frontier costs by 82% in the three tenure arrangements. This percentage is higher, compared to estimates reported for grain production in Norway (3) and China (46), and lower than estimates for Indonesia (4). On average, 74% of economic inefficiency is attributable to technical inefficiency (61% absolute) and the remaining 26% to allocative inefficiency (21% absolute), *i.e.*, most cost inefficiency is associated with long-term rigidities that are external but affect farm management (9, 29). Both inefficiencies turn into a production cost increase per kg of rice. In line with results in table 4, sharecropping shows the lowest monetary cost inefficiency ($77.8), followed by landowners ($80) and tenants ($88.6). These differences can be partly explained by the fact that sharecroppers have frontier costs that, on average, are 7.5% lower than the other tenure arrangements, but mainly because they have lower inefficient allocation costs due to input misallocation (table 4). The latter may be related to monitoring efforts, benefit sharing, and sharecroppers' eventual lower access to external income sources.

Table 5. Average production cost per kg under different inefficiencies (CLP$).
Tabla 5. Costo promedio de producción por kg bajo diferentes ineficiencias (CLP$).

Cost	Tenant	Sharecropping	Landowner
Production cost	163	141	146
Frontier Cost	88.6	77.8	80
Technical inefficiency cost	54.2	47.7	49
Allocation inefficiency cost	20.1	15.6	17.4
Cost Inefficiency	74.3	63.3	66.4
% Cost Inefficiency	0.837	0.815	0.830
% Technical inefficiency cost	0.612	0.614	0.613
% Allocation inefficiency cost	0.226	0.2	0.217

This perspective raises an interesting explanation for the potential benefits of sharecropping as a more efficient production organization system compared to land ownership and leasing systems, especially from a wage point of view. One of the critical aspects is that sharecropping is based on a performance-linked incentive system, in contrast to the time-based compensation that is more common in land ownership and leasing systems. In sharecropping, workers have a greater incentive to deploy additional effort and perform all necessary tasks more efficiently, which can reduce or even eliminate the need for supervisory costs typical in wage labor systems. In addition, sharecropping can be a viable alternative when there are labor shortages or financial difficulties in paying wages. This is because sharecropping arrangements often involve a more equitable sharing of risks and rewards between the landowner and the farmer, which can benefit the farmer and the farm from an economic perspective. From a temporal perspective, it is also important to consider that in agricultural production, there are stages or cycles in which the marginal productivity of labor may be lower than the wage paid, which would not be economically optimal. Sharecropping can mitigate this problem by encouraging greater labor intensity relative to other contracting systems, which could improve farm economic performance (8).

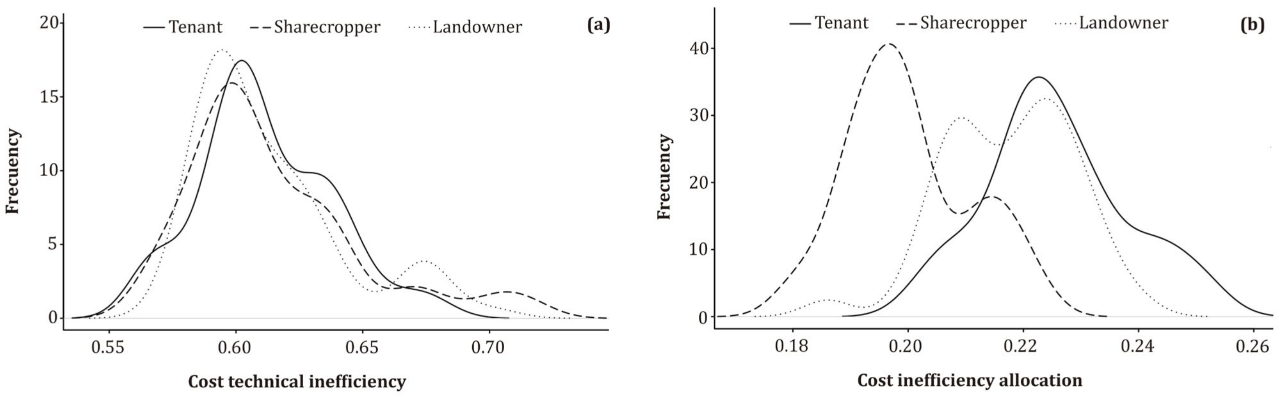
In summary, sharecropping may offer economic and efficiency advantages in the organization of agricultural production, especially in comparison to land ownership and leasing systems, due to its performance-based incentives and its ability to adapt to variable situations in agriculture.

