Tuijin Jishu/Journal of Propulsion Technology
ISSN: 1001-4055
Vol. 44 No. 3 (2023)

Technical And Economic Efficiency in Native Potato Production In The Apurimac Region, Perú

Salvador Quispe Chipana[1], Rosa Huaraca Aparco[2], Yelina Rodriguez Ruelas[3], Niki Franklin Flores Pacheco[4], Juan Alarcón Camacho[5], María Inés Rivero Aedo[6], Rocio Cahuana Lipa[7], Juan Solano Gutierrez[8]

salvador.quispe@unsaac.edu.pe[1], rhuaraca@unajma.edu.pe[2], nflores@unamba.edu.pe[3], yelina.rodruiguez@unsaac.edu.pe[4], jalarconc@utea.edu.pe[5], maria.rivero@unsaac.edu.pe[6], rcahuanal@utea.edu.pe[7], jsolanog@unajma.edu.pe[8].

[1,4,6] Universidad Nacional San Antonio Abad del Cusco, Andahuaylas, Perú.
[2, 8]Universidad Nacional José María Arguedas, Andahuaylas, Perú.
[5, 7]Universidad Tecnológica de los Andes, Andahuaylas, Perú.
[3]Universidad Nacional Micaela Bastidas de Apurimac, Perú.

Abstract
The objective of this work was to evaluate the technical and economic efficiency in the production of native potato (Solanum tuberosum L) in the Kishuara district, Andahuaylas province, Apurímac region in the 2018-2019 agricultural campaign. At the theoretical level, while technical efficiency is aimed at achieving the maximum possible production with the available resources, and economic efficiency is aimed at minimizing input costs. At the same time, the hypothesis was that technical and economic efficiency are positively and significantly related to native potato production in the Kishuara district, Andahuaylas Province, Apurímac Region 2018 - 2019. At the methodological level, it is non-experimental, cross-sectional and econometric. Regarding the results, it was determined that technical and economic efficiency are positively and significantly related to native potato production in Apurimac. At the same time, it was found that producers are significantly using increasing returns to scale (1.27), in this sense the results show that by doubling production factors such as seed, wages and tractor, native potato production goes to more than double.

Keywords: Technical Optimum; Economic Efficiency; Cobb Douglas Production Function; Econometric Model; Production Elasticity.

INTRODUCTION

In terms of average between the years 1991 to 2021, according to the INEI (2022), Puno has had the highest potato production, followed by the regions of Huánuco, Junín, La Libertad, Cusco, Cajamarca and Apurímac. On the other hand, the regions with the lowest production are Lambayeque and Moquegua. As for the price of potatoes, it is observed that in the Tacna region it is more expensive than the rest of the regions.

However, according to Eguren (2021), potato production is not profitable for producers because the price of this product has decreased, going from S / 1.05 soles per kilogram in 2016 to S / 0.98 soles per kilogram in 2021.. Likewise, Eguren (2021) indicates that the Peruvian state should strengthen an agrarian policy to improve potato production and better prices for producers who are dedicated to this product. To address the problem in question, the following question is posed: What is the technical and economic efficiency of the production of native potato (Solanum tuberosum L) in the district of Kishuara, Andahuaylas province, Apurimac region during the 2018-2019 agricultural campaign? Likewise, the general objective of the study is to evaluate the technical and economic efficiency in the production of native potatoes in the aforementioned district and province of Apurimac during the 2018-2019 agricultural campaign.

Sanabria et al. (2022) carried out the evaluation of potato crops in Colombia, which was descriptive cross-sectional, based on an interview and subsequent analysis. Regarding the findings, it was found that there is heterogeneity in agroecosystems especially in agricultural practices and environmental management. Martinez et al. (2022) investigated potato cultivation in southwestern Colombia, where researchers used a sample of 1018 peasant families and the application of a questionnaire for further analysis. As for the results, a gap was found in the types of producers and the efficiency levels of these producers stands at 85%.

Quispe (2022) investigated potato production in Apurimac, whose sample consisted of 40 small farmers, cross-sectional type and the application of a questionnaire. Regarding the results, it was found that labor is being used excessively and this does not generate economic deficiency. Martinez et al. (2021) They investigated the production of eggplant in Colombia, which applied a questionnaire to 62 cross-sectional producers. As for the results, it was found that in this producing area they are using an economy of decreasing scale.

Chavez and Chavez studied potato ((2021)Solanum tuberosum L) production in Peru, where researchers applied time series and econometric. In relation to the results obtained, it was observed that a 1% increase in yield per hectare of potato translates into a 0.9% growth in potato production. Albuja et al. (2020) investigated Andean crops in Ecuador, their study was cross-sectional, with a sample of 57 producers and the application of a questionnaire. As for the results, economic efficiency was found especially in their crops such as corn. At the same time, this producing area presents a distribution of land.

Pasquel et al. (2019) investigated potato production in Peru, where the study was cross-sectional, based on a survey and subsequent analysis. It was concluded that 80% of producers use their own resources for their production and that their potato production is efficient. Calle researched potato production in (2019) Bolivia, which his study was documentary and econometric, where he found that inputs such as seed, irrigation and fertilizer are key in potato production, causing economic efficiency.

