Simultaneous Evaluation of Technical Efficiency and Production Risk of Rice Paddy Fields

Haniye Kazmi Shabanzade Aflaki[1&2], Ozra Javanbakht[1*], Khadijeh Alefi[3]

1- Agricultural Economics Department, Urmia University, Urmia, Iran
2- Agricultural Economics in Sari Agricultural Sciences and Natural Resources University.
3- Agricultural Economics, University of Tabriz, Iran.

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Abstract

Agricultural activities are risky compared to other production activities, and the risk is also often accompanied by inefficiency. So, simultaneous study of risk and inefficiency can lead to more productive production. The present study simultaneously evaluated rice farmers' technical efficiency and production risk in Rasht County in 2018 using a generalized SFP model with the flexible risk properties of Kumbhakar (2002). The results of estimating production risk function showed that rice production was significantly affected by land, seed and labour inputs. Also, land, water, age, and gender variables are risk-increasing, and seed, herbicides, machinery, farmer's education, family size, and farming experience are risk-reducing inputs. In addition, seed, labour, membership in the agricultural cooperatives and insurance, increase technical inefficiency. Nitrate fertilizer, water, gender, rice cultivating experience and participation in educational and promotional classes reduce technical inefficiency in the studied area. The results of estimating technical efficiency showed that the average technical efficiency of the rice paddy field with a risk component was 93.47% and without a risk component, it was 96.27%. Therefore, it's clear that estimating the model without a risk component leads to magnification error in the amount of technical efficiency. In conclusion, it is recommended that the risk component be considered when measuring the technical efficiency of paddy fields to achieve sound risk management and highly efficient production.

Keywords: Agricultural Inputs, Production Risk, Rice Farming, Risk Management, Stochastic Frontier (SPF) Model, Technical Efficiency

JEL classifications: *M11, O13*, *Q12.*

Introduction

Given today’s existing limitations, providing healthy, adequate and high-quality food for the fast-growing population of the world is a great challenge. The limitations exist in all fields, including resources and factors affecting production in the agricultural sector. The only solution to guarantee food security is the use of available sources effectively to deliver more and higher-quality products i.e. improving efficiency. The assessment of the efficiency of agricultural production is also an important issue in the process of development in countries. On the other hand, agriculture is a risky activity and is affected by various factors such as climatic conditions, pests and diseases, fluctuations in inputs and output prices, financial risk, human risk, and input risk in production. Among these, the risk of inputs in production is important because of creating variation in production and yield of the output.

Tveteras (1999) express two main reasons for considering production risk in inputs to examine the behaviour and productivity of farms. First, risk-averse producers choose the amounts of inputs that are different from the optimal level inputs that are chosen by risk-neutral producers. Second, when the risk-averse producers tend to adopt new technologies, they consider its risky aspects. Therefore, they may choose technology that has a high production average.

Also, according to Bokusheva & Hockmann (2006), the risk not only affects production but also influences the producers’ behavior mainly on inputs usage. So when farmers consider risk management and decrease the risk in their decisions, changes in the amount and manner of using inputs may change significantly the technical efficiency. Studies have shown that the effect of risk on production can be investigated through the effect of inputs selection on production variance, because, some inputs increase output variance whilst some others reduce it.

Just & Pope (1978) had promoted the conventional approach of econometrics to evaluate the production risk. The implicit assumption of their model is the lack of inefficiency in the production units (farms). While the surveys show that these units are usually inefficient, researchers have concluded that for the simultaneous study of efficiency and risk, SFP models could be combined with the Just and Pope model (Jaenicke *et al.*, 2003). For example, Battese *et al.*, (1997) used stochastic frontier analysis (SFA) with heteroscedastic error terms to define the efficiency of small farmers in Ethiopia. Kumbhakar (1993, 2002) also applied this method to specify the efficiency and risk preferences of Swedish dairy farms and Norwegian salmon producers. Jaenicke *et al.*, (2003) applied an SFA model with a heteroscedastic error term to compare technical efficiency and risk in different cotton cropping systems. Villano & Fleming (2006) used the methods to rainfed lowland rice farms in the Philippines. Bokusheva & Hockmann (2006) take up this combined approach to evaluate the efficiency of Russian arable farms. Sarker *et al.*, (2016) studied production risk and technical efficiency in Thai koi farming by the Just & Pope framework extended to the stochastic frontier model (SFM) by Kumbhakar (2002). Lemessa *et al.*, (2017) analysed the technical efficiency and production risk of 862 maize farmers in Ethiopia using the stochastic frontier approach with flexible risk properties. Also, the other studies done in this field can mention to Oppong *et al.*, (2016), Yang *et al.*, (2016), Agustina (2016), Baawuah (2015), Adinku (2013), Tiedemann & Latacz-Lohmann (2013), Ogunniyi & Ojedokun (2012) and Villano *et al.*, (2005).

In Iran, a limited number of studies have simultaneously evaluated technical efficiency and production risk, including the study by Esfandiari *et al.*, (2013) (Determining technical efficiency and rice production risk in Marvdasht County, Fars Province); Alikhani *et al.*, (2015) (Evaluation of technical efficiency and production risk of cold-water fish farms in Kurdistan province) and Hosseinzad & Alefi (2016) (Evaluation of technical efficiency and production risk of potato farmers in Ardabil province).

All of these researches show that a production function that takes into account the effects of inputs on both production risk and technical efficiency simultaneously is considerably better able to reflect production technology than a simple analysis of efficiency.

Rice is the second most important foodstuff after wheat for Iranian people. Guilan Province in the north of Iran is one of the important rice-producing provinces. This province has 238,544 hectares of cultivated area and 1,104,551 tons of paddy production. Rasht County also has the largest cultivated area and the largest production of this product among the counties of Guilan Province, with 51,039 hectares of cultivated area and 226,155 tons of paddy production (Statistical Yearbook of Guilan Province, 2022).

