Agricultural Economics Research Review
Vol. 19 July-December 2006 pp 327-351

Fish Supply Projections by Production Environments and Species Types in India[1]

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Abstract

The supply studies on the fisheries sector in India have been addressed at the disaggregated level by production environment and by species groups. These would be more imperative and useful for assessing the fish supply at the national level. The fish supply projections by species groups under different production environments have been obtained to a medium-term horizon, by the year 2015 under various technological scenarios. The study has concluded that the supply response to fish price changes has been stronger under aquaculture than marine environment in India. Price and technology have been reported as the important instruments to induce higher supply. The change in the relative prices of fish species would change the species-mix in the total supply. The fish production has been projected as 4.6-5.5 million tonnes of inland fish and 3.2-3.6 million tonnes of marine fish by the year 2015. More than 60 per cent of the additional fish production will be contributed by aquaculture and mainly by the Indian major carps.

Introduction

Fisheries, a sunrise sector in India, has recorded a faster growth than that of the crop and livestock sectors. The sector contributes to the livelihood of a large section of economically-underprivileged population of the country.

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[1] The paper is drawn from the India study under the multi-country project on 'Strategies and Options for Increasing and Sustaining Fisheries and Aquaculture Production to Benefit Poor Households in Asia'. RETA 5945. Asian Development Bank and WorldFish Center. February 2005.

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It is undergoing a transformation and the policy support, production strategies, public investment in infrastructure, and research and extension for fisheries have significantly contributed to the increased fish production. The share of fisheries in agricultural gross domestic product (Ag-GDP) has increased from 1.7 per cent in the year 1980 to 4.2 per cent in 2000. The fish production increased at the rate of 5.1 per cent per year during 1980-2003 and reached 5.9 million tonnes in 2003 from a level of 1.76 million tonnes in 1970-71 and 2.44 million tonnes in 1980-81 FAO (2005).

The depleting water resources for inland capture fisheries, and high cost of fishing with crafts and gears have led to an increased realization of the potential and versatility of inland aquaculture, making it a sustainable and cost-effective alternative to inland capture fisheries. The emerging production technologies (improved fish breeding, scientific aquaculture practices), higher economic growth and policy reforms with higher emphasis on aquacultural development are driving a rapid growth in the fisheries sector in India. The contribution of inland fisheries to the total fish production has increased significantly, from less than one-third of the total production in 1950-51 to more than its half in 2000-01.

The supply studies on the fisheries sector have not only been limited but have not adequately addressed it also at the disaggregated level by fish types and production environment. The supply studies would be more imperative and useful for pragmatic planning, if addressed at the disaggregated level. The present paper has attempted to: (i) estimate the fish supply and factor demand model under aquaculture and marine production environments, (ii) derive the fish supply and factor demand elasticities by fish species under various production environments, and (iii) provide mid-term projections of fish supply by fish species and production environment.

Data and Methodology

The time-series data on fish production (species-wise) and their prices at the state level were compiled from various sources. The *Handbook on Fisheries Statistics,* published by the Ministry of Agriculture, Government of India, and the specific publications of different states on fisheries statistics were the important sources of data for this study. Some unpublished data were extracted from the state government records personally. The data on input prices (wages, fertilizer, feed, fuel) were obtained from the *Agricultural Prices in India*, reports of the Commission for Agricultural Costs and Prices and Economic Survey, published by the Government of India, and from the *Fertilizer Statistics,* published by the Fertilizer Association of India. The export data on quantity and unit value of various species of fish were compiled from Marine Products Export Development Authority, Kochi. The data on fishery water resources were collected from Central Water Commission. The Indian Livestock Census provided the data on fisherman population and fishery resources. The data used in the study were classified as follows:

- Marine fish production by species for states/ union territories, their quantity and prices.
- Inland fish production by species for states/union territories, their quantity and prices.
- Prawn production by states/union territories, their quantity and prices.
- Exports of marine products by species, their quantity and value.
- Inland fishery resources by states/union territories: Length of rivers and canals, area under reservoirs, ponds and tanks, water bodies, brackish water.
- Coastal length by states/union territories.
- Fisherman population by states/union territories: It included the total number of members, number of family members engaged in fishing operations (full time and part time), family members engaged in fishing-related activities (marketing of fish, repairing of fishing nets, and processing of fish).
- Data on fishing crafts (traditional, motorised traditional, mechanised boats – gill-netters, trawlers, liners) and fishing gears (dragnets, gill nets, trawl nets, cast nets) by states/union territories.

The data on inland fish production, inputs and their prices were compiled for the period 1991-92 to 1998-99, covering 27 states/union territories of India. The data on inputs, viz. land, labour, feed (rice bran, oil cake and other feeds), fertilizer (cow dung, poultry manure, and chemical fertilizers), seed, and specific costs (diesel, medicine and others) were compiled[5] . The data on marine fish production and its value by species were compiled for the period 1986-87 to 1998-99, covering 12 maritime Indian states. The data on labour and fuel were also compiled from various published sources. The quantity of diesel used was worked out by taking into account various types of crafts, number of fishing days, hours of work per day, with the norms that 200 litres of diesel would be used per HP. The total HP utilisation was worked out in consultation with experts.

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[5] The time-series cross-section data on specific inputs were not available at the state level. The input-output coefficients for aquaculture fish were reviewed from various studies. The time-series and cross-sectional information on the use of various inputs were generated and used in the analysis. The data for the missing years were obtained by interpolation. For the missing states, the information from the neighbouring states were used.

The fish species were aggregated into 8 groups (Appendix Table 1) to keep the model simple. These groups were formed on the basis of production environment, commercial value, consumers' taste and preferences and experts' opinion.

The Supply Model

Given a profit function, output supply and input demand equations can be derived using Hotelling's Lemma (Hotelling, 1932) by differentiating with respect to prices. The profit function derivative with respect to the price of a product is equal to the supply function of that product; and its derivative with respect to the price of an input is equal to the negative of the demand function of that input. To implement this process empirically, it was necessary to first specify functional form for the profit function. In the present analysis, we have used normalized quadratic form of the profit function.

