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Study of increasing production using improving technical efficiency in fisheries in the north of the country (Case study: Kilka fishing on the shores of Mazandaran)

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Abstract

The population of fish stocks is constantly exposed to threats and invasion and finally, the problem of extinction due to some reasons. In this study, in order to estimate the technical efficiency of the Kilka fishing industry, the activities of 30 fishing fleets were investigated by the random border production function method and with the proposed maximum likelihood model of Battese and Coelli. Four independent variables used in this research are the number of vessels, the number of manpower, the fishing capital, and the number of nets. The factors selected as affecting the inefficiency are the fishermen's age, the fishermen's education level, the fishermen's second job, the catch manager's working record, the catch manager's education level, the number of stormy days and The number of fishing hours. Error terms (deviations from the efficient boundary) have been divided into two elements as disturbance and inefficiency. The estimation of the technical efficiency is based on the final model at different levels based on which the highest technical efficiency in this group is 0/97 and the lowest is0/46. The mean technical efficiency of the exploiters is 0/87. The range between the minimum and maximum efficiency has been calculated as 0/41. The results showed that efficiency decreased by decreasing stormy days and increasing fishing hours. In contrast, efficiency decreases with the increasing number of stormy days and decreasing fishing hours. It was also found that increasing the level of education of fishermen increases efficiency. The Kilka fishing industry was exposed to various risks, thus in this study, we get to analyze the types of risks such as the effects of the comb jelly (Mnemiopsis leidyi) and weather changes in the Kilka fishing industry.

Keywords: Technical efficiency, Kilka, Random frontier function, The caspian sea, Mazandaran Province, Risk, Mont Carlo Simulation Method
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1 Introduction

Undoubtedly, renewable natural resources and their status in the course of the economic and social changes of various world societies have a fundamental and constructive role, and these resources are the natural resources viewed as the supporter of economic growth and development in any country [14]. The economic growth and optimal management of the natural resources and the environment are inherently interdependent, and economic activities can affect these resources so that if the economic growth gets aligned with the environmental indicators' progress, the sufficient condition for the natural resources and the environmental development will be satisfied. Considering the increasing destruction and immethodical exploitation of nature has led scientists to try to explain the various services resulting from the performance of natural ecosystems, drawing the attention of the macro decision-makers and planners to the requirement of the ever-growing preservation and development of such God-given blessings [11]. Thus, in recent decades, the field of ecological economics has been undergoing an increase in remarkable activities in order to determine the value of the functions, products, and services of natural ecosystems. Many theorists assume that agriculture is the pivot of development, in this sense that if the country is self-sufficient in terms of food, dairy, and protein products, it can progress in other activities as growing in different fields. At the moment, Fishery is one of the sub-sectors of agriculture with a critical role in the economic growth of the country. About the significance of fishery, we can mention its role in providing part of the countrywide valuable animal protein, gaining foreign exchange stocks.

Creating national income, contributing to political independence and preventing imports, and also its role in bringing up direct and indirect employment in fishing activities, creating lateral industries and manufacturing fishing equipment and other associated facilities in the northern, southern and marginal areas of the sea as well as in other parts of the country [19]. In addition to the direct economic effects, other social, cultural, and political impacts of this sub-section cannot be overlooked. The cases such as preventing individuals' immigration through recruitment and employment, maintaining the national borders' boundaries, and preventing social deviations, such as smuggling, are the consequences and effects of fisheries in these areas [1].