Given the significant volume of rice production in Guilan Province and especially Rasht County, a scientific study of the various dimensions of production risk and technical efficiency for making better use of existing facilities and helping planners and decision makers seems logical. Therefore, this study has examined two essential concepts in agricultural economics (technical efficiency and production risk) in an integrated model, unlike traditional methods that examine technical efficiency and production risk separately. Incorporating the production risk helps to obtain unbiased estimates of the technical efficiency. It also investigates production risk, technical efficiency, and factors associated with rice production of smallholder farmers. Thus, rice production variability is assessed from two perspectives: production risk and technical efficiency.

Materials and Methods

Theoretical Framework

The method of analysis proposed for this study is consistent with the stochastic frontier approach, which was independently proposed by Aigner *et al.*, (1977) and Meeusen & Vanden Broeck (1977). This model proposes that inputs have a similar effect on mean and variance outputs. But Just & Pope's (1978) production function proposed separate effects of the inputs on the mean and variance outputs, whilst Kumbhakar (2002) further incorporates the technical inefficiency model. Following Kumbhakar (2002), the production process is represented below as equation 1.

$$y_i = f(x_i;\alpha) + g(x_i;\ \beta)\nu_i - q\big(x_i; z_j; \gamma\ \big)u_i \tag{1}$$

y_i refers to the observed output produced by the i-th farm, $f(x_i;\ \alpha)$ is the deterministic output function, $g(x_i;\ \beta)$ is the output risk function, β's are the to be estimated coefficients of production risk function, x_i are the inputs variables, α's are the to be estimated coefficients of the mean output function, $q(x_i;\ z_j;\ \gamma)$ represents the technical inefficiency model, γ's are the to be estimated parameters in the technical inefficiency model, ν_i is the random noise, representing production risk and u_i denotes farm specific technical inefficiencies. Given the values of the inputs, the inefficiency effects, u_i, the mean output of the i-th farmer is given by equation 2.

$$E(y_i|x_i\ .u_i) = f(x_i;\alpha) - g(x_i;\beta)u_i \tag{2}$$

Technical efficiency of the i-th farm is the ratio of observed output given the values of its inputs and its inefficiency effects to corresponding maximum feasible output if there were no inefficiency effects (Battese & Coelli, 1988). The technical efficiency of the i-th farm is given by equation 3, which is consistent with Kumbhakar (2002) specification of technical efficiency:

$$TE_i = \frac{E(y_i|x_i \,.\, u_i)}{E(y_i|x_i \,.\, u_i = 0)} = \frac{f(x_i;\alpha) - g(x_i;\beta)u_i}{f(x_i;\alpha)} = 1 - \frac{g(x_i;\beta)u_i}{f(x_i;\alpha)} \qquad (3)$$

And technical efficiency becomes as equation 4.

$$TE_i = 1 - TI_i \qquad (4)$$

The technical inefficiency (TI), is represented as equation 5.

$$TI_i = \frac{g(x_i\,;\,\beta)u_i}{\mathrm{f}(x_i\,;\alpha)} \qquad (5)$$

The variance of output or production risk is given by equation 6.

$$\mathrm{var}\,(y_i|x_i \,.\, u_i) = g^2(x_i\,;\,\beta) \qquad (6)$$

The marginal effect of the input variables on the production risk is given as equation 7.

$$\frac{\partial \mathrm{var}(y_i)}{\partial x_i} = \frac{\partial g^2(x_i\,;\,\beta)}{\partial x_i} = 2\mathrm{g}(x_i\,;\,\beta).\,g_i(x_i\,;\,\beta) \qquad (7)$$

The marginal effect of the i-th input on production risk is positive or negative depending on the signs of g(x_i; β), and g_i(x; β), where the latter is the partial derivative of the production risk function with respect to the i-th input. If the marginal risk is positive, it means that input is risk increasing and if the marginal risk is negative, it means that the input is a risk decreasing. Based on the distributional assumptions of the random errors a log likelihood function for the observed farm output is parameterized in terms of $\sigma^2 = \sigma_v^2 + \sigma_u^2$ and $\lambda = \frac{\sigma_u^2}{\sigma_v^2} \geq 0$ (Aigner *et al.*, 1977).

Empirical Model Specification

The empirical application of this study is consistent with models developed by Kumbhakar (2002), Aigner *et al.*, (1977), Meeusen & Vanden Broeck (1977) and Just & Pope (1978). Deterministic part of the production frontier in equation 1 assumed a translog model in equation 8.

$$lny = \alpha_0 + \sum_{i=1}^{n} \alpha_j lnx_{ij} + 0.5\sum_{i=1}^{n}\sum_{k=1}^{n}\alpha_{jk} lnx_{ij} lnx_{ki} + \varepsilon_i \qquad (8)$$

α_j's denote the unknown true values of the technology parameters. If, α_{jk}=0 then the translog stochastic frontier model reduces to Cobb-Douglas model specified as equation 9.

$$lny_i = a_0 + \sum_{j=1}^{n} a_j lnx_{ji} + \varepsilon_i \qquad (9)$$

The error term is specified as equation 10.

$$\varepsilon_i = g(x_i;\,\beta)v_i - q(\,x_i\,;z_j\,;\gamma)u_i \qquad (10)$$

Production elasticity and return to scale

The sensitivity of a variable towards changes another variable is defined as elasticity. The concept of elasticity can be applied to the production function so as to determine the stage of production in which the rice farmers are operating. The translog production function elasticities are a function of the level of input consumption to different inputs. They are expressed as equation 11.

$$\frac{\partial lnE(y_i)}{\partial lnx_{ji}} = a_j + a_{jj}lnx_{ji} + \sum_{k\neq 1} a_{jk}lnx_{ki} \qquad (11)$$

A summation of the partial elasticities of the various input variables to output is a measure of the return to scale (RTS).

If RTS> 1 → Increasing returns to scale (IRS);
If RTS <1 → Decreasing returns to scale (DRS) and,
If RTS = 1 → Constant returns to scale (CRS).