Table 6 shows the results of Welch's mean difference test for inefficiencies, according to tenure agreement. The first column indicates no statistically significant differences in technical cost inefficiency among lease, sharecropping, and ownership. However, there are significant differences between 1% at allocative inefficiency and total inefficiency (columns 2-3). These results suggest that time-invariant structural and institutional factors affect farm management across farm tenure types. Those differences in efficiency may be related to farmers' ability to allocate inputs efficiently. At least in this sample, this ability would be related to tenure type.

Table 6. Mean difference test.
Tabla 6. Prueba de diferencia de medias.

Contrast	Cost inefficiency		
	Technical	Allocation	Both
Rental, sharecropping	-0.533	11.793	3.768
Rental, land ownership	-0.255	3.626	1.124
Sharecropping, land ownership	0.307	-10.338	-2.977

Figure 1 shows the kernel density distributions of both types of inefficiency. In the left-hand panel, the resulting distributions reveal that technical inefficiency scores are skewed to the right for each tenure arrangement. This is confirmed by the 0.403,1.235, and 1.196 skewness coefficients for leasehold, sharecropping, and ownership, respectively. The three distributions look similar, having a high score density, with 92% of the farms located between 0.55 and 0.65. In the right-hand panel, allocation inefficiency distributions for leasing and sharecropping are asymmetric to the right, with coefficients of 0.304 and 0.373. At the same time, owners show an asymmetric distribution to the left with a -0.382 coefficient. Sharecropping shows a high density towards lower inefficiency scores than the other distributions. Particularly, 87% of the farms are between 0.18 and 0.21.



(a) shows the kernel distribution of technical inefficiency costs; (b) shows allocation inefficiency costs.
(a) muestra la distribución kernel de los costos de ineficiencia técnica; (b) muestra los costos de ineficiencia en la asignación.

Figure 1. Cost inefficiency distribution, according to property tenure.
Figura 1. Distribución de la ineficiencia de costos, según tenencia de la propiedad.

Empirical results for the monetary cost determinants of technical and allocative inefficiency are shown in table 7 (page 72). Columns (1) and (4) show that leased land has significantly higher technical and allocative inefficiency costs than owned land (baseline). Regarding sharecropping, the results indicate that this tenure arrangement is statistically more cost-efficient than the ownership system, consistent with previous findings. This efficiency could be related to the fact that sharecropping is based on a contract in which the sharecropper's salary is linked to the farm's performance and, in many cases, is made in kind. Therefore, the sharecropper's earnings are directly related to his performance. This relationship between performance and profits in sharecropping can foster greater efficiency in resource allocation, as both the owner and sharecropper have a shared interest in maximizing farm productivity. Combining the landowner's experience and knowledge with the sharecropper's labor could result in greater efficiency than other land tenure systems.

The estimated coefficients for the land variable suggest that more extensive landholdings are more inefficient, the relationship being non-linear, but decreasing. Although not significant, this result is in line with other findings for the agricultural sector (15, 30, 43). The specialization coefficient indicates that farmers who allocate a larger proportion of the farm to rice production have significantly lower inefficiency costs. As suggested by Jaime and Salazar (2011), this result indicates that farmers who specialize in rice cultivation tend to have some advantages in productivity, compared to farmers who diversify and devote their land to other kinds of crops.

Table 7. Cost determinants of technical and allocative inefficiency.
Tabla 7. Costos determinantes de la ineficiencia técnica y de asignación.