Altamirano et al. (2019) investigated the technical efficiency of irrigation in the districts of Mexico, where the study was descriptive and cross-sectional, based on a survey and subsequent analysis. It was concluded that there is a technical inefficiency in the districts, since producers do not know how to use the appropriate inputs for the production of a good. Pérez and García (2018) conducted a study on technical efficiency for the case of an application in dairy farms in Uruguay, where researchers aimed to analyze the efficiency performance of dairy farms in Uruguay, using cross-section. It was concluded that the average technical efficiency of dairy farms is 74%, and the main determinants of efficiency differences are the specialization of farmers in dairy production and the use of artificial insemination.

Poveda et al. (2018) studied the technical efficiency of potatoes in Colombia, where the study was descriptive and cross-sectional, based on a sample of 56 municipalities and subsequent analysis. It was concluded that there is a heterogeneity in economic efficiency, where municipalities reach an economic efficiency of 48%, this means that producers in each municipality lack sufficient knowledge about the inputs used in the production of different products.

Rebollar et al. (2018) investigated milk production in Mexico, where the study was descriptive and cross-sectional, based on a survey and subsequent analysis of the Cobb-Douglas function. The researchers found an optimal milk technician of 353.80 liters, which producers are using correctly the inputs.

Torres (2018) investigated the production of potatoes and quinoa in Peru, where the work is descriptive and cross-sectional, based on a survey and subsequent econometric analysis. It was concluded that both labor and capital are key inputs that producers achieve economic efficiency in their products. Vélez (2018) investigated potato production in Ecuador, which was descriptive and cross-sectional, based on a sample of 202 producers and subsequent econometric analysis. It was concluded that there is a marked difference in economic efficiency in the different strata of producers.

Trujillo (2017) investigated potato production in Peru, where the study was documentary, time series and subsequent econometric analysis. It was found that producers are using the surface correctly and this generates economic efficiency. Garcia et al. (2017) carried out a work on technical and economic efficiency of potatoes in Peru, where the researchers used a descriptive and cross-sectional study, based on a survey and subsequent econometric analysis. It was found that potato producers are using inputs correctly and that allows them to have responsible technical and economic efficiency.

Cárdenas et al. (2017) carried out a research work on potato production in Peru, under a descriptive and cross-sectional methodology, based on a survey and subsequent econometric analysis. It was found that potato farmers are employing increasing yields. Veloso et al. (2015) investigated the technical effectiveness of cattle producers in Chile, under a descriptive and cross-sectional study, based on a sample of 83 small producers and subsequent econometric analysis. It was found that producers are employing technical efficiency for cattle production.

Melo and Orozco (2015) investigated the technical effectiveness of agricultural production in Colombia, under a descriptive and cross-section, based on a sample of 1565 households and subsequent econometric analysis. It was concluded that there is a marked difference in technical efficiency in producers. Ramirez et al. (2015) investigated agricultural production in Colombia, under a descriptive and documentary work and subsequent econometric analysis. It was concluded that there is a technical inefficiency, that is, producers are misusing inputs in the production of bananas, corn, cassava, beans and potatoes.

Morales et al. executed a study of (2015) technical and economic efficiency of potatoes in Mexico, under a descriptive and cross-sectional study, based on a sample of ten municipalities and subsequent econometric analysis. Technical inefficiency was found in the different municipalities. Jerez and Martín (2012) investigated potato production in Cuba, under a descriptive and cross-sectional scenario, based on a survey and subsequent econometric analysis. It was found that years of experience and daily wages are key in the firm to generate technical efficiency.

Galarza et al. (2015) They point out that for the case of two inputs the production function is as follows: $Q = f(X_1, X_2)$. If the factors have strictly positive prices, , prove that the share of the cost of factor 1 in $(w_1, w_2 > 0)$total costs increases when the relative price of that factor increases, if and only if the elasticity of substitution, in equilibrium, is less than 1.

Pindyck and Rubinfeld (2013) establish that a maximum level of output is reached when inputs are chosen correctly. Rezk (2011) indicates that the estimation of the quadratic production function results in multicollinearity and to solve it is to identify the relevant inputs. Maino(2011) indicates that short-term production exists at least one fixed factor and the only way to increase production is to increase labor.

Mankiw (2017) indicates that production represents the combination of various inputs to achieve adequate production. Garavito (2014) points out that, in the short term, production reaches its maximum quantity produced. From this, a difference is generated between the technical optimum and the technical maximum. Varian(2011) points to three stages in the short term in production. In stage 1, production has an increasing trend. For stage 2, production begins to decrease and in lid 3 production continues to decrease where its marginal product of labor is zero, which the firm must operate in stages 1 and 2.

Fernández (2010) points out that the technical optimum occurs when the average output of the input is crossed with the marginal product of the input. In addition, Quiroz (2016) indicates that the technical maximum is reached when the marginal product of labor is zero. Martínez y Quiroga (2014) mathematically the technical optimum is:

$$máximo PMe_L = \frac{PT_L}{L} = \frac{x(L)}{L}$$

The necessary condition of maximum.

$$\frac{dPMe_L}{dL} = \frac{d\left(\frac{PMe_L}{x}\right)}{dx} = \frac{\left[\frac{dx(L)}{dL}\right].L - x(L)}{L^2} = \frac{1}{L}.\left[\frac{dx(L)}{dL} - \frac{x(L)}{L}\right] = 0 \rightarrow PMg_L = PMe_L$$

Galarza et al. (2015) point out that all inputs are long-term variables . The researchers also point out that the isoquant curve represents the production functions that the producer has used various inputs to achieve adequate production levels. Parkin and Loría (2010) point out that when the firm moves down along an isoquant, the marginal rate of technical substitution decreases. Pindyck and Rubinfeld (2009) point out that in the long run the increasing, constant and decreasing scale appears.