Also, in equation 8, output and input variables have been normalized by their respective means.

Studies, investigated the effect of inputs on production risk in Iran using Just & pope model (1978) such as Mehri *et al.,* (2020), Yazdani & Sassuli (2008), Karbasi *et al.,* (2005), Sharzehei & Zibaei (2001), showed that a little percentage of production risk was related to production inputs (due to the low amount of the coefficient of determination and the adjusted coefficient of determination of the production risk function). So they concluded that various factors such as the geographical location of the farm, the age of the farmer, the level of education and experience, the farmer's gender, access to credit, extension services, rainfall and type of soil were all effective on production risk, and the lack of these variables in the model resulted in a lower coefficient of determination. Therefore, in the present study, in addition to the effects of inputs on production risk, the effect of factors such as farmers' age, education level (edu), experience (exper), gender (gen), marriage status (mar) and household size (fam size) are also considered in the production risk. The linear production risk function is specified as Equation 12.

$$g(x_i;\ \beta)v_i = \beta_0 + \sum_{i=1}^{n} \beta_i\ x_i \qquad (12)$$

Where x_i's represent the input variables; β's are the unknown true coefficients of the risk model parameters and v_i's are the pure noise effects. In production risk function, in addition to the effects of inputs on the production risk, the effect of a number of other variables (as already mentioned) is considered. If β's becomes negative, the respective input reduces output variance and vice versa (Just & Pope, 1978).

The technical inefficiency effects were given by Equation 13.

$$q(x_i; z_j\ ; \gamma) = \gamma_0 + \sum_{i=1}^{n}\gamma_i x_i + \sum_{j=1}^{n}\gamma_j z_j \qquad (13)$$

Where x_i's represent the input variables and z_j's are exogenous (socio-economic) variables; γ denote the unknown true values of the parameters of the technical inefficiency model.

The SFP model with a flexible risk specification includes mean output function, risk function and technical inefficiency which are estimated simultaneously using the maximum likelihood method by using Stata statistical software.

Statement of Hypothesis:

The following hypotheses were tested to determine the ability of the model to achieve the study objectives and whether input production risk and technical inefficiency can significantly explain production variations. The hypothesizes are listed below:

1- H_0: $\alpha_{ij}=0$, the coefficients of the second-order variables in the translog model are zero in favor of the Cobb-Douglas model.
2- H_0: $\beta_1=\ldots=\beta_{14}=0$, output variability is not explained by production risk in inputs and socio-economic variables.
3- H_0: $\lambda=0$, inefficiency effects are absent from the model. Therefore, the variance of the inefficiency term is zero and deviations of the observed output from the frontier output are entirely due to pure noise effect. On the other hand, if $\lambda>0$ then technical inefficiency is present in the data and deviations from the frontier output are as a result of technical inefficiency and pure noise.
4- H_0: $\gamma_1=\ldots=\gamma_{20}=0$, this implies that inputs and socio-economic variables do not account for technical inefficiency. The generalized likelihood-ratio statistic (LR test) tested the entire hypothesis. The statistic for this test is as follows:

$$LR=-2[lnL_r-lnL_{ur}]\sim\chi^2 \qquad (13)$$

In Equation 13, L_r is the value of the likelihood function of the restricted model, and L_{ur} is the value of the likelihood function of the unrestricted model. The likelihood ratio (LR) test statistic has a χ^2 distribution with degrees of freedom equal to the number of parameters under the null hypothesis.

Data and Sampling Technique

In this study, the statistical population was rice farmers in Rasht County. After determining the size of the community at the time of the study (38,763 farmers), the sample size was calculated (Statistics of the Agricultural Jihad Organization of Guilan Province, 2016). Using the Cochran formula with an error rate of 0.065, the sample size (226) was calculated, which covered 58% of the population. In practice, a larger number of questionnaires were completed, but only 221 were usable.

At the time of the study, Rasht County had 6 districts. Given the geographical dispersion of farms in 6 districts and the need to save time and money, avoid bias caused by studying only one district, and reduce sampling error, a two-stage cluster random sampling method was used; such as the studies of Kopahi *et al.,* (2009) in the study of rice farmers in Guilan Province and Esfandiari *et al.*, (2013) in the study of rice farmers in Marvdasht County in Fars Province.

Thus, the first, 4 sections (out of 6 sections) were randomly selected (first stage); then, rice farmers were randomly sampled from each section (second stage). Using a two-stage cluster random sampling method ensures that data is collected from different areas of the county and the results can be generalized to the entire population.

The questionnaire consisted of two parts. The first part was related to the inputs used in the rice production process, and the second part was related to the socio-economic variables of farmers and their farms. It should be noted that Stata and Excel software were used to analyze the data.

A descriptive analysis of variables is presented in table 1; subsequently the demographic characteristics of the respondents were expressed.

Table 1- Summary statistics of the output and the input variables

Variable	Symbol	Type of variable	Unit	Mean	Min	Max	SD

Production	pro	Dependent	Ton	4.94	0.2	36	4.96
Land	ln	Independent	Hectare	1.33	0.112	10	1.24
Seed	se	Independent	Kilogram	98.92	12	450	77.54
Labour	la	Independent	Man-days	29.50	3	128	20.82
Nitrate fertilizer	n	Independent	Kilogram	258.35	0	3500	344.37
Phosphate fertilizer	p	Independent	Kilogram	142.28	0	4000	294.74
Herbicide	hs	Independent	Liter	4.51	0	35	4.51
Machinery	ma	Independent	Hour	65.68	4	795	77.60

Source: Research Findings

According to table 1, the average area under cultivation in the area was 1.33 hectares and rice farmers used on average 98.92 kilograms of rice seed, 29.50 man-days of labor, 258.35 kilograms of nitrate fertilizer, 142.28 kilograms of phosphate fertilizer, 4.51 liters of pesticide and 65.68 hours of agricultural machinery to produce 4.94 tons of output.

