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Technology Choice Under Risk in Marine Fishing

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A risk programming model has been developed for investment decision in marine fishing. The model has been applied on survey data in Digha coastal region of West Bengal in India. Results of the model have been analysed in the light of risk aversion.

Key words : Marine fishing, Technology, Risk.

India has vast potential for marine fisheries development with 2.02 million km^2 area of Exclusive Economic Zone along 7,517 km of coast line (Srivastava *et al.*, 1991). At present marine fishery sector in India provides employment for 95 lakh fishermen, supplies 3.5 kg of animal protein food per capita per year and earns about 4 per cent of the nation's total export earnings. So, the importance of marine fishery stems not only from domestic requirements but from the imperatives of exports also.

However, marine fishing occurs in a risky environment. Variable weather and environmental conditions affect marine fish catch and lead to wide trip-to-trip swings in fishing income (Bain, 1986; Annamalai & Kandoran, 1995, 1996). Marine fishermen respond to these risks and select the "best" technology with respect to risk aversion. This response to risks should also be reflected in theoretical models, so that the results generated in empirical studies bear resemblance to actual decisions and only then these models will be of use in policy analysis.

The present study involves the formulation of a risk programming model for the investment decision in marine fishing in coastal West Bengal. West Bengal is an important maritime state in east coast of India. There are two coastal districts in West Bengal: Midnapore and 24 Parganas. For the purpose of this study, Digha of Midnapore coastal region was selected.

Materials and Methods

A field survey in Digha coastal area of Midnapore district in the year 1992-93 showed that three types of mechanised fishing crafts were in use in this area: Mechanised boat Type I (locally called *Bhut-bhuti*), Mechanised boat Type II (locally called Launch) and mechanised boat Type III (locally called Trawler) (Neogy *et al.*, 1995). Investment costs for these three technologies are shown in Table 1. Summary statistics of fish catch are also shown

Table 1. Investment and summary statistics of fish catch

Item	Mechanised boat Type I	Mechanised boat Type II	Mechanised boat Type III
Investment (Rs.)	63,000	1,50,000	4,50,000
Average fish catch (Rs.)	1,706	4,657	5,734
Standard Deviation (Rs.)	214	1,328	1,382
Coefficient of variation	0.125	0.285	0.241

Source: Neogy *et al.* (1995)

in the same table. Table 1 shows that type III was the costliest technology with high risk (observing the coefficient of variation). Type II was the most risky technology in terms of fish catch. Type I was the least cost technology with least risk.

Percentage distribution of different types of fishing vessels operated in the study area are shown in Table 2. It shows that all three technologies coexist inspite of high cost of Type III and high risk of Type II.

Table 2. Percentage distribution of different types of fishing vessels in Digha coastal region

Type	Percentage
Mechanised Boat Type I	15
Mechanised Boat Type II	45
Mechanised Boat Type III	40

Source: Neogy *et al.* (1995)

Next, an attempt was made to model the above scenario. In general, marine fishing decision process may be represented theoretically as a linear programming model, as follows:

$$\text{maximize } Z = \sum_j c_j x_j$$

subject to the constraints

$$\sum_j a_{ij} x_j \leq b_i,\ i = 1,2, \ldots ,m$$
$$x_j = 0,1,2,\ldots ,\ j = 1,2, \ldots ,n.$$

where,

x_j is the number of fishing vessels of type j employed by the marine fishermen;

c_j is the per unit fish catch contribution by x_j;

a_{ij} is the per unit use of the i^{th} resource (capital, labour, etc.) by x_j and

b_i is the fixed endownment of the ith resource.

Here we assume that (i) there are sufficient stocks of different species in the study area, that are caught by different types of fishing crafts and gears (Table 3), and (ii) fishermen in the study area have the expertise to operate with different types of technologies. Moreover, we assume that there are various kinds of institutions to finance investment, namely commercial banks, Cooperative banks etc (Table 4).