METHODS

The study was conducted in the district of Kishuara, one of the 19 districts of the province of Andahuaylas, located in the Apurimac region of southern Peru, under the administration of the Regional Government of Apurimac. The district has a land area of 309.91 km2 and borders the departments of Cusco and Ayacucho. Based on the research, which focused on the Coob Duollas-like production function in Kishuara native potato production, data relevant to commercial activity, such as roads and population center dwellers, were prioritized. It is important to mention that the road that connects Kishuara is paved and extends from Ayacucho, Chincheros, Andahuaylas, Abancay and Cusco.

During the 2018-2019 agricultural campaign, the population under study was composed of 414 native potato producers, which included both small, medium and large producers, located in the district of Kishuara, Andahuaylas province, Apurimac region. The sample was calculated using the statistical formula of finite population, which according to Aching (2005) indicates that a finite population is when it has less than 100,000 inhabitants.

$$n = \frac{N * Z^2 * p * q}{E^2 * (N-1) + Z^2 * p * q}$$

Where:

- n: sample
- ${Z^2}_\alpha : (1.96)^2$
- p=probabilities: 0.5
- E: Error: 0.05
- N: population: 414

Replacing the values we have:

$$n = \frac{(414)(1.96)^2(0.5)(0.5)}{(0.05)^2(414-1) + (1.96)^2(0.5)(0.5)} = 200$$

The study was cross-sectional and non-experimental, with the purpose of describing the characteristics of native potato producers in the Kishuara district in the 2018-2019 agricultural season. In addition, the study has an explanatory approach, since an econometric model was used to identify the factors that influence the production function of the native potato in the same district.

It is simple random probability sampling. Which were surveyed in their plots the producers who manage the areas of crops, the small producers in plots, the medium ones a sown task and finally the large producers plus one of one hectare planted.

On the other hand, Trujillo (2010) points out that an econometric model is a simplification of a real diagnosis, where control, endogenous, residual variables and parameters participate. The uniequational econometric model of the study is:

$$rend_i = \beta_0 + \beta_1(semila_i) + \beta_2(jornal_i) + \beta_3(tractor_i) + \epsilon_i$$

Where:
$rend_i$: yield of native potato production (Kg per hectare)
$semilla_i$: Seed (Kg per hectare)
$jornal_i$: Direct labour (wages per hectare)
$tractor_i$: Tractor (hours/machine per hectare)
$\beta_0, \beta_1, \beta_{2,}\beta_3$:Parameters
ϵ_i: Error term
Additionally, logarithm was applied to all variables in order to find parameters in terms of elasticity, leaving the econometric model as follows:

$$lnrend_i = \beta_0 + \beta_1(lnsemila_i) + \beta_2(lnjornal_i) + \beta_3(lntractor_i) + \epsilon_i$$

On the other hand, the econometric evaluation comprises three axes, which are economic, statistical and econometric. As for the economic axis, it is to check the right signs. For the statistical axis, significance is verified individually and globally. Likewise, Loria (2007) evaluates the goodness of fit, which is the part that contributes the regressor variables to the model.

As for the econometric evaluation, the normality of the errors is diagnosed, which Gujarati and Porter (2010) point out that the waste has to be distributed in a normal way. At the same time, autocorrelation is evaluated, which according to Loría (2007) points out that residuals should not be correlated. Also, heteroskedasticity is diagnosed, since Loría (2007) indicates that the residual variance must remain constant within the sample period.

Continuing with the econometric axis, the diagnosis of multicollinearity is made, since Loría (2007) points out that the regressor variables should not be correlated. To identify problems of multicollinearity, it was evaluated with the Variance Inflation Factor (IVF), where if it is less than 10, there is no multicollinearity. The program for econometric analysis was the statistical software EViews version 10.

RESULTS AND DISCUSSION

A Cobb Douglas production function has been designed, $Q_t = \beta_0 semilla_t^{\beta_1} jornal_t^{\beta_2} tractor_t^{\beta_3}$ After collecting the data, we proceeded to perform an econometric analysis using a multiple linear regression model. The results are shown in Table 1. It was found that the parameters of the independent variables, such as seed, daily wage and tractor, have a positive impact on native potato production by small, medium and large producers in the Apurimac region during the 2018-2019 agricultural campaign.

63.4% of the variability in native potato production in small, medium and large producers in the Apurimac region is explained by the production function. In addition, the econometric model used was evaluated and it was found that both individual and global parameters are significant with a confidence level of 99% and a significance level of 1%, suggesting that these parameters are important and contribute significantly to the production of this crop.

On the other hand, the econometric evaluation was performed, where the residual part was evaluated normality, autocorrelation and heteroskedasticity. In the case of normality, the Jarque Bera statistic was applied, where a p-value higher than 5% was found, and this means that the residues are distributed normally. Regarding the autocorrelation, the Breusch-Godfrey statistic was applied with 5 lags and a pvalue greater than 5% was found, this means that the correlation of the residuals is null.

Regarding heteroskedasticity, White was applied and a p-value higher than 5% was found, and this means that the variability of the residues remains constant throughout the sample period. Also in the econometric part, multicollinearity was evaluated, that is, if the regressor variables are correlated with each other, where the statistic of the variance inflation factor was applied and it was found that each regressor variable such as seed, wage and tractor have values less than 10, this means that there are no problems of multicollinearity.