Let q be a ($n\times 1$) 'netput' vector composed of k positive values of outputs and l negative values of variable inputs. Let p be the corresponding ($k\times l$) vector of output and input prices. Both fixed inputs and other exogenous factors are included in the vector Z. Let the profit (π) and prices (π) be normalized by the price of the n^{th} commodity (p_n) such that $\pi^* = \pi / \pi_n$ and $p_i^* = p_i / p_n$. The normalized profit function can be written as Equation (1):

$$\pi^* = a_0 + \sum_{i=1}^{n-1} a_i p_i^* + \frac{1}{2} \sum_{i=1}^{n-1} \sum_{j=1}^{n-1} b_{ij} p_i^* p_j^* + \sum_{i=1}^{n-1} \sum_{j=1}^{m} b_{ij} p_i^* z_j^* \qquad \ldots(1)$$

Applying Hotteling's Lemma, the derived system for output supply and factor demand are given by Equation (2) and Equation (3), respectively:

Output supply

$$q = a_i + \sum_{j=1}^{k-1} a_i p_i^* + \sum_{j=1}^{m} b_{ij} z_j \qquad \ldots(2)$$

Factor demand

$$-q = a_i + \sum_{j=1}^{l} a_j p_i^* + \sum_{j=1}^{m} b_{ij} z_j \qquad \ldots(3)$$

Equations (1), (2) and (3) can be estimated using system of equations approach. The supply equation for the n^{th} commodity, whose price served as a numeraire can be worked-out as per Equation (4):

$$q_n = \pi^* - \sum_{i=1}^{k-1} p_i^* q_i = a_0 + \frac{1}{2} \sum_{i=1}^{n-1} \sum_{j=1}^{n-1} b_{ij} p_i^* p_j^* \qquad \ldots(4)$$

Following the theory of production function (*see*, Wall and Fisher, 1988), it is expected that the estimated profit function will follow the properties of homogeneity, symmetry, monotonicity and convexity. Homogeneity in prices is maintained in Equations (1), (2) and (3) due to normalization and hence cannot be tested. Symmetry was implemented by imposing $b_{ij} = b_{ji}$ during estimation.

The monotonicity and convexity properties do not necessarily hold. The consistency of the estimated model with the properties of convexity and monotonicity were evaluated after estimation. For the normalized quadratic form to satisfy the monotonicity condition, the estimated values of output supply and input demand must be positive. To satisfy the convexity condition, the Hessian of price derivatives must be positive semi-definite.

The elasticities can be computed at any particular value of prices and quantities as per Equation (5) :

$$E_{q_i}^{p_j} = b_{ij} \frac{p_j^*}{q_i}, \text{ where, } i, j = 1, 2, \ldots, (n-1) \qquad \ldots(5)$$

Equation (5) measures the own-price elasticity when $i = j$, and cross-price elasticity when $i \neq j$. The corresponding numeraire netput can be derived indirectly using the property of "homogeneity in prices" of the normalized profit function using Equations (6) and (7):

$$E_{q_n}^{p_i} = -\left(\sum_{j=1}^{n-1} E_{q_i}^{p_j}\right) \cdot q_i \cdot \frac{p_i / p_m}{q_m} \qquad \ldots(6)$$

where, $i = 1, 2, \ldots, (n-1)$

and

$$E_{q_n}^{p_n} = -\sum_{i=1}^{n-1} E_{q_n}^{p_i} \qquad \ldots(7)$$

Model Specification

An outline discussion on environment-specific multi-output multi-input models is provided below. A description of the variables used in the both models has been provided in Appendix A.

Inland Zone (Aquaculture)

The inland aquaculture model was consisted of three outputs, three variable inputs and one shifter-pond area. The outputs were Indian major carps (IMC), other freshwater fish (OFW), and freshwater shrimp (FS). In the inputs, feed was measured as crude protein, fertilizer as nitrogen, and labour as person-day[6] . For simplicity, the corresponding unit prices of these variables used in the model were coded as P_{IMC}, P_{OFW}, P_{FS}, P_{feed}, P_{fert}, *Wage1*, Z_{area} (*see* Appendix A for more information).

Marine Zone

The marine capture model was consisted of six outputs and two variable inputs over the time span of the study. The state-level length of coastline (*coast*) served as the shifter variable. The outputs were: pelagic high-value (PHV), pelagic low-value (PLV), demersal high-value (DHV), demersal low-value (DLV), shrimps, and molluscs. The factor demand was composed of the main inputs, namely fuel and labour.

Results and Discussion

Fish Production

Total fish production, including both inland and marine sources, had increased from 4.3 million tonnes to 5.5 million tonnes during the period 1993-1998 with an annual growth rate of 4.8 per cent (Table 1). This inland fish production had increased with annual growth of 6.6 per cent during this period and attained a level of 2.8 million tonnes in the year 1998. The IMC had contributed half to the total inland fish production. Other species of fish, except prawn, had contributed about 37 per cent. The prawn production which was 310 thousand tonnes in the year 1991, had increased to 380 thousand tonnes with an annual growth rate of 4.4 per cent. The marine fish production during 1993-1998 had increased from 2.3 million tonnes to 2.6 million tonnes, with the annual growth rate of 3 per cent. Pelagic fish was found to be the major group of species and contributed nearly half to the

[6] Feed is a critical input in fish production and is used for the purpose of a better and faster growth of fish. Oil cake and rice bran are the most common supplementary feeds in aquaculture. These feeds were converted into crude protein equivalent and used in the estimation of the supply model. The manure and fertilizers are applied in the ponds to facilitate the growth of macro and micro vegetative plants for ultimate consumption by fish. The most common chemical fertilizers used in aquaculture are urea, single super phosphate (SSP), and di-ammonium phosphate (DAP). These fertilizers were converted in nutrient equivalent and included in the producer core system. Stocking refers to application of external fish seeds into the ponds for the purpose of raising them up to marketable size. Data on stocking (i.e. fingerling supply) were not available, it was not included in the model.