The population of fish stocks is constantly exposed to being threatened and violated and ultimately to destruction due to some reasons. The huge stocks being wasted are unfortunately not considered and focused in the calculations of the majority of the exploiters, people, dealers, and none of the economic operators and market players [18]. The dropped Kilka Fish catches will make Kilka fishing, transportation, and processing activities, including the fishermen, fishing vessels' owners and canned and powder fish plants, etc. undergo a lot of economic losses and subsequently, social issues like the unemployed workers' compulsory immigration to large cities and getting into false jobs can also affect the economic and social condition of the country [10]. Unfortunately, the environmental goods have been damaged and changed due to a lack of transparency in the ownership and publicity of this valuable commodity. The economic approaches and tools and the valuation methods today have rushed to deal with the problem broadly and comprehensively. While according to the provisions of the RIO+ 20 Conference in 2012, Iran is committed to preserving the marine environment, restoring marine ecosystems and conserving biodiversity and using them sustainably, and fully implement the obligations of the United Nations Convention on the Sea Codes [20]. Besides, the reduction or suspension of fishing, and proper efforts regarding the stocks' condition, the increased operational management of fishing, discharging, and other ecosystem-related adverse effects of the fishery, including the elimination of the destructive fishing practices and implementation of the Code of Conduct, such as responsible fishing and international practical programs, etc. are the important conference provisions the achievement of which shows the need for this issue [4]. The survival of fishery and the conservation of aquatic resources requires a universal determination to deal with all destructive factors of the stocks, such as human factors (excessive catch), environmental pollution, and pressure on the conservation of high-quality species like Kilka. Gaining technical efficiency and sustainable catch (fishing) with the existing risks are the important advantages in this study. In this respect, there are a lot of questions and ambiguities ahead of us and answering them signifies the importance and necessity of this research.

2 Materials and methods

In the current research, the parametric method, i.e., the random frontier function of the data for the years 2016 to 2017, has been investigated. Five methods can be noted to determine the efficiency [24]:

1. Efficiency Indicators;
2. Production function;
3. Frontier production function;
4. Profit;
5. Mathematical programming;

To estimate the frontier production function, three methods are common:

1. Modified least squares,
2. Linear Programming,
3. Maximum likelihood.

Although the data envelopment analysis models the best one in introducing the reference sets for inefficient enterprises, in the state where the stochastic and incidental factors (weather, good luck, bad luck and invaders and etc.) play a role in determining the ecosystem products, SEA is more appropriate, since, in this model, all deviations from the efficient boundary are not attributed to the inefficiency, rather it is defined by providing the proper statistics and lack of inefficiency [23]. For this reason, it is preferred to estimate the efficiency of the Kilka fishing industry by the random frontier model because ecosystem products are subject to weather conditions (the out-of-control variable), and the random frontier function model separates the two elements of the variables as the out-of-control and inefficiency [6]. Monte Carlo Simulation Method was also used for Risk estimation. The Monte Carlo method requires a mathematical-statistical model with two general random and determinable parts for the study variable.

2.1 Stochastic Frontier Function (SEA) Production Function

One of the common parametric methods estimating the efficiency frontier is SEA [22]. In this method, first, we have to determine the production function form (Cobb Douglas, Transgul, Naranzandenthal and etc.), indicating the relationship between the input and output and also the distribution type of inefficiency is defined after that, the production function parameters are estimated, in which these stages lead to the increased calculations and using various statistical tests that are more difficult compared to DEA model requiring no such calculation for efficiency estimation, but this model has its own merits where adding computation is worth occurring. Compared with the common econometric models, the random frontier model has this feature that it doesn't consider the mean points in function fitness, rather it takes the boundary points into account [16]. Generally, the general structure and schema of the random frontier function model for production can be represented as the following:

$$\begin{aligned} & y_i = f(x_i, \beta) * \exp(u_i - v_i) \\ & v_i \sim N(0, \sigma_v^2),\ -\infty < v_i < \infty \\ & u_i \geq 0 \end{aligned} \tag{2.1}$$

In the above model, is a form of the function has to be determined for the model at the beginning. Y_i stands for the production corporation input vector and xi the applied production factors' vector. B is also the vector of the model parameters. As shown in the above model [15], the points' deviation observed from the production function depends on the value of two variables as u_i and v_i. The variable u_i shows the inefficiency or deviation from the production frontier that, according to the definition of efficiency, it should be non-negative and a one-sided distribution, and it's assumed as independent of any other disturbance elements of v_i and explanatory variables in the model.