Table 1

MCO estimate of native potato from the Apurimac Region, 2018 - 2019

Regressors	estimator	Standard error	Prob.
Constant	3.97	0.326	0.000
ln(seed)	0.32	0.050	0.000
ln(daily)	0.55	0.072	0.000
LN(tractor)	0.40	0.078	0.000
		Statistical evaluation	
F	113.0	F_{pvalue}	0.000
R^2	63.4%	$\overline{R}^2$	62.8%
		Residual assessment	
Normality	Jarque Bera	Pvalue	0.0627
Autocorrelation	Breusch-Godfrey (5)	Pvalue	0.1712
Heteroskedasticity	White	Pvalue	0.1302
		Systematic evaluation	
Multicollinearity FIV	ln(seed)	1.41	
	ln(daily)	1.57	
	LN(tractor)	1.28	

Note: Own elaboration with Eviews 10.

Equation (1) expressed in natural logarithm was used to obtain the elasticity of native potato production in the Apurimac Region during the 2018-2019 agricultural season. This was achieved by calculating the partial derivatives of each factor in relation to native potato production.

$$lnrend_t = \beta_0 + \beta_1(lnsemila_t) + \beta_2(lnjornal_t) + \beta_3(lntractor_t) \quad (2)$$

where β_1 is the elasticity of the rend with respect to the seed:

$$\beta_1 = \frac{\partial lnrend_t}{\partial lnsemilla_t} = \frac{\frac{d(rend_t)}{rend_t}}{\frac{d(semilla_t)}{semilla_t}} = \frac{\frac{d(rend_t)}{d(semilla_t)} * semilla_t}{rend_t} = 0.32$$

This elasticity of the seed parameter is 0.32, which means that before an increase of 1% in the seed, the production of native potato will experience a growth of 0.32% and therefore is inelastic. For β_2 is the elasticity of the rend with respect to the wage:

$$\beta_2 = \frac{\partial lnrend_t}{\partial lnjornal_t} = \frac{\frac{d(rend_t)}{rend_t}}{\frac{d(jornal_t)}{jornal_t}} = \frac{\frac{d(rend_t)}{d(jornal_t)} * jornal_t}{rend_t} = 0.55$$

This elasticity of the wage parameter is 0.55, which means that before a rise of 1% in the wage, the production of native potatoes will experience a growth of 0.55% and therefore is inelastic. For β_3 is the elasticity of the rend with respect to the tractor:

$$\beta_3 = \frac{\partial lnrend_t}{\partial lntractor_t} = \frac{\frac{d(rend_t)}{rend_t}}{\frac{d(tractor_t)}{tractor_t}} = \frac{\frac{d(rend_t)}{d(tractor_t)} * tractor_t}{rend_t} = 0.40$$

This elasticity of the tractor parameter is 0.40, which means that before a rise of 1% in the tractor, the production of native potato will experience a growth of 0.40% and therefore is inelastic.

On the other hand, the production of native potatoes in producers in the 2018-2019 agricultural campaign is: $\beta_1 + \beta_2 + \beta_3 = 0.32 + 0.55 + 0.40 = 1.27$; where it is stated that they are increasing yields to scale. This means that, as inputs such as seed, wages and tractors double, native potato production will more than double.

In relation to the calculation of the average and marginal input of native potato production in the Apurimac Region in the period 2018-2019, the calculation of the production function of this crop was carried out using the average statistical values of each factor. With these values it was possible to obtain the medium and marginal input for the production of native potatoes.

$$rend_t = e^{3.97} * semilla_t^{\;0.32} * jornal_t^{\;0.55} * tractor_t^{\;0.40}$$
$$rend_t = 52.98 * (1126)^{0.32} * (68.87)^{0.55} * (22.27)^{0.40}$$

$rend_t = 17809.00$ kg/ha

After having found the production of native potato, we proceed to find the average products of each factor that has intervened in the production.

Average seed product:

$$PMesemilla_t = \frac{rend_t}{semilla_t} = \frac{17809.00\, kg/ha}{1126\, kg/ha} = 15.82$$

This value 15.82, means that to produce the native potato of 17 809 kg / ha has been used on average 15.82 kg / ha in seed.

Average daily wage product:

$$PMejornal_t = \frac{rend_t}{jornal_t} = \frac{17809.00\, kg/ha}{68.87\, jornales/ha} = 258.60$$

This value 258.60, means that to produce the native potato of 17 809 kg / ha has been used on average 258.60 wages / ha in labor.

Average product of the tractor:

$$PMetractor_t = \frac{rend_t}{tractor_t} = \frac{17809.00\, kg/ha}{22.27\, horas/maquinaria/ha} = 799.67$$

This value 799.67, means that to produce the native potato of 17 809 kg / ha has been used on average 799.67 hour / tractor / ha in tractor capital. On the other hand, the marginal products of each factor of the native potato production function were found, which are the following:

Marginal seed product:

$$PMgsemilla_t = \frac{\Delta rend_t}{\Delta semilla_t} = \frac{d(rend_t)}{d(semilla_t)}$$

$$PMgsemilla_t = 0.32 * e^{3.97} * semilla^{-0.68} * jornal^{0.55} * tractor^{0.40}$$

$$PMgsemilla_t = 5.06$$

This value 5.06 means that, when increased by one kilogram of seed, production will increase by a value of 5.06 kg / ha, keeping the other productive factors constant.