Variables	Cost of technical inefficiency			Cost of inefficiency allocation		
	(1)	(2)	(3)	(4)	(5)	(6)
Land	0.426(0.576)	0.438(0.576)	0.433(0.565)	0.162(0.161)	0.169(0.158)	0.158(0.149)
Land squared	-0.011(0.024)	-0.013(0.024)	-0.013(0.024)	-0.013(0.007)	-0.004(0.007)	-0.004(0.006)
Education		1.036(0.841)	0.987(0.839)		0.678***(0.231)	0.680***(0.221)
Experience			-0.021(0.124)			-0.016(0.033)
Specialization	-7.478*(3.806)	-7.700**(3.805)	-7.669**(3.795)	-7.773***(1.062)	-3.919***(1.044)	-3.676***(0.998)
Reservoir	3.674*(1.859)	3.008(1.927)	2.961(1.893)	1.223**(0.519)	0.805(0.529)	0.745(0.498)
Rental	7.530***(2.479)	6.570**(2.596)	6.325***(2.630)	2.525***(0.692)	1.897***(0.712)	1.863***(0.693)
Sharecropping	-2.250(2.032)	-2.258(2.045)	-2.730(2.387)	-1.582***(0.567)	-1.783***(0.561)	-1.567**(0.628)
Fixed effects commune	No	No	Yes	No	No	Yes
Constant	65.956***(3.349)	64.448***(3.562)	63.524***(4.435)	17.708***(0.934)	16.722***(0.977)	15.334***(1.167)
R^2	0.123	0.1297	0.130	0.239	0.269	0.278
N	214	214	214	214	214	214

Standard errors in parenthesis. *, **, and *** indicate statistical significance at 10%, 5% and 1%, respectively.
Errores estándar en paréntesis. *, **, y *** indican significancia estadística al 10%, 5% y 1%, respectivamente.

Education is included in columns (2) and (5) to control for farmer-level heterogeneities. Again, the sharecropping coefficient is only significant in explaining allocative inefficiency costs. The estimated coefficients for leasing and weeding decrease when compared to the results in columns (1) and (4). In the first case, the drop is between 12.7% and 24.9%, while in the second case, it is between 13.7% and 12.7%. This indicates that when controlling for the farmer's educational level, the tenure arrangement's effect tends to be more favorable in terms of inefficiency costs. This finding could be related to the fact that better educated farmers have better access to information on good agricultural practices, technical advice and training programs, subsidies, or new production technologies, all of which have a positive impact on efficiency. However, note that the education coefficient is positive and statistically significant for the allocative inefficiency cost, which is not expected but is in line with the findings of Henderson (2015) and Vasconcelos (2020). It is reasonable to think that farmers with higher educational attainment face higher opportunity costs in their occupational choice and may see a reduced effort in rice production due to less reliance on farming for income generation.

Columns (3) and (6) include experience as a determinant of inefficiency cost and commune fixed effects. In inefficiency costs, the coefficients for tenure arrangements change slightly, implying that commune-specific market characteristics and imperfections appear to be unimportant in driving the relationship between land tenure and inefficiency costs. This result makes sense given that the communes of Ñiquén and San Carlos are in the Ñuble region and only 33 km apart, implying that there are unlikely to be significant differences in the land market, productive infrastructure, accessibility to inputs, and employment opportunities that contribute significantly to reducing technical and allocative inefficiency costs in each land tenure arrangement.

Finally, it is studied how rice production costs could change with an improvement in the allocation of land input, using current costs as a benchmark. Table 8 (page 73), partially reproduces the results of table 5 (page 70) and incorporates the estimated costs for different levels of inefficiency. Relative to benchmark, a 40% efficiency improvement potentially reduces allocation costs by 40.8% for leasehold and ownership and by 41.2% for sharecropping. This leads to an average decrease of 4%-5% in production costs and an increase of 17.8%, 11.2% and 12.9%, and in profits for leasehold, sharecropping, and ownership, respectively. The last three rows of the table show costs when land allocation is efficient relative to cash input. Costs of 1.5%-1.6% due to inefficient allocation of labor and other inputs remain. This finding suggests that about 93% allocation costs are associated with deficiencies in land use, particularly the underutilization of input relative to the numeraire. The potential impact on profits is considerable. The leased land is the most favored with 49.1% increase in earnings. On the other hand, sharecropping and ownership could increase their profits by 25.3% and 29.8%, respectively. These results are intuitive as they demonstrate the monetary impact of efficiency; allow us to understand that there are significant differences depending on the land tenure arrangement; and highlight the need for public policies encouraging the efficient use of productive factors.