The function $y_i = f(x_i, \beta). \exp(v_i)$, depicts the random production frontier function in which the variable vi is the common disturbance element and explains the factors such as the out-of-control and the external influencing shocks of the production unit, the measurement error, and the effect of the insignificant and put-aside variables from the model [9]. It's assumed that the disturbance element has an independent two-sided normal distribution with a mathematical expectation of zero and a constant variance of δ_v^2. It's required to point out that the combined disturbance term $\varepsilon_i = (v_i - u_i)$ in Eq. [4] is an asymmetric and abnormal term whose asymmetric degree depends on the standard deviation ratio of the inefficiency element to the standard deviation of the typical disturbance $\lambda = \frac{\delta_u}{\delta_v}$. Selecting the distribution type for the variable u_i is important in terms of selecting the method for model estimation [12]. A general criticism of the random frontier model is that you can't propose any certain hypothesis about the distribution form of the inefficiency variable [5]. In this respect, regarding the inefficiency element being one-sided, various distributions have been assumed for it, the most common of which are as the following:

1. Assuming semi-normal distribution
2. Assuming truncated distribution
3. Assuming exponential distribution

Based on these assumptions, various models have been developed in the framework of the random frontier function method. The point requiring attention about the random frontier function is that the element u_i isn't directly observable, and for this, in the initial models and the typical disturbance element, v_i seemed far-fetched in the combined error term. Thus, in the initial estimation techniques, only the combined term ε_i is satisfied and what resulted from the model estimation was an estimation of the average efficiency level of all study corporations [13]. However, in order to measure the corporations' inefficiency level, two elements of inefficiency and the typical disturbance have to be separated from each other [7]. This point is especially important from a policymaking view. The economic logic of separating these two elements in the model is that these two terms are separable and have different features.

As stated, the random frontier function model is a statistical method based on a series of statistical inferences. Thus, before analyzing the results of the model estimation and efficiency level, first off, a series of the assumptions of the statistics is tested [21], and then Kilka fishing technical efficiency has been dealt with through estimating the random frontier production function by the Frontier software package.

2.2 Mont Carlo Simulation Method

The stages of this method for estimating the desired products' risk in this study are as the following:

1. To determine the probable processes and the process parameters for the study variable (e.g., to determine that according to the historical and previous data of that variable, with what likelihood (relative frequency) each outcome or event will occur).
2. The hypothetical simulation for the applied variables (i.e., based on the process of creating random numbers, some values are created or produced for that variable using Excel 2007)
3. Estimating and determining the expected variable's value from the simulated variable (in other words, estimating mathematical expectation or weighted mean (weights are the same as the occurrence probabilities) of that variable regarding the values obtained in the prior stages.
4. Repeating the stages 2 and 3 repeatedly (1000 times in this study) for scenario development.
5. Comparing the values obtained from the prior stages with the real values and risk analysis.

3 Results

3.1 Model Estimation

In order to estimate the catch (fishing) function, the Cobb - Douglas function is applied:

$$\log Y = \beta_0 + \beta_1 \log X_1 + \beta_2 \log X_2 + \beta_3 \log X_3 + \beta_4 \log X_4 \tag{3.1}$$

$\log Y$ is the catch level(kg) logarithm; $\log X_1$ stands for the logarithm of the number of vessels; $\log X_2$ is the logarithm for the human force number; $\log X_3$ is the logarithm for the catch capital; $\log X_4$ is the logarithm for the nets' number. The total value of the products has been calculated from the total fishing products' value of the units based on the mean price in the study year.

3.1.1 Technical Efficiency of Fishing Vessels Owning Exploiters and Fishing Units

In Table 1, the function estimation derived results have been included. The coefficients indicate that they are operating in the second zone of production regarding the exploiters' catches using the study inputs. The function's homogeneity degree of 0.958 denotes the incremental return to scale (i.e., if the production inputs get twice more, the production level increases less than two times). The R^2 statistics is also 85% set forth as a criterion for the regression model's goodness of fit, suggesting 85% of the variation of the dependent variable (the catch value) has been accounted for by the independent variables (the vessels number, the human force number, the nets number, and the catch capital) showing an acceptable %. Besides, $\bar{R}^2$ statistics, a more reliable criterion, close to R^2 statistics, indicates the fitted model's goodness and reliability. Durbin-Watson statistics also show that the performed regression doesn't have any problem in terms of auto-correlation. Comparing computational F statistics with Table, F also rejects the zero hypotheses of all regression coefficients and the performed regression's insignificance.