Marginal product of the wage:

$$PMgjornal_t = \frac{\Delta rend_t}{\Delta jornal_t} = \frac{d(rend_t)}{d(jornal_t)}$$

$$PMgjornal_t = 0.55 * e^{3.97} * semilla^{0.32} * jornal^{-0.45} * tractor^{0.40}$$

$$PMgjornal_t = 142.23$$

This value 142.23, means that, when increased by one day, production will increase by a value of 142.23 kg / ha, keeping the other productive factors constant.

Marginal product of the tractor:

$$PMgtractor_t = \frac{\Delta rend_t}{\Delta tractor_t} = \frac{d(rend_t)}{d(tractor_t)}$$

$$PMgtractor_t = 0.40 * e^{3.97} * semilla^{0.32} * jornal^{0.55} * tractor^{-0.60}$$

$$PMgtractor_t = 319.87$$

This value 319.87, means that, when increased in one hour of tractor, production will increase by a value of 319.87 kg / ha, keeping the other productive factors constant.

To find the technical effectiveness in the production of native potatoes in producers in Apurímac, 2018 - 2019, first the technical optimum of the seed has been found, then the technical optimum of the workforce and finally the technical optimum of the tractor. Also, to find the technical optimum of each factor, a factor has first been kept constant and then the estimated production function in each scenario has been determined and then the statistical average of each factor has been replaced in the new native potato production function, where we present the three technical optimums.

Technical optimum of the seed (keeping the tractor constant)

$$rend_t = 183.28 * {semilla_t}^{0.32} * {jornal_t}^{0.55}$$

$$rend_t = 1878.62 * semilla_t{}^{0.32}$$
$$\frac{drend_t}{semilla_t} = 601.16 * semilla^{-0.68}$$

It is then equated with the marginal product of the seed.

$$601.16 * semilla^{-0.68} = 5.06$$
$$semilla^{0.68} = 118.83$$
$$semilla = 1125.21$$

Now we find the seed yield

$$rend_t = 1879.62 * semilla_t{}^{0.32}$$
$$rend_t = 17792.37$$

With respect to the technical optimum of the seed, a maximum production of 17792.37 kg / ha has been found, when a maximum seed value of 1125.21kg / ha is used.

Technical optimization of labor (keeping the tractor constant)

$$rend_t = e^{3.97} * semilla_t{}^{0.32} * jornal_t{}^{0.55} * tractor_t{}^{0.40}$$
$$rend_t = 183.31 * semilla_t{}^{0.32} * jornal_t{}^{0.55}$$
$$rend_t = 1735.96 * jornal_t{}^{0.55}$$
$$\frac{drend_t}{jornal_t} = 954.77 * jornal^{-0.45}$$

Then it equals the marginal product of the wage:

$$954.77 * jornal^{-0.45} = 142.23$$
$$jornal^{0.45} = 6.71$$
$$jornal = 68.79$$

Now we find the performance

$$rend_t = 1735.95 * jornal_t{}^{0.55}$$
$$rend_t = 17793.49$$

With respect to the technical optimum of labor, a maximum production of 17793.49 kg / ha has been found, when a maximum value of labor is used in 68.79 days / ha.

Technical optimum of the tractor (keeping the wage constant)

$$rend_t = e^{3.97} * semilla_t{}^{0.32} * jornal_t{}^{0.55} * tractor_t{}^{0.40}$$
$$rend_t = 543.05 * semilla_t{}^{0.32} * tractor_t{}^{0.40}$$
$$rend_t = 5142.68 * tractor_t{}^{0.40}$$

$\frac{drend_t}{tractor_t} = 2057.07 * tractor^{-0.60}$

This result is equated with the marginal product of the tractor:

$2058.74 * tractor^{-0.60} = 319.87$

$tractor^{0.60} = 6.44$

$tractor = 22.24$

Now we find the performance

$$rend_t = 5142.68 * tractor_t{}^{0.40}$$
$$rend_t = 17793.67$$

With respect to the technical optimum of the tractor, a maximum production of 17793.67 kg / ha has been found, when a maximum tractor value is used in 22.24 hours / machine / ha.

The search for the economic sweet spot is done by considering labor and capital costs. The cost of labor is set at S / 35.00 Soles per day and the cost of capital at S / 60.00 Soles per machine hour. With this data the production function is applied:

$$Q = 52.98 * semilla_t{}^{0.32} * jornal_t{}^{0.55} * tractor_t{}^{0.40}$$

$\overline{semilla}$ =1126, seed

$\overline{jornal}$ =68.87, daily wage per hectare of cultivation

$\overline{tractor}$ =22.27, tractor machine hours per hectare of crop

$Q = 52.98 * (1126)^{0.32} * (68.87)^{0.55} * (22.27)^{0.40} = 17807.74$

Now the Lagrangean function of production optimization is proposed:

$$L = 35jornal + 60tractor - \lambda(501.89jornal^{0.55}tractor^{0.40} - 17807.74)$$

