Asian Fisheries Science **9** (1996): 69-85.
Asian Fisheries Society, Manila, Philippines

https://doi.org/10.33997/j.afs.1996.9.1.007

Market Demand and Supply Potential of Chinese Fish Products

Y. YE

Fishery Resources Group
Shanghai Fisheries University
Shanghai 200090, China

Abstract

This paper reports the econometric estimation of market demand for fish and production of capture fisheries and aquaculture in China. Market demand for fish in China is highly income-led and price-inelastic. With economic development, demand will expand further. However, there are limitations for increasing production from capture fisheries. Aquaculture has to de-velop substantially and play an increasingly dominant role in order to supply the market with sufficient aquatic products. A tentative prediction suggests that demand will reach 25.04 million tons by the year 2000. The maximum production from capture fisheries is only 8.4 million tons. If market demand is not depressed by high prices, 22.7 million laborers and $7.2 \cdot 10^4$ km^2 of cul-ture area may need to be committed to aquaculture by the turn of the century.

Introduction

Fish production in China was 4.6 million tons in 1978, and increased threefold to 15.58 million tons by 1992. It would be interesting to know the future demand for fish, and to be able to determine the policies that should be implemented for fisheries to cope with sharply increasing demand. To answer these questions, demand and production analyses are necessary.

Prior to 1978, China's economy was centrally planned. Goods distribution was marked by inefficiency. The physical infrastructure was primitive, production units were overstaffed, unwanted goods accumulated, and high quality goods were scarce. Most consumer goods moved either through the Supply and Marketing Cooperatives or through the wholesale and retail system under the jurisdiction of the Ministry of Commerce. Capital equipment and other industrial products moved directly from producer to final buyer according to the dictates of the planning system. Competition was absent.

In such a system, prices remained almost constant, and short supply was overcome by rationing and long queues in streets. It was difficult to estimate real market demand. Since 1978 the scope of planning had been greatly reduced, and by mid-1980s only a small number of commodities were subject to planned allocation and prices. By 1988 only half of China's retail sales took place at state-set prices (Anon. 1989).

However, economic reforms have taken place at a variable pace in different sectors. Reform in fisheries was first because of its relatively small scale and produce popularity. With the implementation of reforms in the aquatic marketing sector, production units were permitted to sell certain quantities in excess of the fixed quota, at negotiated prices. By 1985, the sales quota system for aquatic products was completely abolished, and prices were regulated by the market (Guan and Chen 1989). Econometric analysis for aquatic products based on market theory is possible, therefore, only after 1978.

An understanding of the demand for aquatic products, working of markets and fish production is necessary for planning fishery strategies. The level of profitability in fisheries is affected by the interactions of demand and supply, and the level of demand will determine the extent to which it is worthwhile to increase supplies through extra investment. Patterns of production define those product forms and markets which may potentially develop. This paper examines the market demand for Chinese aquatic products using econometric methods, investigates the production potentials of both capture fisheries and aquaculture, and concludes with some tentative predictions for the future.

Demand Analysis

The Data Used

The study focused on the analysis of total demand for aquatic products and not for a single species of fish, as demand analysis by species is tedious and almost impossible. This is not only because a huge amount of data is required, but also because aquatic products are close substitutes for each other and interspecies interactions between price and demand are obvious and strong, which makes the estimation of demand for an individual species problematic. In estimating salmon demand functions, Bird (1986) found that relationships estimated at the aggregate level could be more reliable because of deficiencies in the data for individual species.

Another difficulty in demand analysis at aggregate levels is the definition of price. Statistical data for both landings and prices are not available throughout the country; however, some detailed data are available for provinces or cities where fishery is an essential part of the local economy. But prices of all species of fish could not be obtained. One way to circumvent this obstacle is to get an estimate of the price from the data of total gross revenue and production.

Zhoushan City, with over 600 islands, is the most important city from a fisheries point of view (Zhao 1986). Prices for general aquatic products were derived from total production and gross revenue since 1978 (Table 1). They are believed to be good representations of market prices for the whole country (Bird 1986).

Fish consumption depends on the price of fish, income of people and prices of other foods. Since the economic reforms, the annual increase in gross national product (GNP) has been 5-15%. The distribution system is becoming more decentralized. Fish consumption is closely related with real earnings. The decentralized distribution relates with workers' earnings, hence national income should represent changes in real earnings and buying power in fish markets. Hence per capita national income is used as an index of people's earnings in this study.

Specification

The estimation of consumer demand from time series is fraught with difficulties. The first is identification - is it possible to isolate the demand schedule using only quantity consumed and price? The data points in a time series of price and quantity represent the intersection of supply and demand curves. Supply and demand must not depend on exactly the same parameters if one curve is to be identified (Walters 1970).