Also, according to completed questionnaires, the average age of rice farmers in the sample was 51 years old and more than 97% were married. The average size of the households was 3 people and 92% were male and the rest were female. Rice farming was the main job of more than 53% of respondents and more than 81% of them are landowners. About the ownership of machinery, only 10% of farmers owned the machinery and the others used rental machinery. More than 48% of farms were insured and 21% of them had participated in educational programs.

Results and discussion

Results of the estimated generalized SFP model of Kumbhakar (2002)

The results of estimating the stochastic frontier function with and without considering risk are reported in Table 2. A single-stage maximum likelihood estimation (MLE) framework was implemented to estimate the production function (equation 8), production risk (equation 11), and technical efficiency models (equation 12) concurrently. Since translog coefficients cannot be directly interpreted, input elasticities were calculated for economic interpretation.

Table 2- Results of estimation of the stochastic frontier model and efficiency with and without risk consideration

		Model estimation with risk component			Model estimation without risk component		
variable definition	**Symbol**	**Coefficients**	**z**	**P>|z|**	**Coefficients**	**z**	**P>|z|**
Production function							
Constant	cons	0.01	0.58	0.56	-0.042	-1.11	0.266
Log Land	lln	1.11***	22.02	0.000	0.756***	6.98	0.000
Log Seed	lse	-0.125**	-2.45	0.014	-0.049	-0.65	0.514
Log Labour	lla	0.05*	1.95	0.051	0.027	0.5	0.62
Log Nitrate fertilizer	ln	-0.004	-0.14	0.888	0.167***	2.8	0.005
Log Phosphate fertilizer	lp	0.008	0.29	0.775	0.128**	2.48	0.013
Log Herbicide	lhs	0.019	0.47	0.642	0.045	0.7	0.482
Log Machinery	lma	-0.002	-0.07	0.947	-0.016	-0.29	0.771
0.5*(Log Land)^2	lln^2	1.377***	19.92	0.000	0.789***	5.71	0.000
0.5*(Log Seed)^2	lse^2	0.643***	3.85	0.000	0.202	0.77	0.44
0.5*(Log Labour)^2	lla^2	-0.283***	-2.58	0.01	0.066	0.51	0.607

0.5*(Log Nitrate)^2	ln^2	0.059***	2.63	0.009	0.05**	2.14	0.033
0.5*(Log Phosphate)^2	lp^2	0.003	0.66	0.507	0.024***	2.66	0.008
0.5*(Log Herbicide)^2	lhs	0.048	1.08	0.278	0.006	0.23	0.816
0.5*(Log Machinery)^2	lma^2	0.053	0.58	0.565	0.103	0.94	0.349
Log Land*Log Seed	llnlse	-1.087***	-8.79	0.000	-0.225	-0.88	0.376
Log Land*Log Labour	llnlla	0.773***	9.77	0.000	0.305**	2.41	0.016
Log Land*Log Nitrate	llnln	-0.272***	-3.57	0.000	-0.17*	-1.79	0.074
Log Land*Log Phosphate	llnlp	-0.011*	-1.92	0.055	-0.012	-1.02	0.307
Log Land*Log Herbicide	llnlhs	-0.232***	-5.5	0.000	-0.041	-0.45	0.65
Log Land*Log Machinery	llnlma	-0.022	-0.26	0.797	-0.414***	-2.94	0.003
Log Seed*Log Labour	lsella	-0.122	-1.45	0.148	-0.259*	-1.79	0.073
Log Seed*Log Nitrate	lseln	-0.599	-1.35	0.178	-0.021	-0.31	0.755
Log Seed*Log Phosphate	lselp	-0.013	-0.57	0.568	-0.013	-0.3	0.763
Log Seed*Log Herbicide	lselhs	0.442***	5.85	0.000	0.004	0.04	0.968
Log Seed*Log Machinery	lselma	0.065	0.98	0.328	0.262**	2.26	0.024
Log Labour*Log Nitrate	llaln	0.055	0.73	0.463	-0.053	-0.54	0.588
Log Labour*Log Phosphate	llalp	0.069***	5.08	0.000	0.062**	2.44	0.014
Log Labour*Log Herbicide	llalhs	-0.198**	-2.09	0.037	0.088	1.13	0.26
Log Labour*Log Machinery	llalma	-0.27***	-3.66	0.000	-0.165*	-1.77	0.076
Log Nitrate*Log Phosphate	lnlp	-0.028**	-2.46	0.014	-0.007	-0.54	0.588
Log Nitrate*Log Herbicide	lnlhs	0.032	1.12	0.261	0.041	1.06	0.287
Log Nitrate*Log Machinery	lnlma	0.12***	2.77	0.006	0.094	1.44	0.15
Log Phosphate*Log Herbicide	lplhs	-0.037	-1.25	0.213	-0.55	-1.37	0.171
Log Phosphate*Log Machinery	lplma	-0.007	-0.4	0.687	-0.009	-0.47	0.639
Log Herbicide *Log Machinery	lhslma	-0.093**	-2.48	0.013	0.011	0.14	0.888
Risk function							
Constant	Cons	-9.187***	-5.18	0.000	-	-	-
Land	ln	4.409***	7.84	0.000	-	-	-
Seed	se	-0.045***	-5.53	0.000	-	-	-
Labour	la	-0.005	-0.58	0.562	-	-	-
Nitrate fertilizer	n	-0.001	-1.23	0.22	-	-	-
Phosphate fertilizer	p	-0.0007	-0.44	0.662	-	-	-
Herbicide	hs	-0.342***	-3.77	0.000	-	-	-
Machinery	ma	-0.006**	-2.05	0.04	-	-	-
Water	wa	1.458**	2.38	0.017	-	-	-
Age	age	0.128***	6.23	0.000	-	-	-
Gender	gen	3.877***	3.05	0.002	-	-	-
Marital status	marr	-0.819	-0.85	0.397	-	-	-
Educational level	edu	-0.249*	-1.95	0.051	-	-	-
Household size	famsize	-0.556***	-5.45	0.000	-	-	-
Experience	exper	-0.076***	-4.62	0.000	-	-	-
Technical inefficiency function							
Constant	cons	-1.6	-0.43	0.669	-13.74*	-1.77	0.076
Land	ln	-1.213	-0.84	0.401	10.91	1.1	0.269
Seed	se	0.037***	2.69	0.007	-0.002	-0.15	0.882
Labour	la	0.058*	1.73	0.083	0.034	0.54	0.59
Nitrate fertilizer	n	-0.034***	-4.1	0.000	-0.017	-1.12	0.261
Phosphate fertilizer	p	0.005	0.62	0.535	0.017	1.29	0.196
Herbicide	hs	0.357	1.08	0.279	-2.115	-1.24	0.215
Machinery	ma	0.005	0.76	0.446	-0.058	-1.32	0.188
Water	wa	-2.486***	-2.63	0.008	-7.97**	-2.05	0.04
Age	age	-0.039	-0.63	0.530	0.225	0.86	0.388
Gender	gen	-2.761***	-2.73	0.006	4.91	0.99	0.321
Marital status	marr	2.397	0.92	0.355	-11.93	-0.89	0.374
Educational level	edu	0.039	0.13	0.895	-1.884	-0.43	0.669
Household size	famsize	0.221	0.79	0.432	1.487	1.12	0.263