3.1.2 Statistical Tests and Model Estimation

Logarithm statistics is one of the most commonly used statistics for maximum likelihood estimators' tests. The hypotheses on the model's estimation results are tested using the stated statistics. This ratio is the maximum likelihood

Table 1: Fishing Vessels 'Exploiters and Fishing Units' Function Estimation Results

Parameter	**Coefficient**	**T value**	
β_0	1643	2.7	$R^2 = 85$
β_1	0.157	1.3	$R^2 = 85.5$
β_2	0.132	2.8	$= 33.4$
β_3	0.456	3.2	$D.W. = 2.08$
β_4	0.213	2.88	

function value for bound functions under hypothesis zero (H_0) to the maximum non-bound functions likelihood value under the opposite hypothesis, which can be expressed as the following:

$$LR = -2(\log \text{likelihood} H_0 - \log \text{likelihood} H_1) \tag{3.2}$$

in which $\log \text{likelihood} H_0$ and $\log \text{likelihood} H_1$ are the likelihood logarithms under the hypothesis zero (H_0) and (H_1). As an asymptotic, the above statistics have a Chi-square distribution with a degree of freedom corresponding to the number of constraints imposed on the model under H_0. The value of the logarithm of the likelihood function evaluated in non-bound estimates has to be close to the likelihood function logarithm's value evaluated in the bound estimations. Three models, namely, the modified least squares, linear programming, and maximum likelihood, are common to estimate the frontier production function. In the current study, the maximum likelihood method proposed by Battese and Coelli [2] has been used. For that sort of statistical test, first, we consider the frontier profit function model as the Battese and Coelli [2] profit function:

$$\log Y = \beta_0 + \beta_1 \log X_1 + \beta_2 \log X_2 + \beta_3 \log X_3 + \beta_4 \log X_4 + V_i - U_i \tag{3.3}$$

$\log Y$ is the logarithm for the catch level (Kg); $\log X_1$ is the logarithm for the vessels' number; $\log X_2$ is the logarithm for the human force number; $\log X_3$ is the logarithm for the catch capital; $\log X_4$ is the logarithm for the nets' number, V_i stands for the symmetric element and including the out-of-control factors' effect induced random production variations such as weather, and it has a normal distribution with the mean zero and variance σ_v^2. On the other hand, U_i is related to the units' technical efficiency and covers the managerial factors, and has a normal distribution with one-sided range, and for the units whose production locates on the frontier production function, U_i equals zero. For the units whose production locates below the frontier production function, U_i is larger than zero. Thus it indicates the frontier production surplus from the real production at a certain level of the input consumption. The disturbance term is a combination in which U_i is the inefficiency element and also other random disturbances. The inefficiency element in the above model is assumed with truncated distribution at zero points with a mean of m_i and variance σ_u^2. The inefficiency effects based model is as it follows:

$$U_i = \sigma_0 + \sigma_1 z_1 + ... + \sigma_6 z_6 + w_i \tag{3.4}$$

the factors influencing U_i are as the following, Z_1 is the fishermen's age; Z_2 is the fishermen's education level; Z_3 is the fishermen's second job; Z_4 is the catch manager's work record; Z_5 is the catch manager's education level; Z_6 is the number of stormy days; Z_7 The amount of fishing hours. The technical efficiency is:

$$TE_{it} = \exp(-U_{it}) = \exp(-z_t \delta - w_{it}). \tag{3.5}$$

Based on what was proposed by Battese et al. [3], the random frontier function and the factors' effect on the technical inefficiency have to be estimated simultaneously. To simultaneously estimate the two functions, the Frontier 4/1 software package proposed by Battese et al. [3] is applied. The likelihood hypothesis test yielded results for the frontier function model parameters have been given in Table 2. $\gamma = \frac{\sigma_u^2}{(\sigma_u^2+\sigma_v^2)} = 0$ is the most important study