Table 1. Production and price of fish by species group, India

Species	Production (million kg)			Price (Rs/kg)		
	TE1993	TE1998	Annual growth (per cent)	TE1993	TE1998	Annual growth (per cent)
			Inland fish			
Indian major carps	958562 (46.3)	1418262 (49.8)	8.1	27.1	30.9	2.6
Other freshwater fish	803573 (38.8)	1047258 (36.7)	5.4	15.8	24.6	9.3
Freshwater shrimp/prawn	309005 (14.9)	383930 (13.5)	4.4	43.1	63.6	8.1
Total	2071140 (47.7)	2849450 (52.0)	6.6	25.1	33.0	5.6
			Marine fish			
Pelagic (high-value)	353273 (15.6)	374128 (14.2)	1.2	13.4	27.7	15.7
Pelagic (low-value)	896014 (39.5)	931422 (35.4)	0.8	7.4	14.2	13.9
Demersal (high-value)	270841 (11.9)	367666 (14.0)	6.3	9.2	18.6	15.1
Demersal (low-value)	205830 (9.1)	216237 (8.2)	1.0	7.9	14.0	12.0
Marine shrimp	244377 (10.8)	255774 (9.7)	0.9	33.1	52.0	9.5
Molluscs	299349 (13.2)	486886 (18.5)	10.2	10.8	15.0	6.7
Total	2269683 (52.3)	2632114 (48.0)	3.0	11.8	19.4	10.4
Grand total	4340822	5481563	4.8	18.2	26.5	7.8

Note: Figures within the parentheses are the shares of fish species in total production.

total marine fish production, followed by demersal (22.2%), molluscs (18.5%) and shrimp (9.7%).

Input Use

Aquaculture: The inputs were categorized into two groups, viz. fixed and variable inputs. Only variable inputs, viz. human labour, manures, fertilizers, and feed were taken into account in the supply analysis in the fish model. The most crucial inputs were labour and management. The share of inputs in the total variable cost varied across states at around 33 to 52 per cent for labour, 9 to 33 per cent for feed, 12 to 19 per cent for stocking, 9 to 15 per

Table 2. Annual use of inputs in aquaculture and marine fishery: 1991-1998

Item	Unit	1991	1995	1998	Annual growth (per cent)
		Aquaculture			
Labour	Million person-days	432.0	375.9	331.0	-3.7
Feed	Million kg crude protein	497.5	525	573.4	2.0
Fertilizer	Million kg nutrients	89.5	113.4	121.7	4.5
Wages	Rs/day	20.8	40.4	56.1	14.3
Feed price	Rs/kg of crude protein	12.3	11.3	18.2	4.2
Fertilizer price	Rs/kg nutrient	16.9	27.2	29.3	8.6
		Marine			
Labour	Million person-days	432.5	476.6	505.2	2.2
Diesel	Million litres	34.9	40.9	45.9	4.0
Wages	Rs/day	28.3	44.8	59.2	11.6
Diesel price	Rs/litre	5.3	7.5	10.9	8.8

cent for fertilizer and 15 to 22 per cent for specific inputs (Table 2). The total labour employment in aquaculture which was 432 million person-days during 1991, declined to 331 million person-days in the year 1998, at the rate of (-)3.7 per cent per annum. The negative employment trend was confirmative to the survey conducted by NSSO on employment recently (1999). The wage which was Rs 20.8 per person-day in 1991 had gone up to Rs 56 per person-day in the year 1998, with an annual growth rate of 14.3 per cent. The crude protein used for aquaculture had increased from 497.5 million kg in 1991 to 573.4 million kg in 1998, with an annual growth rate of 2 per cent. The prices of crude protein per kg also increased from Rs 12.30 to Rs 18.20, with an annual growth rate of 4.2 per cent. The fertilizer-use had increased from 16.9 million kg in 1991 to 29.2 million kg in 1998, with an annual growth rate of 4.5 per cent in quantity and 8.6 per cent in terms of value. The utilization of diesel had increased with 4 per cent growth and attained a level of 46 million litres in year 1998.

Marine*:* Labour and fuel being the major inputs in the marine fisheries sector, were taken into account in the estimation of the supply functions for this sector. The marine sector in fish catching activity had used 432.5 million person-days of labour in 1991, which had increased to 505.2 million person-days in 1998, with an annual growth rate of 2.2 per cent. The use of diesel had increased from 34.9 million litres to 45.9 million litres, with annual growth rate 4 per cent during the period 1991-98. The wages had increased from Rs 28.30 per person-day to Rs 59.20 per person-day during the period 1991-1998, with an annual growth rate of 11.6 per cent. It was followed by the diesel prices from Rs 5.30 per litre to Rs.10.90 per litre, with annual growth rate of 8.8 per cent. The increase in fuel-use was due to the modernization and the replacement of a large number of traditional boats by the mechanised boats.

Total Factor Productivity

Aquaculture Sector: The fish input, output and TFP indices for aquaculture farming revealed that during 1992-1998, the annual growth rate of input index was 2.1 per cent and of output index was 6.1 per cent (Figure 1). The TFP index had moved with an annual growth rate of 4.0 per cent. The TFP growth rates were found to be much higher in the aquaculture sector than crop sector (Rosegrant and Evenson, 1992; Kumar, 2001; Kumar *et al*., 2004).

Marine Sector: The input index for the marine sector had moved 25 points during the period 1987-1998 with an annual growth rate of 2.1 per cent (Figure 2). The fish output index increased from 62 points in the year 1991 and 83 points in the year 1998, with an annual growth of 4.1 per cent. The TFP growth had moved 47 points with 2.0 per cent annual growth. The growth was observed to be higher in the marine sector than the TFP growth in the crop sector.