Experience	exper	-0.118**	-2.05	0.041	-0.44	-0.91	0.365
Main occupation	otherjob	0.339	0.37	0.713	5.167**	1.98	0.048
Land ownership	pland	0.407	0.35	0.726	6.261	0.96	0.338
Machinery ownership	pmachine	0.837	0.63	0.529	6.534	0.88	0.38
Membership in cooperatives	membershipe	3.081***	3.82	0.000	6.598**	2.18	0.029
Insurance	insure	2.682***	3.57	0.000	4.656	1.05	0.295
Participating in training classes	class	-10.66***	-3.56	0.000	-2.463	-0.95	0.342
Observations		221			221		
Log likelihood		55.07			-10.5368		
Wald chi2(35)		422720.45			1973.21		
Prob>chi2		0.000			0.000		
E(sigma-u)		0.1581			-		
E(sigma-v)		0.2919			-		
lambda ($\lambda = \frac{\sigma_u}{\sigma_v}$)		0.54			-		

Source: Research Findings ***, **, * indicate 0.01, 0.05 and 0.1 level of significance respectively.

Results of estimated production elasticity and returns to scale (RTS)

The concept of input elasticity in a production function is used to determine the stage of production in which the rice farmers are operating in using each input. The output elasticity shows the degree of responsiveness of rice output to changes in the amount of various inputs and a summation of the partial elasticities of the various inputs with respect to output is a measure of the return to scale of the rice farms.

Table 3- Estimation results of production elasticities and returns to scale

Variable	Elasticities	Production Area
Land	1.04	First
Seed	-0.251	Third
Labour	-0.046	Third
Nitrate fertilizer	0.258	Second
Phosphate fertilizer	0.033	Second
Herbicide	0.058	Second
Machinery	0.0003	Second
Returns to Scale (RTS)	1.092	-

Source: Research Findings

According to Table 3, the elasticity of land input is positive and equals 1.04, showing one percent increase in the use of land input will increase output by 1.04 percent, and this input was used in the first stage of production in the studied area. The elasticities of nitrate and phosphate fertilizers, herbicide and machinery inputs had a positive sign and were 0.258, 0.033, 0.058 and 0.0003, respectively. It means that a one percent increase in the usage of nitrate and phosphate fertilizers, herbicide and machinery inputs will increase output by 0.258, 0.033, 0.058 and 0.0003 percent, respectively. Also, the value of these elasticities is between zero and one, indicating that farmers were currently operating in the second stage of production for these inputs. Consistent with our findings, Esfandiari *et al.,* (2013) similarly reported positive production elasticities for both land and phosphate fertilizer inputs in rice production of Marvdasht County, Fars Province.

The seed input exhibited a negative elasticity of 0.251 percent, indicating that one percent increase in seed usage would decrease mean production by 0.251 percent. This negative elasticity value suggests over-utilization of seeds in the study area. In production economic terms, this places seed usage in Stage III of the production function (the irrational zone of production).

The labour input demonstrated negative elasticity (-0.046 percent), implying that a one percent increase in labour usage would reduce mean output by 0.046 percent. This statistically significant negative elasticity confirms that labour is being overutilized in the study area, placing it in Stage III of the production function - the economically inefficient zone where the marginal product is negative.

The sum of the partial elasticities of inputs to output indicates returns to scale (RTS) and, in fact, the flexibility of production.

The returns to scale coefficient was estimated at 1.092. This means that a one percent increase in the use of production inputs increases the amount of rice produced by more than one percent, which is called increasing returns to scale. Sharzehei *et al.*, (2001) also found that rice production in Guilan Province exhibits increasing returns to scale.

Estimation results of the production risk function

Output variability in the production process has been explained by the inputs and exogenous variables which provide important information for production risk management. According to the estimated coefficients of the production risk function in the middle part of Table 2, the inputs of area under cultivation (Land), water, farmer's age, and gender increase production risk, and seeds, herbicides, machinery, education, household size, and rice farming experience reduce production risk.

In other words, the land input coefficient was obtained as 4.409, showing that land input has a significant and positive effect on the risk of rice production and is a risk-increasing input. Because rice farming is labor-intensive, increasing the area under cultivation makes it difficult for each farmer to control the farm, and the time spent per square meter during the planting and harvesting stages of the rice crop decreases. This result is consistent with the findings of Yazdani & Sassuli (2008), Kopahi *et al.*, (2009), Esfandiari *et al.*, (2013), Villano & Fleming (2006), Tiedemann & Latacz-Lohmann (2013), Guttormsen & Roll (2014) and Oppong *et al.*, (2016).