Table 3. Group-wise fish catch by different technologies (expressed as percentage of total catch by mechanised boats)

Species	Mechanical boats			Total
	Type I	Type II	Type III	
Prawns	0.01	2.95	9.68	12.64
Pomfret	0.58	6.89	6.19	13.66
Ilsha	1.66	14.56	23.00	39.22
Fish Group I	0.66	9.56	4.90	15.12
Fish Group II	1.75	6.49	11.12	19.36
Total	4.66	40.45	54.89	100.00

Source: Neogy *et al.* (1995)

Note: All fish and shell fish were divided into 5 groups based on their demands as follows:

1. *Penaeus monodon* (prawn) and *Macrobrachium rosenbergii* (Fresh water prawn) both had high demand in the export market.
2. *Pampus argentus* (Silver pomfret) had demand in the export market.
3. *Tenulosa ilisha* (Ilsha) had a high demand within West Bengal.
4. Fish Group I consisted of *Liza parsia* (Persa), *Mystus vittatus* (Tangra), *M. seenghala* (Arr), *Tachysurus sona* (Kanta), *Polynemus paradiseus* (Topsa), *Sardinella longiceps* (Sardine), *Dasyatis sp.* (Shankar). These fish had high demand not only in West Bengal but also in other states such as Bihar, Madhya Pradesh etc.
5. Fish Group II included *Rastrelliger kangurta* (Mackerel), *Harpodon nehereus* (Lote), *Glossogobius giuris* (Bele), *Setipinna phase* (Phansa), *Anabas testudineus* (Patki), *Trichurus haumela* (Rupa Patia), *Gudusia chapra* (Khaira) and *Pama pama* (Bhola). These fish were in demand only at the local market.

Table 4. Different sources of loan used for fishing and fishing allied activities (percentage)

Sources	Mech. boat Type I	Mech. boat Type II	Mech. boat Type III
Bank	41.93	72.56	51.45
Money lender	-	9.03	3.35
Others (Aratdar+/ Relatives)	58.07	18.41	45.20
Total	100.00	100.00	100.00

+ Aratdar - Wholesale fish traders advancing money (@ 5-6% per month) on the condition that the fish catch is sold to them.

Ordinarily in linear programming models, the parameters c_j, a_{ij} and b_i are assumed to be known with certainty. But in marine fishing this assumption should be relaxed in view of the wide variation in returns, specially for c_j (Annamalai & Kandoran, 1995) and subjects of these parameters should be treated probabilistically as in risk programming (Boisvert & McCarl, 1990). Under these conditions, the set of 'x_j' s consitutes a decision associated with the most desirable probability distribution of marine fish catch.

A risk programming formulation of the above linear programming problem is

$$\text{maximise } Z - \emptyset\, \sigma_z^2 = \sum_j \bar{c}_j x_j - \emptyset \sum_i \sum_j \sigma_{ij} x_i x_j$$

subject to the constraints

$$\sum_j a_{ij} x_j \le b_i, \; i = 1,2 \dots , m$$
$$x_j = 0,1,2, \dots , j = 1,2, \dots , n$$

Here the objective function maximizes expected income from total fish catch less a "risk aversion coefficient" ($\emptyset$) times the variance of total income from fish catch. It is assumed that x_j's are normally distributed with the mean Z and the variance σ_z^2. The objective has been derived using the expected utility hypothesis (Freund, 1956). But one major problem with this formulation is that it is a quadratic programming problem and is harder to solve than a linear program.

A linear approximation to the above E-V (Mean-Variance model) is MOTAD (Minimization of Total Absolute Deviations) model (Hazell, 1971). In this model, risk is measured by absolute deviations from mean returns rather than by the variance of total returns. The MOTAD model is

$$\text{maximize } \sum_j \bar{c}_j x_j - \Phi \sum_k (d_k^+ + d_k^-)$$

subject to the constraints

$$\sum_j a_{ij} x_j \le b_i, \quad i = 1,2, \dots , m$$
$$\sum_j (c_{kj} - \bar{c}_j) x_j - d_k^+ + d_k^- = 0, \quad k = 1,2, .. , N$$
$$d_k^+ , d_k^- \ge 0$$
$$x_j = 0,1,2, \dots\dots$$