The pond area is likely to be the limiting factor of aquaculture supply. In the light of growing demand, fish supply would be input-based and the practice of over-fishing would pose a greater environmental threat. A deceleration in the TFP growth for fisheries would be the most likely scenario for both the aquaculture and marine fish sectors in future. Following the Asia Fish

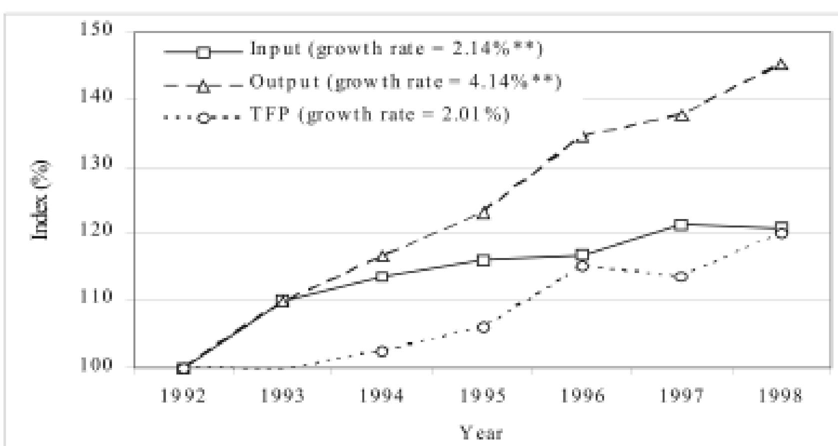

Figure 1. Input, output and TFP indices for inland aquaculture, India

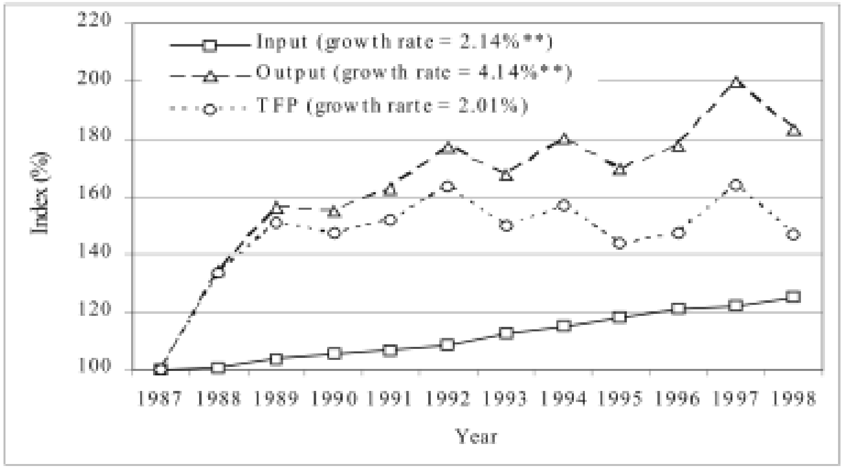

Figure 2. Input, output and TFP indices for marine capture, India

Model (Dey *et al.*, 2005), supply by fish types has been projected under different scenarios[7] of a decelerated TFP growth.

Estimation of Supply Model

In both the production environments, the model with the normalized quadratic profit function included in the specification was not satisfactory. It was because the number of parameters in the profit equation was large and the Hessian matrix became ill-conditioned. As a consequence, the normalized quadratic profit function was dropped from the specification, leaving only the systems of output supply and factor demand for the estimation. Though this might have resulted in some loss of efficiency, the inherent multicollinearity problems were reduced.

The supply system was estimated using the cross-section time-series data described earlier. Estimates of the model were obtained using the Zellner's generalized least squares with correction for serial correlation and heteroscedasticity in the disturbance terms. Following the application of the

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[7] Scenario I: Baseline assumptions with the existing growth in TFP for marine capture (2%) and aquaculture (4%) to continue till 2015

Scenario II: Baseline assumptions with 25% deceleration in TFP growth by 2015

Scenario III: Baseline assumptions with 50% deceleration in TFP growth by 2015

Scenario IV: Baseline assumptions with 75% deceleration in TFP growth by 2015

Scenario V: Base line assumptions without TFP growth during the projected period, by 2015

Prais-Winsten estimator, the GLS SUR estimator was applied to the transformed variables from the last iteration of the Prais-Western estimator to generate the final parameter estimates for the system of equations in the supply system.

Aquaculture Fish Supply and Input Demand

During the analysis all possible input/output prices were used as the numeraire. OFW turned out to be best numeraire. The estimated parameters of price variables in the supply and input demand equations agreed with a sign of *a-priori* expectations (Table 3). The own-price parameters for fish supply were statistically significant and positive. The cross-price parameters were negative and in general, significant also. Both the own- and cross-price parameters in the output supply were important in fish supply decisions. Price of inputs had a negative influence on the fish supply, but it was not significant for IMC and prawn/shrimp. The significance could not be tested for OFW, being the numeraire in equation. The own-input price parameters in the factor demand equation were significantly negative. The rise in wages and other input prices will adversely affect the employment and use of input levels in aquaculture. The shifter pond area under aquaculture, as expected, would induce fish supply and inputs. The supply of IMC would increase significantly with time. The results revealed that the input demand and fish supply were sensitive to their own-prices. This suggests that Indian fish producers respond to price changes in an effective manner. Price instruments along with technological policy were likely to be quite effective in the fish supply. The changes in relative price of fish species would influence the supply-mix consisting of various fish species. Significant cross-price effects for fish supply and insignificant crop-price effects for input demand were observed. Since fish supply was interrelated through prices, policymakers should ensure that the effects of one policy do not conflict with the policy decisions for other fish types. It is suggested that a comprehensive approach to fish price policy be taken rather than the product-by-product approach.

The elasticities calculated at mean data values have been given in Table 4. The own-price elasticity estimates had the expected signs; they were greater than unity for IMC and OFW, and less than unity for prawn/shrimp (FS). The prawn-cultivation was more capital-intensive as compared to other species. The short-run price effect on supply was sharp and quick for IMC and OFW than FS. The price of IMC would affect the FS supply negatively. The cross-price elasticity of IMC and FS was negative and highly elastic (-4.03). The input price had the mild effect on IMC supply, whereas the supply of prawn and OFW was affected sharply. Since the acreage effect on fish supply was quite high (0. 7) for all the aquaculture