Subsequently, the partial drift of each input is carried out

$\frac{dL}{djornal} = 35 - \lambda(276.04jornal^{-0.45}tractor^{0.40}) = 0$ (1)

$$\lambda = \frac{35jornal^{0.45}}{276.04tractor^{0.40}}$$

$\frac{dL}{dtractor} = 60 - \lambda(200.75jornal^{0.55}tractor^{-0.60}) = 0$ (2)

$$\lambda = \frac{60tractor^{0.60}}{200.75jornal^{0.55}}$$

$\frac{dL}{d\lambda} = -(501.89jornal^{0.55}tractor^{0.40} - 17807.74) = 0$ (3)

$$501.89jornal^{0.55}tractor^{0.40} = 17807.74$$

Now we match 1 and 2:

$$\frac{35jornal^{0.45}}{276.04tractor^{0.40}} = \frac{60tractor^{0.60}}{200.75jornal^{0.55}}$$

$$\frac{35jornal^{1}}{276.04tractor^{1}} = \frac{60}{200.75}$$

$$\frac{jornal}{tractor} = \frac{16562.40}{7026.25} = 2.36$$

$$jornal = 2.36tractor$$

Now we replace it in equation 3:

$$501.89jornal^{0.55}tractor^{0.40} = 17807.74$$

$$501.89(2.36tractor)^{0.55}tractor^{0.40} = 17807.74$$

$$804.32tractor^{0.95} = 17807.74$$

$$tractor^{0.95} = 22.14$$

$$tractor = 26.06$$

Now we find the wage:

$$501.89 jornal^{0.55} tractor^{0.40} = 17807.74$$
$$501.89 jornal^{0.55} (26.06)^{0.40} = 17807.74$$
$$1849.27 jornal^{0.55} = 17807.74$$
$$jornal^{0.55} = 9.63$$
$$jornal = 61.43$$

After making the corresponding calculations, it was possible to determine the economic optimum for the workforce and the tractor, this being 61.43 wages per hectare and 26.06 machine hours per hectare, respectively. By keeping the other inputs constant, the combination of these factors allowed the agricultural producer to obtain a production of 17807.69 kilos per hectare.

$$Q = 501.89 * {jornal_t}^{0.55} * {tractor_t}^{0.40}$$

$$Q = 17807.69$$

A calculation was made of the income obtained from the sale of the native potato in the local market, considering a price of S / 0.50 per kilo. After subtracting the production costs, the benefit per hectare cultivated in the Apurimac region is obtained.

Benefits = Income - costs

Cost equation:

$$CT = w * jornal + r * tractor = 35 * jornal + 60 * tractor$$

$$CT = 35 * 61.43 + 60 * 26.06$$

$CT = 3713.65$ Suns

Income equation:

$$I = P * Q$$
$$I = (0.50) * (17807.69)$$

$I = 8903.85$ Suns

Proceeds:

$$Beneficios = Ingresos\ total - costo\ total$$

$Beneficios = 5190.20$ Suns

Under the mathematical calculation, the farmer of the Apurimac Region dedicated to the production of native potatoes, obtains economic benefits of S / 5 190.20.

Under these results, we find in García et al. (2017) They carried out a work on technical and economic efficiency of potatoes in Peru, where they found that potato producers are using inputs correctly and that allows them to have responsible technical and economic efficiency. Albuja et al. They investigated Andean crops in (2020) Ecuador, where they found economic efficiency especially in their crops such as corn. Melo and Orozco (2015) investigated the technical effectiveness of agricultural production in Colombia, where they found that there is a marked difference in technical efficiency in agriculture.

CONCLUSIONS

An analysis was carried out with an econometric model and it was concluded that there is a positive and significant correlation between technical and economic efficiency with native potato production in the district of Kishuara, located in the Andahuaylas province of the Apurimac region during the agricultural campaign of the year 2018-2019.

In Apurímac, producers are using increasing yields to scale (1.27) significantly, meaning that if production factors such as seed, daily wage and tractor double, native potato production would more than double. Importantly, labor is a key factor in potato production, as without it, farmers would struggle to produce. In addition, machinery is crucial for potato production, as it is used to prepare the land and ensure it is in good condition for planting.

In relation to the technical optimums, it was found that when a maximum production of 17 792.37 kg / ha is reached, a maximum seed value of 1125.21 kg / ha is used, when a maximum production of 17793.49 kg / ha is reached, a maximum labor value is used in 68.79 days / ha and when a maximum production of 17793.67 kg / ha is reached, A maximum tractor value is used in 22.24 hours/machine/ha.

The results indicate that farmers engaged in native potato production in the district of Kishuara, Andahuaylas province, Apurimac region, obtain an economic gain of S / 5 190.20 for each hectare cultivated during an agricultural campaign. Despite this, it is important to highlight that other inputs must continue to be implemented to improve the efficiency of native potato production.

THANKS
To Dr. Edson Apaza Mamani for advice. To the teachers of the Graduate School of the National University of the Altiplano for guidance during my academic training. To the native potato growers of the Kishaura district, for their support in the study.

CONFLICT OF INTEREST
The author has no conflict of interest.

REFERENCE

[1] Albuja Illescas, L., Basantes Vizcaíno, T., & Aragón Suárez, J. (2020). Economic analysis of Andean crops present in the provinces of Imbabura and Carchi – Ecuador. *Agrarian Economics, 21*(1), 43-60. https://raea.com.ar/revistaaaea_arg/article/view/38

[2] Altamirano Aguilar, A., Valdez Torres, J., Valdez Lafarga, C., León Balderrama, J., Betancourt Lozano, M., & Osuna Enciso, T. (2019). Evaluation of the performance of irrigation districts in Mexico through technical efficiency analysis. *Water Science and Technology, 10*(1), 85-121. https://doi.org/10.24850/j-tyca-2019-01-04

[3] Central Reserve Bank of Peru. (2022). *Inflation report September 2022.* Lima: BCRP.