Table 2: Likelihood Hypothesis Test Gained Results for Study Frontier Function Model Parameters

Rejecting or approving the hypothesis	Critical level at 5%	Freedom degree	LR Statistics level	Max Likelihood function log	H_0
Rejecting H_1	34.7	6	76	-63	$\gamma = \frac{\sigma_u^2}{(\sigma_u^2+\sigma_v^2)} = 0$
Rejecting H_1	3.81	1	12	-98	$\mu = 0$
Rejecting H_1	9.34	5	118	-63	$\sigma_0 = \sigma_1 = ... = \sigma_5 = 0$

hypothesis. This hypothesis is true if the inefficiency effects don't exist in the random frontier function. In the case of approving this hypothesis, efficiency won't be observable, and the difference in Kilka fishing will be due to out-of-control factors. Regarding this point that U_i is a non-negative random variable, thus the factors influencing inefficiency have to be random. As Battese et al. [3] assume, in the case of the factors influencing the efficiency being non-random, these factors are taken as the explanatory variable, and consequently, the assumptions for U_i and V_i are not valid in the random model, and the coefficients won't be estimated. For this assumption, we estimate two models. In the 1st model, the factors affecting technical inefficiency exist, but they are absent in the 2nd model: $LR = 2(-101 + 63) = 76$.

Not approving the 1st model indicates the random distribution of the technical inefficiency effects in the model, and thus, the technical efficiency is observable or, in other words, it can be measured. Whenever the LR statistics is greater than the critical level, assuming H_0 in terms of the existence of inefficiency element is rejected, where this hypothesis is rejected. Therefore, based on the gained results, the inefficiency effects exist in the model, and the fishermen's catch difference isn't only due to the out-of-control factors. $\mu = 0$ is the test related to the incomplete normal distribution or a semi-normal distribution for the inefficiency element. μ indicates the mean disturbance term of U. This parameter being normal suggests the two-sided normal distribution, and it's being zero indicates the one-sided normal distribution for U, $LR = 2(-104 + 98) = 12$.

The computational value of the μ statistic is greater than the critical value at the confidence level of 95%; H_0 is rejected; therefore, the semi-normal distribution is sufficient for the inefficiency element. $\sigma_0 = \sigma_1 = ... = \sigma_5 = 0$ of this hypothesis denotes it's being zero or lack of the socio-economic factors' effects on efficiency. This hypothesis shows that the explanatory variables chosen as the factors influencing inefficiency have no effects on the inefficiency of the Kilka fish catch: $LR = 2(-122 + 63) = 118$. The test results showed the inefficiency-affecting variables' parameters being meaningful at the significance level of 5%.

Table 3: Study Model Parameters' Max Likelihood Estimation Results ($*$ indicates the significance level at 1%. $**$ indicates significance level at 5%. $***$ indicates significance level at 10%.)

Variables	Parameter	Coefficients	S.D	t statistics
constant	β_0	0.626*	0.043	3.22
$\log X_1$	β_1	-0.076*	0.064	2.57
$\log X_2$	β_2	0.214*	1.35	2.65
$\log X_3$	β_3	0.134*	1.07	3.16
$\log X_4$	β_4	-0.187*	0.432	3.07
constant	σ_0	1.34***	1.22	1.88
Z_1	σ_1	0.354*	0.098	2.34
Z_2	σ_2	-0.63**	0.532	-3.08
Z_3	σ_3	0.321*	1.13	2.89
Z_4	σ_4	-0.167*	0.96	-2.45
Z_5	σ_5	-0.067*	0.543	-2.654
Z_6	σ_6	0.454*	1.07	2.41
Sigma-squared	$\sigma^2 = \sigma_u^2 + \sigma_v^2$	11.433*	1.14	10.032
(γ) Gamma	$\gamma = \frac{\sigma_u^2}{(\sigma^2)}$	0.99	00000	50765.76
Log-likelihood			-76.871	