Table 3. Aquaculture fish supply and input demand models, India

	Indian major carps		Freshwater Shrimp/Prawn		Labour		Feed		Fertilizer		Other freshwater fish
	Coefficient	t-value	Coefficient	t-value	Coefficient	t-value	Coefficient	t-value	Coefficient	t-value	Coefficient
Intercept	-12991.90	2.55	1843.47	1.23	-125.63	0.10	615.08	0.25	67.07	0.12	–
Price (Rs/kg)											
Indian major carps	40.14	2.05	-16.58	3.56	1.19	0.30	1.25	0.15	-0.03	-0.03	5.98
Prawn	-16.58	3.56	2.99	1.64	0.87	0.82	1.71	0.72	0.46	1.19	-2.48
Labour	-1.19	0.30	-0.87	0.82	-5.10	2.02	1.86	0.53	0.73	0.45	-3.12
Feed	-1.25	0.15	-1.71	0.72	1.86	0.53	-34.45	4.12	-0.37	0.25	-20.11
Fertilizer	0.03	0.03	-0.46	1.19	0.73	0.45	-0.37	0.25	-4.19	2.19	-2.14
Other freshwater fish	5.98		-2.48		3.12		20.11		2.14		51.75
Shifters											
Area (ha)	0.00	8.55	0.00	6.88	0.00	12.19	0.00	12.16	0.00	8.14	0.01
Year	6.52	2.55	-0.91	1.21	0.07	0.11	-0.30	0.24	-0.03	0.11	
IMR	-35.51	2.17	-10.35	3.77	–	–	–	–	–	–	–

System weighted $R^2 = 0.2441$

Table 4. Aquaculture fish supply and input demand elasticities, India

Variables	Fish supply			Input demand		
	Indian major carps	Other fresh water fish	Prawn	Labour	Feed	Fertilizer
Fish price						
Indian major carps	1.560	0.294	-4.032	0.174	0.032	-0.013
Other freshwater fish	0.157	1.716	-0.224	0.254	0.818	0.637
Fresh water Shrimp/Prawn	-0.645	-0.221	0.727	0.127	0.043	0.171
Input price						
Labour	-0.046	-0.185	-0.210	-0.746	0.047	0.270
Feed	-0.048	-0.415	-0.417	0.272	-0.872	-0.138
Fertilizer	0.001	-0.088	-0.113	0.107	-0.009	-1.544
Fixed factor						
Area under aquaculture	0.731	0.737	0.73	0.717	0.794	0.626

species groups, it could be used as an instrument for increasing fish supply to meet the domestic demand and export till new technological breakthrough in fish comes about. The inland fish supply was not sensitive to input prices as the cross input price and fish supply elasticities were highly inelastic, except feed price in the case of prawn and OFW. A higher fish price would not attract the higher use of inputs. The input demand elasticity with respect to own-prices were estimated as (-)0.75 for labour, (-)0.87 for feed, and (-)1.54 for fertilizer demand. One-way complementarity between labour and material inputs was observed. In India, fish culture is largely practised in village ponds, tanks and cages with low level of input-use, lack of good quality fish seed, lack of access of poor farmers to fish nurseries and unorganized system of fish marketing. Therefore, fish productivity was observed quite low. A majority of fish producers belonged to the socio-economically backward community. Any improvement in fish production practices through institutional efforts would increase the demand for quality inputs and supply of fish. This would reduce the cost per unit of production and increase the income level and quality of life of these poor households.

Marine Fish Supply and Input Demand

While estimating the normalized quadratic profit function, labour-input was used as the numeraire. The estimated parameters for fish supply and the input-demand equations did not agree with the sign of *a-priori* expectations. All the signs of own-price elasticities for fish supply and input demand turned out to be of opposite sign and did not agree with *a-priori* expectations. By changing the numeraire and introducing the state dummies, the expected sign of the parameters could not be obtained. Since, a majority of cross-price parameters were insignificant, the supply function was estimated by dropping the cross-price variables. The estimated equations then turned-out with expected sign for own prices.

The final results of marine fish supply and input-demand model have been presented in Table 5. The most of the estimated parameters were statistically significant at the 1 per cent level. Only two fuel price parameters in PHV and DHV supply equations and one fish price parameter in fuel input-demand equation were not statistically significant. This was reasonable for the supply system models of this size. The R^2 statistics were used as a measure of goodness of fit. Its value was about 0.97 for all the equations, indicating high degree of explanatory power. In the estimation, labour was used as the numeraire variable, the parameter of wages in supply equations, fuel-demand equation and the parameters of labour demand were derived from the estimated model. The coastal length and time trend had positive and significant influence on fish supply and input demand. The own-price was a statistically significant determinant of fish supply. It was true for all the fish species groups. Diesel price and wages influenced the fish supply and factor demand negatively.

The elasticities, calculated at mean data values, have been given in Table 6. The own-price elasticity of fish supply was highest for shrimp (0.49), followed by DHV (0.45), PLV (0.32), molluscs (0.28), PHV (0.28) and was minimum for DLV (0.20). The effect of diesel price on shrimp supply was more negatively pronounced than that on the supply of other species groups. The effect of wages on fish supply was highly inelastic. It was because the labour-input was almost fixed for the marine fishing for a given technology. The diesel price elasticity of fuel demand was highly elastic (-4.6). The fuel price inflation would hinder the process of modernization from the traditional non-mechanized boats to modernized boats. There is a need to extend the diesel subsidy to help the fishermen to adopt modern technologies. The operating costs accounted for the maximum proportion (92%) of the total cost in the traditional fishing units, followed by ring seine (89%), gill net (84%), trawler (78%) and purse seine unit (74%). The high operating cost of the fishing unit was due to high cost on fuel. Keeping the price of fuel lower would improve the working conditions and socio-economic status of the crewmen by adopting mechanization. Until the fishers get an opportunity to work with improved technologies, they would continue to be under the trap of poverty.