Table 8. Production costs under different levels of inefficient land allocation.
Tabla 8. Costos de producción bajo diferentes niveles de asignación ineficiente de la tierra.

Inefficiency	Cost	Tenant	Sharecropping	Landowner
100%	Production	163	141	146
	Allocation inefficiency	20.1	15.6	17.4
	% Allocation inefficiency	0.226	0.2	0.217
90%	Production	161	140	145
	Allocation inefficiency	18.1	14	15.7
	% Allocation inefficiency	0.203	0.18	0.196
60%	Production	155	135	139
	Allocation inefficiency	11.9	9.17	10.3
	% Allocation inefficiency	0.134	0.118	0.129
30%	Production	149	130	134
	Allocation inefficiency	5.7	4.45	5.03
	% Allocation inefficiency	0.064	0.057	0.063
0%	Production	144	127	130
	Allocation inefficiency	1.45	1.18	1.3
	%Allocation inefficiency	0.016	0.015	0.016

Conclusions

This paper empirically investigated how agricultural land ownership, sharecropping, and leasing regimes may affect production cost efficiency. For this purpose, a sample of 107 rice producers from the Ñuble Region in Chile, observed from 2014 to 2015, was used, and a stochastic frontier model of costs was estimated using the primal system approach. This allowed estimating misallocation measures for productive factors, technical and allocative efficiency scores, and decomposing production costs into three components: frontier costs, costs due to technical inefficiency, and costs due to allocative inefficiency.

The results revealed that, on average, inefficiency increases rice production costs by 82%. Of this increase, 61% was attributed to technical inefficiency, while 21% was due to costs due to allocative inefficiency. Regarding the latter costs, statistically significant differences were found among the various land tenure regimes. In particular, the sharecropping system stood out as the most efficient, with production costs 13.5% lower than the rental system and 3.4% lower than those of the ownership system.

The finding may be connected to sharecropping's potential benefits over land ownership and leasing systems as a production organization system, particularly regarding higher labor productivity and reduced labor and supervision costs. One of the critical factors in this regard is that, in contrast to the time-based wage that is more typical in land ownership and leasing systems, sharecropping in Chile is based on a performance-linked incentive structure. Sharecroppers have a higher incentive to exert more effort and complete all responsibilities more efficiently, which can cut down on or do away with the costs associated with supervision that are typical in wage labor systems. This is because sharecropping agreements frequently entail a more equitable distribution of risks and benefits between the landowner and the farmer, which can benefit the farmer and the farm from an economic perspective.

An additional relevant finding is that, regardless of the land tenure regime, a public policy that addresses the misallocation of the productive factor of land among farms could potentially reduce up to 93% of the costs associated with inefficient allocation per kilogram of rice. This would substantially impact farmers' profits and, consequently, wealth generation in the rice industry. According to estimates, improving land use efficiency would result in significant, cross-sectional profit increases for all land tenure types.

This study provides valuable data on the efficiency of rice production. It highlights differences in cost efficiency levels according to land tenure type. It suggests that these differences may be related to the potential of each tenure system to ensure better farm yields. It also highlights the need for public policies that promote a better allocation of productive resources for the whole sector's benefit. A limitation of this study is assuming that all farmers, regardless of tenure type, have the same skills for working the land. In this sense, relaxing this assumption could solve input misallocation by redistributing them from less to more skilled farmers so that optimum marginal productivities are equated. The latter could be a topic for future research on the particular case of Ñuble Region in Chile.

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