Table 3 exhibits the parameters' max likelihood in the model. Regarding four inputs of fishing vessels' number, the human force number, the catch capital, and nets being meaningful at 1% and given this matter that the inputs have been included in the logarithm as functions, the return to scale ratio are ascending. Considering γ level, we conclude a high level of inefficiency in the model, and a low % of deviations from the efficiency boundary is due to the out-of-control variables and the variables not included in the model, the Durbin-Watson statistics also suggest that the model has no problem in terms of auto-correlation. In this model, $R^2 = 0.98$ has been achieved that reveals the fitness model is good and valid. The influencing factors' results indicate that as the number of vessels and the nets increases, the economic efficiency declines, and as the human force number and catch capital increase, the economic efficiency rises. Three factors out of the influencing factors have had a negative effect on the study of Kilka fish catch economic inefficiency, namely, 1) Fisherman's education level, 2) Catch manager's working record, 3) Catch manager's education level. As the education of the fishermen and manager gets higher, the inefficiency factor drops, and thus, in this regard, the graduates who have studied in the related majors should be hired in this sector. The more their working record and their managerial experience, the more the economic efficiency of catch will increase.

In this study, the amount of fishing hours has a positive effect on efficiency. It was found that as the hours of fishing operations increase, the amount of fishing and fishing efficiency increases and as the hours of fishing operations decrease, the amount of fishing and fishing efficiency also decreases. In the current research, the effect of the variable known as the stormy days on Kilka fish catch efficiency has been studied; as Yazdani et al. [25] analyzed the effect of stormy days on the cooperatives' efficiency for the first time since in the interviews with fishermen and cooperatives' directors, this factor has been stated as the most important factors behind low efficiency. In the current thesis, this variable exerts a negative effect on catch efficiency. This variable's coefficient indicates that the increase of the mean stormy days decreases efficiency.

The variable as the second job of the fishermen exerts a negative effect on catch efficiency so that if the fishermen aren't engaged in an activity in the first half of the year and their income merely comes from the 2nd half of the year catch, which has a negative effect on the catch efficiency. Thus, if the conditions are paved so much that the fishermen in the 1st half-year get engaged in fishing-related activities, it will have a positive effect on Kilka catch efficiency. The results in Table 4 illustrate the final model-based technical efficiency estimation at different levels, according to which the highest technical efficiency in this group is 97% and the lowest one is 46%. The mean technical efficiency of the exploiters is 87%.

Table 4: Exploiters' Technical Efficiency

Relative frequency	**Frequency**	**Technical Efficiency %**
0	0	≤ 40
13.5	3	< 40 and ≤ 60
0	0	< 60 and ≤ 80
87.5	27	< 80 and ≤ 100
1	30	Total
Min 43	88	Mean
Max 97	41	Range

4 Monte Carlo Simulation Results

Employing the real data of the products' performance related to various years' products statistics, 1000 random numbers have been developed and its basis is established regarding the weather and the invasive comb jelly density fluctuations %, causing Kilka product performance to decrease or increase (the percentage of probability of damage to performance) in the long term; the performance variation for each product has been simulated separately and compared with its normal value. In Table 5, the column for the mean variation % of the average drought performance indicates the mean changes out of the years with average drought weather conditions. Two columns of the mean variation % of normal performance and highly humid indicate the mean changes of performance out of the years with that type of weather condition. The column of the mean simulated performance changes % suggests the mean performance changes % of 1000 simulated numbers using the changes % under various weather conditions and the density of the invaders. The column of the expected performance value has been estimated using Eq. (4.1).

$$m = m_1(m_2 + 1) \tag{4.1}$$

where, $m =$ is the expected performance value, $m_1 =$ is the mean normal performance and $m_2 =$ is the mean simulated changes %.