Table 5. Marine fish supply and factor demand, India

Variable	Output supply												Input Demand		
	Pelagic (high-value)		Pelagic (low-value)		Demersal (high-value)		Demersal (low-value)		Shrimp		Molluscs		Fuel		Labor
	Coeffi-cients	t-value	Coeffi-cients	t-value	Coeffi-cients	t-value	Coeffi-cients	t-value	Coeffi-cients	t-value	Coeffi-cients	t-value	Coeffi-cients	t-value	Coeffi-cients
Intercept	0.061	0.660	0.017	0.170	-0.006	0.050	0.236	0.920	0.002	0.020	-0.004	0.070	1.25900**	4.07	–
Price of fish															
Pelagic (high-value)	3.735	9.830													0.026
Pelagic (low- value)			21.428	9.170											0.026
Demersal (high-value)					8.967	7.180									0.026
Demersal (low-value)							3.140	2.860							0.025
Shrimp									2.325	12.130					0.025
Molluscs											9.031	14.080			0.026
Average price													0.209	0.820	
Input price															
Fuel	-2.015	1.060	-20.751	4.220	-4.788	1.760	-7.318	6.780	-22.655	10.040	-12.257	3.310	-4.631	10.300	-0.026
Labour	-0.065		-0.121		-0.259		0.056		0.048		-0.003		-0.090		-0.134
Fixed factors															
Coast length	0.021	14.030	0.036	6.830	0.017	6.230	0.014	12.640	0.012	5.630	0.043	14.780	0.006	13.420	0.006
Year	0.059	5.410	0.280	9.580	0.006	0.330	0.062	7.650	0.141	11.730	0.069	3.410	0.038	15.430	0.038
R^2	0.987		0.990		0.987		0.982		0.988		0.974		0.977		

Table 6. Marine fish supply and factor demand elasticities, India

Variables	Pelagic (high-value)	Pelagic (low-value)	Demersal (high-value)	Demersal (low-value)	Shrimp	Molluscs	Fuel	Labour
Fish price								
Pelagic (high-value)	0.276							0.001
Pelagic (low- value)		0.326						0.001
Demersal (high-value)			0.454					0.001
Demersal (low-value)				0.203				0.001
Shrimp					0.494			0.003
Molluscs						0.278		0.001
Average fish price							0.095	
Input price								
Fuel	-0.059	-0.242	-0.142	-0.368	-0.964	-0.274	-1.099	-0.001
Wages	-0.004	-0.004	-0.010	0.002	0.005	0.000	-0.002	-0.016
Fixed factors								
Coast length	0.445	0.309	0.375	0.527	0.367	0.714	1.080	
Year	0.318	0.602	0.033	0.576	1.101	0.284	1.639	

Supply Projections

The projected growth of fish supply for the period 2000-2015 has been depicted in Table 7. The results revealed that the fish production would grow at the rate of 3.0 per cent corresponding to the baseline Scenario I (with the existing growth in TFP), would decline to 2.2 per cent in Scenario III (with 50 per cent deceleration in the existing TFP) and would stagnate in the absence of technological growth (Scenario V). The supply would steeply decline with the deceleration of TFP growth. Across the species, the growth in supply was found to vary significantly. It was highest for inland fish (Indian major carps and other freshwater fish), ranging between 2.7 and 3.9 per cent per annum. The supply of shrimp would grow at a faster rate with an annual growth of 2.5-3.4 per cent. The supply of marine fish species is projected to grow in the range of 1.4 to 1.9 per cent per annum during 2000-

Table 7. Projected growth in fish supply and prices, India: 2000-2015

Variable	Scenario I	Scenario III	Scenario V
Supply			
Indian major carps	3.88	2.78	-0.09
Other freshwater fish	3.81	2.71	-0.18
Shrimp	3.40	2.51	0.18
Pelagic (high-value)	1.95	1.40	-0.05
Pelagic (high-value)	1.95	1.40	-0.05
Demersal (high-value)	1.92	1.36	-0.09
Demersal (low-value)	1.99	1.43	-0.01
Molluscs	1.98	1.42	-0.03
All	3.04	2.17	-0.06
Producer Price			
Indian major carps	-2.85	-1.80	1.03
Other freshwater fish	-2.72	-1.67	1.17
Shrimp	2.07	2.62	4.10
Pelagic (high-value)	-0.06	0.39	1.60
Pelagic (high-value)	-0.76	-0.22	1.21
Demersal (high-value)	1.61	1.99	2.99
Demersal (low-value)	-1.31	-0.75	0.73
Molluscs	1.66	2.09	3.24
All	-0.33	0.38	2.24

Scenario I: Baseline assumptions with the existing growth in TFP for marine capture (2%) and aquaculture (4%) to continue till 2015

Scenario III: Baseline assumptions with 50 per cent deceleration in TFP growth by 2015

Scenario V: Base line assumptions without TFP growth during the projected period 2000-2015

2015, except for the shrimp. The Scenario V revealed that the fish production would stagnate if the technological growth does not take place in future. To maintain the supply at the desired level, concerted efforts need to be put for improving the efficiency of fish production and catches, and enhancement of the growth in TFP through appropriate policies for research, extension, and development.

The rise in fish supply would not affect a decline in the price of shrimp. It is true for the export-oriented species. The prices of IMC and OFW are expected to decline in the projected period at the rate of 1.7 to 2.8 per cent per annum. Among the low-value marine species of fish, price would decline less than 0.76 per cent per annum for PLV and 0.75-1.31 per cent for DLV. The price of export-oriented fish species would continue to rise in spite of the increasing supply of fish. The higher growth in fish supply for the species used in the domestic market would benefit the common man, as this fish species would be available at cheaper prices in future. In the fish species which are export-oriented, the rise in supply would not cut down the price in the domestic market substantially, and the price would keep rising and would benefit the producer. The price of shrimp, the most potential export fish, would rise from 2.1 per cent to 2.6 per cent annually. Other exportable fish species would be: PHV, DHV and molluscs; for these also, the price would rise from 1.6 per cent to 2 per cent.

Under the baseline scenario, with the increase of fish supply (as projected in various scenarios), producers' prices in the domestic market would decline at an annual rate of 2.9 per cent for IMC, 2.7 per cent for OFW, 1.3 per cent for DLV, and 0.8 per cent for PLV. These species are meant mostly for the domestic market. Shrimp, PHV, DHV and molluscs (high-value) are the potential exportable species. A part of their output would be retained for domestic consumption also. Their prices in the domestic market are unlikely to decline even after the increase in their supply; rather their prices are likely to increase by 2.1 per cent for shrimp, 1.6 per cent for DHV and 1.7 per cent for molluscs. The prices of PHV group are likely to remain unchanged. Exports would help the producers to stabilize fish prices in the domestic market (at the aggregate level). Taking all the species together, the price of fish would move within a very narrow band with the annual growth ranging from –0.3 per cent to 0.4 per cent at constant price.