N is the number of observations, c_{kj} is the per unit fish catch by x_j under the k^{th} observation. d_k^+ is the positive deviation of the k^{th} catch occurrence from mean catch and d_k^- is the associated negative deviation. The above model is most often written in terms of negative deviations from the mean only, because the sum of positive deviations about the mean is always equal to negative deviations. Then the model is

$$\text{maximise } \sum_j \bar{c}_j x_j - 2\Phi \sum_k d_k^-$$

subject to the constraints

$$\sum_j a_{ij} x_j \le b_i, \quad i = 1,2, \dots ,m$$
$$\sum_j (c_{kj} - \bar{c}_j) x_j + d_k^- \ge 0, \quad k = 1,2 \dots ,N$$
$$d_k \ge 0$$
$$x_j = 0,1,2, \dots\dots$$

Table 5. Technology choice under risk

Objective	Investment	Risk aversion parameter (Ø)	Value of objective function (Rs.)	Fishing Vessels X1	X2	X3
Maximization of Total Fish catch	1,50,000	1.00	1708	2	-	-
		0.75	2134	2	-	-
		0.50	2560	2	-	-
		0.25	2986	2	-	-
		0.00	4656	-	1	-
Maximization of Total Fish catch	4,50,000	1.00	5124	6	-	-
		0.75	6402	6	-	-
		0.50	7680	6	-	-
		0.25	9143	4	1	-
		0.00	13969	-	3	-
Maximization of Ilsha Fish catch	1,50,000	1.00	0	-	-	-
		0.75	0	-	-	-
		0.50	0	-	-	-
		0.25	473	-	1	-
		0.00	1902	-	1	-
Maximization if Ilsha Fish catch	4,50,000	1.00	0	-	-	-
		0.75	0	-	-	-
		0.50	129	4	1	-
		0.25	2404	4	1	-
		0.00	5706	-	3	-
Maximization of prawn catch	1,50,000	1.00	0	-	-	-
		0.75	0	-	-	-
		0.50	0	-	-	-
		0.25	0	-	-	-
		0.00	206	-	1	-
Maximization of prawn catch	4,50,000	1.00	0	-	-	-
		0.75	0	-	-	-
		0.50	0	-	-	-
		0.25	0	-	-	-
		0.00	632	-	-	1

Ignoring positive deviations in this case does not alter the solution. Results of application of this model are discussed in the following section.

Results and Discussion

The model yields the income maximizing solution ($X_3 = X_2 = 0$ and $X_1 \neq 0$) for high risk aversion parameters and for different investment levels (Table 5). This income is from total fish catch. The variable X_2, i.e., Mechanised boat Type II enters the solution as the risk aversion parameter (Ø) decreases. But, Mechanised boat of Type III does not enter the solution even when Ø = 0 (i.e. a high risk taking investor).

The result improves a little more when this model has been applied on Ilsha fish catch which has a very high domestic demand. It shows that the objective of the investor in Mechanised boat Type II is mainly to maximize the expected income from Ilsha fish catch rather than income from total fish catch. However, both the cases (i.e. total fish catch and IIsha fish catch) do not explain the investment decision in Mechanised boat of Type III.

The scenario changes when the objective of the decision maker is to maximize income from exportable fish catch. Here we consider only prawn. Results in Table 4 show that the investor will select X_3 (i.e. Mechanised boat Type III) when $\emptyset = 0$, i.e. the investor will take the highest risk in increasing his income from prawn catch. It is expected that the scenario will improve more if other exportable varieties like pomfret, etc. are taken into consideration.

The risk programming model that has been developed in this paper for the investment decision for marine fishing in coastal West Bengal is based on the assumption that sufficient stocks of different species and expertise to operate with different technologies are available in the study area. The model shows rationality in explaining the behaviour of fishermen in adopting different types of technologies. It explains that fishermen in the study area adopted costliest technology i.e. mechanised boat Type III only when their objective was to maximize income from fish catch of exportable variety. Here remains a scope from the policy aspect to extend the model by inclusion of financial subsidy on investment in high cost technology and to observe the overall influence on choice of technology.

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