Table 5: the expected performance results of products after weather changes' simulation

Fish Species	Mean drought performance changes %	Mean normal performance changes %	Mean highly humid performance changes %	Mean simulation performance changes %	Expected performance value (ton/year)
Common Kilka	−18	−23	−41	−8.6	2638.718
Coarse eye Kilka	−14	−3	5	−2.7	2075
Anchovy Kilka	−11	16	23	−1.1	1856.353

Table 6: Results of products' expected performance after simulating Invasive Comb Jelly's Effect on Ecosystem

Fish Species	Mean high density performance changes %	Mean average performance changes %	Mean low density performance changes %	Mean simulation performance changes %	Expected performance value (ton/year)
Common Kilka	−8	−11	4	1.2	1690.04
Coarse eye Kilka	−12	−21	−9	−5.1	1074.268
Anchovy Kilka	−25	−43	−11	−10.6	1277.526

The results of Tables 5 and 6 have been given based on the highest quantity of Kilka fish. For example, the mean simulated performance changes for common Kilka in terms of weather changes is 8/6 less than the mean normal performance level. In other words, what should be expected as the performance of this product based on the past results and the real statistics (normal performance) isn't 2887 tons, rather it is lower than this equivalent to 2638.718 tons. The reduced performance results from the effect of risk on efficiency of this product in the region.

5 Discussion and Conclusion

As we know, developing countries such as Iran need to use economic resources, including natural resources such as the sea, for economic development and growth. Fishing is an inevitable issue and resistance to it seems largely impossible. Today, the view of environmental economics, which is a combination of the views of economists and environmentalists, can play an effective role as an effective and efficient tool to maximize economic benefits by relying on minimizing the degradation of natural resources. In order to estimate the technical efficiency, components such as out-of-control factors, management factors, level of education and rate of resource depletion by different ships were examined.

In this study, using a parametric method, i.e., the random frontier function of the data for the years 2016-2017, has been studied. The maximum likelihood method proposed by Battese and Coelli [2] has been employed. Four independent variables used in the research are the number of vessels, the number of human force, the catch capital, and the number of nets. The factors influencing inefficiency selected here are the fishermen's age, the fishermen's education level, the fishermen's second job, the catch manager's working record, the catch manager's education level, the number of stormy days and the number of fishing hours. Error terms (deviation from the efficient border) have been divided into two elements as disturbance and inefficiency.

Table 7: Likelihood Hypothesis Test Results for Study Frontier Function Model's Parameters

Approving or Rejecting Hypothesis	H_0
1st Hypothesis Rejection	$\gamma = 0$
1st Hypothesis Rejection	$\mu = 0$
1st Hypothesis Rejection	$\sigma_0 = \sigma_1 = ... = \sigma_5 = 0$

The hypotheses test results revealed that, not approving the 1st hypothesis indicates the random distribution of the model's technical inefficiency effects, and thus, the technical efficiency is observable, or in other words, it's measurable. $\mu = 0$ is the incomplete normal distribution test or the semi-normal distribution for the inefficiency element. The semi-normal distribution for the inefficiency element is an appropriate and sufficient one. The 3rd hypothesis indicates it's being zero or lack of socio-economic effect on efficiency. This hypothesis suggests that the explanatory variables selected as the factors influencing inefficiency exert no effect on Kilka fish catch inefficiency. Moreover, the test result related to the existence or absence of inefficiency in the model indicates that the major deviations from the efficiency border are due to the inefficiency element or a negligible % is because of the disturbance element. Estimating Kilka fishermen's profit function using the random frontier function method revealed that the fishermen's frontier profit has a negative relationship with the number of the nets and the number of the vessels. That is, as these variables increase, the efficiency decreases. And as the human force number rises, the economic efficiency catches capital increases.

The variable known as the fishermen's second job has a negative effect on catch efficiency, this way that if the fishermen aren't engaged with an activity in the first half of the year and their income is merely earned in the 2nd half of the year, it exerts a negative effect on catch efficiency level. Thus, if the conditions are provided in such a manner that the fishermen get engaged with fishing-related activities, it has a positive effect on Kilka catch efficiency. Out of the influencing factors, three factors have a negative effect on Kilka catch efficiency's economic inefficiency as: 1) The fishermen's education level, 2) The catch manager's working record, 3) The catch manager's education level. 4) The amount of fishing hours 5) The number of stormy days.