Based on the projected growth rate, the supply of fish has been estimated under various scenarios using TE 1998 as the base year (Table 8). Scenarios I, II, and III are the most likely scenarios that would prevail in future; these have assumed that the maximum decline in the TFP growth of fish production

Table 8. Projected supply, import and production of fish in India:2005-2015

(million kg)

Year	Scenario I	Scenario II	Scenario III	Scenario IV	Scenario V
			Supply		
1998(base)	5481.6	5481.6	5481.6	5481.6	5481.6
2005	6741.8	6669.0	6576.3	6441.2	5460.1
2010	7833.7	7575.0	7275.5	6893.9	5445.0
2015	9119.4	8519.5	7894.1	7199.4	5430.1
			Import		
1998(base)	70.7	70.7	70.7	70.7	70.7
2005	75.6	75.4	75.1	74.7	71.6
2010	79.3	78.7	77.9	76.8	72.3
2015	83.3	81.9	80.3	78.5	73.0
			Production		
1998(base)	5410.9	5410.9	5410.9	5410.9	5410.9
2005	6666.3	6593.6	6501.2	6366.5	5388.5
2010	7754.4	7496.3	7197.6	6817.1	5372.7
2015	9036.1	8437.6	7813.8	7121.0	5357.1

Scenario I: Baseline assumptions with the existing growth in TFP for marine capture (2%) and aquaculture (4%) to continue till 2015
Scenario II: Baseline assumptions with 25 % deceleration in TFP growth by 2015
Scenario III: Baseline assumptions with 50 % deceleration in TFP growth by 2015
Scenario IV: Baseline assumptions with 75 % deceleration in TFP growth by 2015
Scenario V: Base line assumptions without TFP growth during the projected period, 2000-2015

would be 50 per cent by the year 2015. Under the most optimistic Scenario I, the production of fish[8] would be 9.04 million tonnes by the year 2015. Considering the other scenarios, the fish production has been projected to be 8.4 million tonnes in Scenario II; 7.8 million tonnes in Scenario III; and 7.1 million tonnes under Scenario IV. For the scenario without TFP growth, the production would be stagnant almost at the current level.

A perusal of Figures 3a and 3b revealed the annual production of inland fish in the year 2005 to be in the range of 3.6 - 3.7 million tonnes, which would reach 4.6-5.5 million tonnes by 2015, with an annual growth rate of 2.9 - 4.0 per cent under different scenarios. The share of inland fish in the total fish production, which was about 50 per cent in the year 2000, would increase to 61 per cent by 2015. The production of marine fish, which has been 2.9 - 3.0 million tonnes in 2005, will grow to 3.2 - 3.6 million tonnes by

[8] The production projection has been arrived at after subtracting the projected import from the supply projection.

2015. The fish production is likely to grow at the annual rate of 2.9 - 4.0 per cent for inland fish and 1.2 - 1.8 per cent for marine fishes. The share of marine fish in the total fish production would decline from 50 per cent in the year 2000 to about 40 per cent by 2015.

The supply of IMC, which contributed 25 per cent to the total supply, has been projected to be 1.79 -1.85 million tonnes by 2005, 2.04 - 2.24 million tonnes by 2010 and 2.26-2.71 million tonnes by 2015 (Table 9). The supply of other fish categories by 2015 has been projected as 1.6 - 1.8 million tonnes for pelagic fish, 0.7 - 0.8 million tonnes for demersal fish, and 0.6 - 0.7 million tonnes for molluscs, etc. The changes in the share of different species in total production during the period 2000 - 2015 have revealed that the share of IMC in the total fish production would increase to 30 per cent by 2015 from 25 per cent in 2000 and of OFW to 22 per cent from 19 per cent. The share of shrimp, however, is likely to remain almost unchanged. The shares of pelagic, demersal, and molluscs have been projected to decline during this period.

By the year 2015, the incremental production has been projected to be 3.3 million tonnes. In this additional production, IMC would contribute maximum (36%), followed by OFW (26%), pelagic (14%), shrimp (13%), demersal (6%), and molluscs (5%).

A comparison of Scenarios I and V provides the effect of TFP growth on fish supply (Table 9). The production of fish would decline substantially with deceleration in the fish technological growth. The contribution of TFP to total fish production has been projected as 2.4 million tonnes by 2010 and 3.7 million tonnes by 2015 (41%). The contribution of TFP has been projected to be the highest (48%) in the inland fish sector by 2015. The technological change (measured in terms of TFP) would contribute about 29 per cent to the total marine fish production, except shrimp, by 2015. In the case of shrimp, it would be about 20 per cent by 2005 and 42 per cent by 2015.

Conclusions

The study has concluded that the TFP growth for the fish sector has been higher (2-4 %) even to that in the crop and livestock sectors (< 2%, *see* Rosegrant and Evenson, 1992; Dholakia and Dholakia, 1993; Kumar *et al*., 1998; Kumar *et al.*, 2005). Price response to fish supply has been stronger for aquaculture than marine fisheries. Price instruments along with technological policy would be the dominating factors to increase the fish supply, especially for aquaculture. The changes in relative prices of fish species would change the supply-mix consisting of various species. Fish supply would be 4.6-5.5 million tonnes under the inland sector and 3.2-3.6

Table 9. Projected production of fish by species and TFP contribution, India: 2005-2015