[4] Begg, D., Fischer, S., Dornbusch, R., & Fernández Díaz, A. (2006). *Economics (8th ed.).* Madrid: McGraw - Hill.

[5] Mirror Street, D. (2019). *Economic determinants of yield per hectare of potato cultivation in Bolivia [Undergraduate thesis, Universidad Mayor de San Andrés].* http://repositorio.umsa.bo/xmlui/handle/123456789/22356

[6] Cárdenas Tapia, C., Medrano Martel, N., & Orneta Leiva, C. (2017). *Analysis of the production function cobb douglas and its application in potato production in the province of Pachitea - Huanuco 2015[Undergraduate thesis, Universidad Nacional Hermilio Valdizán].* Huanuco. https://hdl.handle.net/20.500.13080/1217

[7] Chavez Aquino, A., & Chavez Palacin, L. (2021). *Main factors related to potato production in the Pasco region during the period 2002-2019 [Undergraduate thesis, Universidad Nacional Daniel Alcides Carrión]*. http://repositorio.undac.edu.pe/handle/undac/2392

[8] Economic Commission for Latin America and the Caribbean. (2021). *The paradox of recovery in Latin America and the Caribbean. Growth with persistent structural problems: inequality, poverty, low investment and low productivity.* Santiago: ECLAC.

[9] Eguren, F. (2021). *Right to land and concentration of property*. Lima: Centro Peruano de Estudios Sociales - Cepes.

[10] Fernández Baca, J. (2010). *Microeconomics. Theory and applications. Volumes I and II.* Lima: Universidad del Pacífico.

[11] Frank, R. (2001). *Microeconomics and Behavior (4th ed.).* Madrid: McGraw-Hill.

[12] Galarza, E., Galarza, F., & Ruiz, J. (2015). *Intermediate microeconomics exercises.* Lima: Universidad del Pacífico.

[13] Galarza, E., Galarza, F., & Ruiz, J. (2015). *Intermediate microeconomics exercises.* Lima : Universidad del Pacífico.

[14] Garavito Masalías, C. (2014). *Microeconomics: consumers, producers and market structures.* Lima: Fondo Editorial de la Pontificia Universidad Católica del Perú.

[15] García, M., Chuquillanqui, C., Veneros, J., & García, S. (2017). Technical and economic evaluation for two production methods of pre-basic potato seed (Solanum tuberosum L.) under greenhouse. *Scientific and Technological UPSE, 4*(3), 36-45. https://doi.org/10.26423/rctu.v4i3.277

[16] Graue Russek, A. L. (2006). *Microeconomics. Business focus.* Mexico: Pearson Education.

[17] Graue Russek, A. L. (2009). *Fundamentals of Economics.* Mexico: Pearson Education.

[18] Gujarati, D., & Porter, D. (2010). *Econometrics.* Mexico: McGraw-Hill.

[19] National Institute of Statistics and Informatics. (2022). *Peru: Departmental Economic Outlook.* Lima: INEI.

[20] National Institute of Statistics and Informatics. (2022). *Regional information system for decision-making.* Lima: INEI.

[21] Jerez Mompies, E., & Martín Martín, R. (2012). Growth behavior and yield of the potato variety (Solanum tuberosum L.) spunta. *Tropical Crops, 33*(4), 53-58.

[22] Loría, E. (2007). *Econometrics with Applications.* Mexico: Pearson.

[23] Maino, M. (2011). *Class notes: Introduction to microeconomics.* Santiago de Chile: Universidad Andrés Bello.

[24] Mankiw, G. (2002). *Principles of economics.* Madrid: McGraw Hill.

[25] Mankiw, G. (2017). *Principles of Economics.* Mexico: Cengage Learning.

[26] Martínez Azúa , B., & Quiroga Ramiro, A. (2014). *Microeconomic analysis.* Spain: University of Extremadura.

[27] Martinez Giralt, X. (2008). *Advanced Microeconomics.* Barcelona: Universitat Autonoma de Barcelona.

[28] Martínez Reina, A., Tordecilla Zumaqué, L., Grandett Martínez, L., & Rodríguez Pinto, M. (2021). Technical efficiency of the cultivation of eggplant (Solanum melongena L.) in producing areas of the Colombian Caribbean. *Agricultural and Natural Resources Research and Innovation, 8*(3), 66-76. https://doi.org/10.53287/mvqd3972pu29t

[29] Martínez, J., Tarazona Velásquez, R., Martínez Pachón, E., & Ramos Zambrano, H. (2022). Potato farming in Southwest Colombia: Types of farmers and their technical efficiency. *Cienc. Tecnol. Agricultural,* 23(2), 1-23. https://doi.org/10.21930/rcta.vol23_num2_art:2236

[30] Maté García, J., & Pérez Domínguez, C. (2007). *Advanced microeconomics. Questions and exercises resolved.* Madrid: Pearson Education.

[31] Melo Becerra, L., & Orozco Gallo, A. (2015). *Technical efficiency of households with agricultural production in Colombia.* Bank of the Republic Colombia.

[32] Morales Hernández, J., Rebollar Rebollar, S., Hernández Martínez, J., & González Raz, F. (2015). Determination of the technical and economic optimum in the cultivation of temporary potatoes. *Economic Paradigm, 7*(1), 87-106.