As the catch manager's and fishermen's education level increases, the inefficiency factor declines, and thus in this respect, the graduates in the related majors have to be hired in this sector. The higher the working record and managerial experience, the more the catch economic efficiency increases. Also, the effect of stormy days on the fishing efficiency of Kilka fish was investigated and the results showed that increasing the average of stormy days reduces the efficiency. In this study, the amount of fishing hours has a positive effect on efficiency. It was found that as the hours of fishing operations increase, the amount of fishing and fishing efficiency increases and as the hours of fishing operations decrease, the amount of fishing and fishing efficiency also decreases. It is important to note that further depletion of resources increases efficiency and benefits, but more fishing involves more depletion of the Kilka population, resulting in an environmental loss that is in stark contrast to environmental benefits. This is an environmental loss and is completely contrary to environmental interests. The variable of fishing hours showed that more fishing involves more depletion of Kilka population and as a result it is an environmental loss. The shorter the fishing hours, the less depletion and the less environmental damage. The government can use economic tools such as heavy taxes to maintain stocks to reduce the economic efficiency of fleets compared to the present time. This can reduce fishing effort and help maintain stocks in the long run. Therefore, it is appropriate for the Fisheries Department to intervene in this matter and monitor the fishing hours and maintain stocks.

The final model-based technical efficiency estimation at different levels is this way that according to which the highest technical efficiency in this group is 97%, and the lowest is 46%. The mean technical efficiency of the exploiters is 87%. The efficiency range between min and max has been estimated as 41% that can be attributed to managerial issues, and through improving and revising management practices. In the current research, the effect of precipitation drop or increase on fish catch performance in the Mazandaran Coasts is significant ;in other words, according to the results, the weather and precipitation fluctuations can create meaningful fluctuations in the performance and as a result, create performance risk in the region's fishermen's catch; thus, as one of the important parameters in predicting performance of fish catch, precipitation should be taken into account more; in other words, as the results suggest, the invaders' number fluctuations can results in significant fluctuations in performance and consequently, performance risk development in the region's fishermen's catch; therefore, the invasive comb jelly should be considered more seriously as one of the critical parameters in predicting the fishermen's catch performance, it is possible to increase the production and efficiency using the production inputs.

Suggestions

- Given the stocks of kilka fish and the high nutritional value of this fish and its reasonable price, it is suggested that the government and other affiliated agencies support the investment of investors in the navy to provide community protein.
- The results show that by increasing the number of ships and tours, economic efficiency decreases. As a result, the declining trend in the number of vessels and increasing their quality should be continued, because this will prevent further destruction of stocks and, to a large extent, the performance of fishermen will be economical.
- Given that efficiency increases with increasing fishing capital, it is necessary for the government to help the fishing community by providing appropriate facilities and long repayments.
- It is important to note that in the current situation, Anchovy and big eyed kilka stocks are in a critical situation, and ordinary kilka stocks are relatively small and limited, and have a vulnerability.
- Therefore, policies to protect kilka fish stocks should be a priority and should not exceed the maximum sustainable harvest under the pretext of increasing fishing efficiency.

Due to the fact that increasing the level of education of fishermen increases efficiency, the need for appropriate, regular and planned training courses in the field of fishing, particularly marine stocks, is necessary for fishermen. Using the Monte Carlo simulation method for risk measurement indicated that it is possible to apply this method to determine and prioritize various fish species catch risk; then, it is suggested to use this method at a broader level and for various products in the country. Considering the predicting power of the Monte Carlo method and its scenario development, the policymakers of the fishery sector are suggested to apply this method for predicting and developing future plans and evaluating various scenarios and analyzing different risks, to be able to come up with closer predictions to the reality in line with better and more efficient management of this important sector of the economy.

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