The coefficient of water inputs was also 1.458, which indicates that water has a positive and significant effect on rice production risk. Because of the abundant rainfall and climate conditions of the studied area, water input is considered as a dummy variable, usage of water from channels against traditional sources of water supply. Because the channels' water is released on a certain date, it leads to a delay in the preparation of rice paddy fields and defers the stages of the rice production process, which increases production costs. So water is a risk-increasing input, which is consistent with Yazdani & Sassuli (2008) on investigating the effects of inputs on the risk of rice production.

The seed input coefficient was -0.045, which indicates that seed input has a negative and significant effect on rice production risk and is, in fact, a risk-reducing input. A risk-averse farmer will employ more seed to reduce output variance. In the study area, rice farmers also used more seeds. This issue has two reasons: after transferring the seedlings to the mainland, some seedlings were damaged or were removed from their place by the flow of water; or the stem of the seedlings was separated by some aquatic insects and was destroyed, requiring replacement with healthy seedlings. farmers used the seedlings remaining in the storage to reduce the production risk. The studies of Guttormsen & Roll (2014), Baawuah (2015) and Oppong *et al.,* (2016) confirm this finding.

The herbicide input coefficient was also found to be -0.342. It means that herbicide had a significant and negative effect on rice production risk. Using herbicide to destroy weeds can create sturdy rice bushes and improve the quality and quantity of the product. Similarly, Kopahi *et al.,* (2009), Villano *et al.,* (2005), Villano & Fleming (2006) and Baawuah (2015) found that herbicide is risk reducing input in rice production.

The input of machinery became significant, with a coefficient of -0.006. This means that machinery was a risk-reducing input. This implies that proper management of machinery can be used to reduce output variance. This result is in agreement with the findings of Karbasi *et al.,* (2005), Adinku (2013), and Hosseinzad & Alefi (2016).

Studies that examined the effect of inputs on production risk (Yazdani & Sassoli, 2008; Karbasi *et al.*, 2005; Sharzehei & Zibaei, 2001) showed that a small percentage of production risk is related to production inputs, and various factors such as the geographical location of the farm, the farmer's age, the level of literacy and education or experience, the farmer's gender, access to credit, the extension services provided, rainfall, and the type of agricultural soil all affect production risk. Therefore, in the present study, in addition to examining the effect of inputs on production risk, the effect of factors such as the farmer's age, education level, experience, and farmer's gender, marital status, and household size on production risk was examined. These results are explained below.

According to Table 3, the coefficient of the age variable was 0.128 and was significant. it means that age is a risk-increasing variable. As farmers get older their physical and cognitive powers diminish and the one behaves more conservatively and risk-averse showing a less tendency to adopt new technologies. Also, older farmers are more likely to be at individual risk.

The coefficient of the gender variable was 3.877 and had a significant positive effect on production risk. If the manager and decision maker of a farm is male, he will take more risky decisions. This can be consistent with the general belief that women are relatively risk-averse. On the other hand, men have more financial independence than women, which can affect their decision-making. It can be true, especially in rural communities where women are more responsible for household duties. This result is consistent with the studies of Wik *et al.,* (2004) and Guttormsen & Roll (2014).

The coefficient of the education variable in the production risk function was -0.249. This variable had a negative and significant effect on production variance and it was a risk-reducing variable. The higher level of education will reduce the production risk. Because more educated farmers have comprehensive vision and a better understanding of issues related to their profession including production, markets for selling their product etc.

The coefficient of the household size variable was -0.556 and was statistically significant. This result shows that the household size variable has a negative and significant effect on the risk of rice production and is a risk-reducing variable. A big family is considered to have more labour input at different stages of production, reducing the risk of labour scarcity in the production process and so on the production risk.

The coefficient of the agricultural experience variable was -0.076 and was statistically significant. So, the experience of farmers in producing rice reduces production risk and is a risk reducing variable. The experienced farmers work better in their field of agricultural activities, which can ultimately improve productivity and reduce production risk.

Labour, nitrate and phosphate fertilizers, and marital status did not have a significant effect on the risk of rice production in the studied area.

The labour has a negative sign and is a risk decreasing input, but not significant in this study. The studies of Yazdani & Sassuli (2008), Kopahi *et al.*, (2009), Ogundari & Akinbogun (2010), Alikhani *et al.*, (2015), Baawuah (2015) and Hosseinzad & Alefi (2016) also confirmed that labour is a risk reducing input.

Estimation results of the technical inefficiency Model

The last part of Table 2 shows the results of estimating the technical inefficiency function. It should be noted that negative signs of the estimated variables indicate positive effects on technical efficiency, which imply such variables reduce rice production inefficiency, and the positive sign shows the negative effect on technical efficiency.

According to Table 2, the seed variable coefficient was obtained as 0.037. It means that with each additional unit of seed used, the amount of 0.037 units of farm inefficiency increases. So, seed has a positive and significant effect on technical inefficiency, indicating that farmers who have used more seeds were less efficient. Using more seed increases production costs and on the other hand, by increasing output density per hectare land reduces marginal productivity.

The coefficient of labour input was 0.058 and was statistically significant. This indicates that labour input has a positive effect on the technical inefficiency of rice farms. Using more labour due to the high level of wages increases production costs, and on the other hand, because of the excessive labour accumulation per hectare, production decreases.

The coefficient of the variable membership in cooperatives was also positive and significant, with a value of 3.081. This means that membership in cooperatives in the study area had a positive effect on the technical inefficiency of farmers. Cooperative companies have different categories according to their activities. The cooperative corporations distribute various types of fertilizers and herbicides. Some cooperatives in the studied area were inactive, and rice farmers had to buy these inputs from the market at higher prices, which in turn would increase production costs. It should be mentioned that active cooperatives recommended fertilizers and herbicides to farmers without any soil testing and just based on their own experience, which cannot be the optimum amounts. According to the studies of Esfandiari *et al.*, (2013) and Alikhani *et al.*, (2015), membership in cooperatives has a significant relationship with technical inefficiency, which can be positive or negative.