[33] Mungaray Lagarda, A., & Ramírez Urquidy, M. (2004). *Microeconomics lessons for microenterprises.* Mexico: Universidad Autónoma de Baja California.

[34] Nicholson, W. (2008). Microeconomic theory. Basic Principles and Extensions (9th ed.). Mexico: Cengage Learning.

[35] Food and Agriculture Organization of the United Nations. (2021). *The State of Food and Agriculture 2021.* FAO. https://doi.org/10.4060/cb4476es

[36] Parkin, M., & Loría Díaz, E. (2010). *Microeconomics. Latin American version (9th ed.).* Mexico: Pearson Education.

[37] Pasquel Loarte, L., Ramos Cornelio, E., Quispe Zevallos, T., Ortiz Tarazona, D., & Cajas Bravo, V. (2019). Yellow potato production. A study from its factors for agricultural development, Huánuco. *Valdizana Research, 13*(2), 67-76. https://doi.org/10.33554/riv.13.2.231

[38] Perez Quesada, G., & Garcia Suarez, F. (2018). Technical efficiency measurement: an application on dairy farms in Uruguay. *Economia Agraria, 20*, 15-29. https://doi.org/10.22004/ag.econ.287197

[39] Pindyck, R. S., & Rubinfeld, D. L. (2009). Microeconomics (7th ed.). Spain: Pearson prentice hall.

[40] Pindyck, R., & Rubinfeld, D. (2009). *Microeconomics.* Madrid: Pearson Education.

[41] Pindyck, R., & Rubinfeld, D. (2013). *Microeconomics (8th ed.).* Pearson Education.

[42] Poveda Pineda, W., Arango Londoño, C., & Pinzón Rueda, W. (2018). Technical efficiency of the potato harvest in Boyacá, Colombia, using data envelopment analysis – DEA. *I+T+C Research, Technology and Science, 1*(12), 29-38. https://revistas.unicomfacauca.edu.co/ojs/index.php/itc/article/view/itc2018_pag_29_38

[43] Quiroz Calderón, B. (2016). *Microeconomics.* Chimbote: Universidad Católica Los Ángeles de Chimbote.

[44] Quispe Delgado, E. (2022). *Cobb-Douglas production function and its application in the native potato production of COOPAGRO partners in the district of Kishuara - Apurimac 2020[Master's thesis, José Carlos Mariátegui University].* https://hdl.handle.net/20.500.12819/1447

[45] Ramírez, J., Perfetti, J., & Bedoya, J. (2015). *Estimation of technological gaps and their determinants in the Colombian agricultural sector.* Bogotá - Colombia: FEDESARROLLO. http://hdl.handle.net/11445/2392

[46] Rebollar Rebollar, S., Callejas Juárez, N., & Guzmán Soria, E. (2018). The Cobb-Douglas function of semi-intensive milk production in the south of the State of Mexico. *Economic Analysis, 33*(82), 125-141.

[47] Rezk, E. (2011). *Progress in microeconomics.* Buenos Aires: Fondo Editorial Consejo.

[48] Salvatore, D. (2009). Microeconomics. In R. Del bosque (Ed.). Mexico: McGraw-Hill. https://es.slideshare.net/MarcoSanabria2/microeconomia-de-dominick-salvatore

[49] Sanabria Hurtado, C., Sanabria Totaitive, I., & Sánchez Cuervo, R. (2022). Evaluation of the sustainability of potato crops (páramo de Gámeza, Boyacá, Daita sector, Colombia). *Mutis, 12*(1), 1-15. https://doi.org/10.21789/22561498.1769

[50] Santos, J., Foster, W., Ortega, J., & Ramirez. (2006). Study of the Technical Efficiency of Potato Producers in Chile: The Role of INDAP's Technology Transfer Program. *Agrarian Economics, 10*(14), 119-132. https://doi.org/10.22004/ag.econ.97362

[51] Torres Vilca, E. (2018). *Determinants of quinoa and potato production in the community of Cullillaca Joven, district of Cabanilla, province of Lampa – Puno, period 2017 [Undergraduate thesis, Universidad del Altiplano].* http://repositorio.unap.edu.pe/handle/UNAP/10650

[52] Trujillo Calagua, G. (2010). *Econometrics with Eviews.*Cajamarca : National University of Cajamarca.

[53] Trujillo Saavedra, D. (2017). *Determinants of potato production in Peru for the period 1990 – 2013[Undergraduate thesis, Universidad Peruana de Ciencias Aplicadas].* http://hdl.handle.net/10757/621688

[54] Varian, H. (1992). *Microeconomic analysis (3rd ed.).* Barcelona: Antoni Bosch.

[55] Varian, H. (2011). *Intermediate Microeconomics (8th ed.).* Barcelona: Antoni Bosch.

[56] Vélez Meza, A. (2018). *Production and commercialization of the super chola potato variety (solanum tuberosum) in the Tulcán canton, province of Carchi, year 2017[Undergraduate thesis, Universidad Técnica del Norte, Ecuador].* http://repositorio.utn.edu.ec/handle/123456789/8592

[57] Veloso Contreras, F., Cabas Monje, J., Velasco Fuenmayor, J., Vallejos Cartes, R., & Gil Roig, J. (2015). Technical Efficiency of Small Bovine Producers in the South Central Region of Chile. *Scientific Review, 25*(2), 99-106.

[58] Vial, B., & Zurita, F. (2007). *Intermediate microeconomics.* Santiago: Pontificia Universidad Católica de Chile.