Year	Production (million kg)			TFP contribution	
	Scenario I	Scenario III	Scenario V	Quantity (million kg)	Per cent
			Indian major carp		
2005	1851.7	1793.6	1409.2	442.5	23.9
2010	2240.2	2039.7	1402.7	837.5	37.4
2015	2710.3	2260.9	1396.2	1314.0	48.5
			Other freshwater fish		
2005	1360.6	1317.8	1034.3	326.3	24.0
2010	1640.3	1493.0	1025.1	615.2	37.5
2015	1977.5	1648.4	1016.0	961.5	48.6
			Shrimp (marine and freshwater)		
2005	808.2	787.6	647.8	160.4	19.8
2010	955.2	885.1	653.7	301.4	31.6
2015	1128.8	974.3	659.7	469.1	41.6
			Pelagic (high-value)		
2005	428.4	421.5	372.9	55.5	13.0
2010	471.9	449.8	372.0	99.9	21.2
2015	519.9	473.8	371.1	148.7	28.6
			Pelagic (low-value)		
2005	1066.5	1049.3	928.4	138.0	12.9
2010	1174.8	1119.8	926.3	248.5	21.1
2015	1294.0	1179.7	924.2	369.9	28.6
			Demersal (high-value)		
2005	419.9	413.1	365.4	54.5	13.0
2010	461.7	440.1	363.8	97.9	21.2
2015	507.7	462.7	362.3	145.4	28.6
			Demersal (low-value)		
2005	248.2	244.2	216.0	32.1	12.9
2010	273.8	261.0	215.9	57.9	21.2
2015	302.1	275.4	215.8	86.4	28.6
			Molluscs and others		
2005	558.4	549.4	486.0	72.4	13.0
2010	615.8	587.0	485.4	130.4	21.2
2015	679.1	619.0	484.8	194.3	28.6
			All fish categories		
2005	6666.3	6501.2	5388.5	1277.8	19.2
2010	7754.4	7197.6	5372.7	2381.7	30.7
2015	9036.1	7813.8	5357.1	3679	40.7

Scenario I: Baseline assumptions with the existing growth in TFP for marine capture (2%) and aquaculture (4%) to continue till 2015
Scenario III: Baseline assumptions with 50 % deceleration in TFP growth by 2015
Scenario V: Base line assumptions without TFP growth during the projected period, 2000-2015

million tonnes under the marine sector by the year 2015. Indian major carps would be the major player in aquaculture supply. The contribution of technology in fish supply has been estimated to be 48 per cent and 29 per cent, respectively for the inland and marine sectors by 2015. Social welfare has been anticipated for both producers and consumers. The technological development in fisheries would make the fish available at cheaper prices and would improve household nutritional-security.

The study has suggested that aquaculture should be given priority in the national fisheries strategies. Fish production is technology-driven and largely dependent on national strategies towards prioritization of fish technologies to benefit the poor households. Constraints to its growth lay beginning from input supply, down to post-harvest services, processing, and marketing, in addition to dissemination of technology. On input side, the major constrains outlined are unavailability of quality fish seed, and lack of access to credit. Both need to be addressed by hatchery and quality brood stock policy as well as credit institutions. On the post-harvest and processing side, need has been projected to invest in landing and development of post-harvest facilities, training of fishers and processors towards better quality and global food safety standards and market access. Strengthening of community-based institutions for managing common areas, as well as investments in appropriate stock enhancement and enrichment systems, are the promising means for increasing supply under marine environment and providing benefits to the poor fishermen.

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Appendix A

Definition of variables

P_{IMC}	:	Price of Indian major carp (Rs/kg)
P_{OFW}	:	Price of other fresh water fish (Rs/kg)
P_{Prawn}	:	Price of prawn (Rs/kg)
Wage1	:	Wages for labour working in aquaculture (Rs/day)
p_{feed}	:	Price of feed (Rs/kg of crude protein)
p_{fert}	:	Price of fertilizer (Rs /kg of nutrients)
Z_{area}	:	Area under aquaculture in ha
P_{PHV}	:	Price of pelagic (high-value) (Rs/kg)
P_{PLV}	:	Price of pelagic (low-value) (Rs/kg)
P_{DHV}	:	Price of demersal (high-value) (Rs/kg)
P_{DLV}	:	Price of demersal (low-value) (Rs/kg)
P_{Shrimp}	:	Price of shrimp (Rs/kg)
$P_{Molluscs}$	:	Price of molluscs (Rs/kg)
p_{Fuel}	:	Price of diesel (Rs/litre)
Wage 2	:	Wages for labour working in marine (Rs/day)
Z_{Coast}	:	Coastal length in kilometres by state
q_{IMC}	:	Production of IMC (million kg)
q_{OFW}	:	Production of OFW (million kg)
q_{Prawn}	:	Production of prawn (million kg)
q_{PHV}	:	Production of PHV (million kg)
q_{PLV}	:	Production of PLV (million kg)
q_{DHV}	:	Production of DHV (million kg)
q_{DLV}	:	Production of DLV (million kg)
q_{Shrimp}	:	Production of shrimp (million kg)
$q_{Molluscs}$	:	Production of molluscs (million kg)
Fish inputs are defined as		
$q_{Labour1}$	:	Labour input in million person-days used in aquaculture farming
q_{feed}	:	Feed input in terms of crude protein in million kg
q_{fert}	:	Fertilizer input in terms of nitrogen in million kg
$q_{Labour2}$	:	Labour input in million person-days used in aquaculture farming
q_{Fuel}	:	Diesel used in marine catch in million litres
Z_{coast}	:	Coastal length in kilometres

Appendix Table 1

Fish species groups and fish species composition in India

Species group	Short/ Variable name	Major species
Freshwater fish (aquaculture)		
(1) Indian major carps	IMC	Rohu, catla, mirgal, calbasu
(2) Other freshwater fish	OFW	Silver carp, grass carp, common carp, murrels, hilsa (inland) and other unspecified inland fish
(3) Prawn/Shrimp	FS	Penaeid shrimp
Marine fish (capture)		
(4) Pelagic (high-value)	PHV	Seerfish, oceanic tunas (yellowfin tuna, skipjack tuna), large carangids (*Caranx* sp.), pomfrets, pelagic sharks, mullets
(5) Pelagic (low-value)	PLV	Sardines, mackerel, anchovies, bombayduck, coastal tunas, scads, horse mackerel, barracudas
(6) Demersal (high-value)	DHV	Rock cods, snappers, lethrinids, big-jawed jumper (*Lactarius*), threadfins (polynemids)
(7) Demersal (low-value)	DLV	Rays, silverbellies, lizard fish, catfish, goat fish, nemipterids, soles
(8) Crustaceans	MS	Shrimps, lobsters
(9) Molluscs and others	Molluscs	Cephalopods (squids, cuttlefishes and octopus), mussels, oysters, non-penaeid prawns