According to the results, the crop insurance variable also became significant, with a coefficient of 2.682 and had a positive effect on the technical inefficiency of rice farmers. Most of the rice farmers who had insured their product did not receive any indemnity after damage or received only a little, which was not enough to cover their costs. Thus, they considered the rice insurance program as an additional useless cost that only increases their production costs. Also, a large number of rice farmers had small farms, and due to the high amount of premium, they did not insure their product.

The coefficient of nitrate fertilizer was -0.034. This means that nitrate fertilizer had a negative and significant effect on the technical inefficiency of rice farmers. In other words, nitrate fertilizer has a positive effect on technical efficiency and increases it. Nitrate fertilizer is agronomically an important input for increasing rice yield and can increase production if used at the right time.

According to the results, water input had a negative and significant effect on the inefficiency of rice farmers. In other words, water input has a positive effect on the technical efficiency of farmers. The coefficient of water input was calculated as -2.486. As mentioned earlier, this input was considered a dummy variable. Using the water of channel because of the stability of its source increases technical efficiency. The findings of Esfandiari *et al.*, (2013) also showed that the source of water supply has a positive effect on technical efficiency in rice production.

In this study, the gender variable was significant with a coefficient of -2.761. So, Men work more efficiently than women. This could be explained by the fact that men have easier access to credit, probably because of cultural prejudice, and hence men are closer to the production frontier. Also, men are more interested in expanding their activities. This result is consistent with the findings of Kibaara (2005), Onumah & Acquah (2010), Taraka *et al.*, (2012), Adinku (2013), Baawuah (2015) and Kea *et al.*, (2016).

The experience variable with a coefficient of -0.118 had a negative and significant effect on farmers' inefficiency. In other words, experienced farmers are less inefficient. So, there is a positive relationship between farmers' experience and technical efficiency. Findings of Esfandiari *et al.*, (2013), and Alikhani *et al.*, (2015), Ogundari & Akinbogun (2010), and Taraka *et al.*, (2012) also confirm this result.

The variable of educational classes was also significant with a value of -10.66. This variable had a negative effect on technical inefficiency and in other words a positive effect on the technical efficiency of rice farmers in the studied region. Educational classes that upgrade farmers' information and their managerial capacity, will increase production efficiency.

The variables of phosphate fertilizer, herbicide, machinery, age, marital status, education, household size, non-agricultural occupation, land ownership, and machinery ownership did not affect the technical inefficiency of rice farmers in the studied area. Adinku (2013) showed that age, land ownership, size of household and main occupation did not have any significant effect on technical inefficiency of rice production in Ghana. Also, according to Esfandiari *et al.*, (2013), the variables of household size, primary occupation, and machinery ownership did not affect the technical efficiency of rice production in Iran.

Testing of hypotheses

The likelihood ratio test (LR) results for the hypothesises of the study are presented in table 4.

Table 4- Hypothesis test for model specification and statistical assumptions of stochastic frontier model with flexible risk properties

Null Hypothesis	Log-likelihood Value	LR Test	Critical value (α=0.001)	Decision
1. H_0: $\alpha_{ij} = 0$	-27.18	164.52^{***}	58.30	Reject H_0
2. H_0: $\beta_1=\ldots=\beta_{14}=0$	-10.53	131.23^{***}	36.12	Reject H_0

3. H_0: $\lambda=0$	-42.68	195.5^{***}	67.98	Reject H_0
4. $H_{0:}$ $\gamma_1=\ldots=\gamma_{20}=0$	22.63	64.89^{***}	48.26	Reject H_0

Source: Research Findings *** Statistically significante at 0.001 significance level.

According to the table 4:

1- The translog model is an adequate representation of the data, given its specification.

2- Production risk in inputs and socio-economic variables and technical inefficiency are present and estimated lambda is 0.54 and it is significantly greater than zero. This implies that variations in the observed output from the frontier output is due to technical inefficiency (u) and random noise (v).

4- The study finds technical inefficiencies are explained by the exogenous factors and the conventional input factors.

Comparison of technical efficiency values with risk and without risk component

The results of estimating technical efficiency with and without considering risk components are shown in Table 5.

Table 5- Technical efficiency with and without risk component

Technical efficiency	Min	Max	SD	Mean	Technical inefficiency
Technical efficiency with risk	25.37	100	12.31	93.47	6.53
Technical efficiency without risk component	15.49	100	10.43	96.27	3.73

Source: Research findings

As can be seen, the average technical efficiency of farms with the risk component was 93.47 percent. In this case, there is a 6.53 percent inefficiency. Also, the average technical efficiency of farms without considering risk was 96.27 percent. That is, in this case, the units have a 3.73 percent inefficiency.

Therefore, considering risk in the production process clearly affects technical efficiency. The difference in the efficiency in both cases indicates that with the same amounts of inputs and facilities, the production level can be increased significantly, and this increase in production increases when the factors that create risk can be controlled. Therefore, it can be concluded that by considering risk in production, production can be increased by 6.53 percent by using available resources efficiently. Without considering risk, this amount reaches 3.73 percent. The economic interpretation of the efficiency estimate can be expressed as follows: On average, rice farmers in the study area can increase their technical efficiency by 6.53 percent (with risk component) and 3.73 percent (without risk component) without requiring additional resources for production.

So, the technical efficiency score is overestimated when the production risk component is excluded. So, the conventional stochastic frontier model understimates technical efficiency scores than a stochastic frontier model with flexible risk specification. This result is consistent with findings of Alikhani *et al.*, (2015), Ogundari & Akinbogun (2010), Adinku (2013), Baawuah (2015) and Oppong *et al.*, (2016).

Conclusion and Recommendation

This study was carried out to investigate the technical efficiency and production risk of rice paddy fields in Rasht County (Guilan province) using the stochastic frontier model with flexible risk properties. In this model, the translog production function was estimated simultaneously with production risk and technical inefficiency by a single-stage maximum likelihood estimation using Stata software.

According to the results, the translog production function was the most appropriate functional form for the production function part in the generalized SFP model of Kumbhakar (2002). Since the coefficients in the translog function are not interpreted directly, the concept of input elasticity should be used for interpretation. The results of calculating the production elasticity showed that the production elasticity of the inputs of cultivated area (Land), nitrate fertilizer, phosphate fertilizer, herbicide, and machinery were positive, and an increase in each of these inputs could potentially increase the average production. However, the production elasticity of seed inputs and labour was negative. This means that an increase in each of these inputs leads to a decrease in the average rice production in the study area. Also, the rice fields studied in Rasht County had increasing returns to scale.Also, production changes are explained by production risk in inputs. According to the estimated coefficients of the production risk function, the inputs of area under cultivation (Land), water, age, and gender increase production risk and are, in fact, risk-increasing inputs. On the other hand, the inputs of seed, Herbicide, machinery, farmer education, household size, and rice farming experience reduce production risk.Changes in technical efficiency are explained by the combination of the effects of inputs and exogenous variables. The results of the estimation of the technical inefficiency model showed that seed inputs, labor, membership in cooperatives, and agricultural insurance had a positive and significant effect on the technical inefficiency of rice production units in the study area, and the variables of nitrate fertilizer, water, gender, rice cultivation experience, and participation in educational and extension classes had a negative and significant effect on the inefficiency of the units.Based on the results, farms in the study area operate below the production frontier, and this eviation from the production frontier is due to technical inefficiency and risk.

The average technical efficiency estimated using the stochastic frontier function with flexible risk properties was 93.47%, and the average technical efficiency calculated without considering the risk component was 96.27%, which showed a higher value. Therefore, it is observed that not considering the risk component in estimating technical efficiency leads to biased results of technical efficiency.Based on the findings of this study, the following recommendations are made to help farmers and policymakers to increase rice output, eliminating technical inefficiencies and decreasing the effect of risk in the production process:1- With the formation of continuous and practical training classes and encouraging farmers to take part in these classes, farmers are briefed in terms of enough amounts of seed appropriate to the size of the farm and the timing and the correct use of nitrate fertilizer.2- by educating the correct farm management skills the indirect effect of increasing the area of cropping on production risk reduces.3- Because herbicides and machinery are risk decreasing inputs by choosing the best compound and controlling of the market and proper usage of machinery, production can be maximaized.4- By giving the low-interest loan to the farmers to buy transplanting machines, the high labour cost will be saved.5- It is also recommended cooperatives corporations provide farmers with fertilizers and herbicides based on soil test results to reduce the inefficiency of farms.6- considering the impact of agricultural insurance (rice insurance), it is suggested that insurers stick to their obligations and compensate the damage fully and immediately in order to encourage the rice farmers to use this risk management tool.

7- And finally, by removing barriers, a suitable atmosphere should be created in rural areas so the young are encouraged to involve themselves in productive activities such as rice farming.

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ارزیابی همزمان کارایی فنی و ریسک تولید مزارع برنج

هانیه کظمی شعبانزاده افلاکی[۱و۲]، عذرا جوان‌بخت[۱]، خدیجه الفی[۳]

۱- گروه اقتصاد کشاورزی، دانشکده کشاورزی، دانشگاه ارومیه، ارومیه، ایران
۲-گروه اقتصاد کشاورزی، دانشگاه علوم کشاورزی و منابع طبیعی ساری، ساری، ایران
o.javanbakht@urmia.ac.ir
۳- گروه اقتصاد کشاورزی، دانشگاه تبریز، تبریز، ایران

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چکیده

فعالیت های کشاورزی در مقایسه با سایر فعالیت های تولیدی، فعالیتی پرریسک بوده و این ریسک اغلب با ناکارآمدی همراه است. بنابراین مطالعه همزمان ریسک و عدم کارایی می تواند منجر به تولید کاراتر شود. مطالعه حاضر به طور همزمان کارایی فنی و ریسک تولید برنج‌کاران شهرستان رشت را در سال ۱۳۹۷ با استفاده از مدل تعمیم‌یافته SFP با ویژگی‌های ریسک انعطاف‌پذیر کامبکار (۲۰۰۲) ارزیابی مورد ارزیابی قرار داده است. نتایج تخمین تابع ریسک تولید نشان داد که تولید برنج به طور معنی‌داری تحت تأثیر نهاده‌های زمین، بذر و نیروی کار قرار دارد. همچنین، نهاده‌های سطح زیرکشت، آب، سن شالیکار و جنسیت ریسک فزاینده و بذر، علف‌کش‌ها، ماشین‌آلات، تحصیلات کشاورز، اندازه خانواده و تجربه کشاورزی از نهاده‌های ریسک کاهنده هستند. علاوه بر این، بذر، نیروی کار، عضویت در تعاونی های کشاورزی و بیمه، ناکارایی فنی را افزایش می دهد. کود نیترات، آب، جنسیت، تجربه کشت برنج و شرکت در کلاس های آموزشی و ترویجی اثر مثبت بر کارایی فنی در منطقه‌ی مورد مطالعه داشتند. نتایج برآورد کارایی فنی نشان داد که میانگین کارایی فنی شالیکاران با مولفه ریسک ۹۳/۴۷ درصد و بدون مولفه ریسک ۹۶/۲۷ درصد بوده است. بنابراین واضح است که برآورد مدل بدون مولفه ریسک منجر به خطای بزرگنمایی در میزان کارایی فنی می شود. در نتیجه، توصیه می شود هنگام اندازه گیری کارایی فنی شالیزارها برای دستیابی به مدیریت ریسک صحیح و تولید بسیار کارآمد، مؤلفه ریسک در نظر گرفته شود.

کلمات کلیدی: نهاده‌های کشاورزی، ریسک تولید، شالیکاری، مدیریت ریسک، مدل مرزی تصادفی (SPF)، کارایی فنی