The landed quantity of fish indicates the amount of production, as well as the amount sold or consumed. Such data give little information about consumer demand because most aquatic products cannot be stockpiled like other goods. Even if cold storage can store some fish, the amount would be small compared to the total landings. In China, the total capacity of cold storage is 503,000 tons in one freezing (Guan and Chen 1989). From the pattern of increase in both price and per capita consumption since 1978 (Table 2), it could be inferred that demand is not fully met and the landings are more likely to represent supplies. In the estimation of the demand function for fish, this problem is usually avoided by using price-dependent demand models (Bell 1968; Devoretz 1980, 1982; Bird 1986). This implies that markets adjust price to exogenously determined supply and the supply function is free of price. Actually, price and landed quantity affect each other. Although in open-access capture fisheries there are few attempts by fishers to influence landing prices by deliberate variation in quantity landed, changes in fish prices do affect investment in fisheries and alter future fish landings.

The demand function used in this study is the most commonly used constant-elasticity function. Its logarithmic form becomes linear, making it attractable to least square analysis, and allows elasticities to be read off directly. The demand for aquatic products is supposed to be a function of price and income:

$$Q_t^d = aP_t^{\alpha} I_t^{\beta}, \qquad \text{...1)}$$

where Q_t^d : quantity demanded at year t
P_t : price at year t
I_t : per capita national income at year t
a, α, β : constants.

Due to the particular characteristics of fish products, the landed quantity represents the amount provided rather than demanded. Real quantities of market demand could not be obtained. It is assumed here that the supply in g years, S_{t+g}, is a proxy of the demand, Q_t (Ye 1994). So, the demand function to be fitted is in fact:

$$\ln S_t = a+\alpha lnP_{t-g} + \beta lnI_{t-g} \quad ...2)$$

The demand analysis in this study starts with a specific model led by the researchers' prior expectations. If enough data and time series are available, the Hendry technique (Hendry 1979) could be used. However, in this study, few data series are available, and the time series is for 14 years only. Such a set of data is not suitable to build a valid general model. For example, if time lags of first to third orders are considered in a general model, degrees of freedom will become too small and make the regression results unreliable (Bird 1986). Although the model is specific in this study, time lags are determined by statistical analysis.

Table 1. The price of general aquatic products.

Year	Revenue (10^6 Yuan)	Production (10^3 tons)	Price (Yuan·ton^{-1})	Consumer price index
1978	153.40	23.97	639.97	75.00
1979	192.84	31.09	620.29	79.00
1980	220.34	34.69	635.18	81.63
1981	244.19	33.19	735.75	83.67
1982	190.13	32.57	583.67	85.39
1983	234.44	28.68	817.44	87.02
1984	321.89	33.97	947.61	89.39
1985	427.17	37.00	1154.51	100.00
1986	494.00	40.14	1230.61	107.02
1987	743.46	41.56	1788.75	116.41
1988	698.24	42.27	1651.97	140.69
1989	612.63	40.53	1511.66	163.43
1990	712.51	41.87	1701.60	176.31
1991	765.23	44.24	1729.62	190.81

Sources: Fisheries statistic yearbook of Zhejiang of 1978-91, International Financial Statistics Yearbook of 1990, International Monetary Fund.

Demand Function

Independent variables used in the model are price and per capita national income, which are expressed as real values, removing general price trends from the data by dividing with the consumer price index. The dependent variable is annual per capita consumption. Variables are logged so that their coefficients represent rates of change. They are termed elasticities of demand, and show proportional changes in the value of the variable.

The demand model has a form as follows

$$lnQ_t^d = a+\alpha\, lnP_{t-3} + \beta\, lnI_{t-3} \quad ...3)$$

Data used in the estimation of demand function are shown in Table 2. Due to unavailability of real quantities of market demand, production is used instead

Table 2. Data used in the estimation of the demand function.

Year	Q (kg·person^{-1})	P (Yuan·ton^{-1})	I (Yuan·person^{-1})	Consumer price index
1978	4.52	639.97	412.47	75.0
1979	4.12	620.29	430.51	79.0
1980	4.25	635.18	453.56	81.6
1981	4.34	735.75	466.98	83.7
1982	4.83	583.67	488.93	85.4
1983	5.05	817.44	526.24	87.0
1984	5.67	947.61	604.38	89.4
1985	6.40	1,154.51	663.61	100.0
1986	7.45	1,230.62	686.12	107.0
1987	8.46	1,788.75	734.86	116.4
1988	9.27	1,651.97	757.63	140.5
1989	10.23	1,511.66	721.13	163.4
1990	10.81	1,701.61	761.71	176.3
1991	11.50	1,729.60	840.32	190.8

Sources: Guan and Chen (1989), Zhang and Wu (1992), Chen and Wei (1993) and Zhang (1993) and International Financial Statistics Yearbook of 1990, International Monetary Fund.

(equation 2). The time lag between demand and production could be justified partially by the continuous increase in production (Tables 4 and 6), but the number of 3 years (g in equation 2) for both price and income are found by the statistical criteria, mainly the t-statistic and the Durbin-Watson value.

This model produces a significant fit to the data (Table 3, Fig. 1), giving an income elasticity of 1.93. Its t value is highly significant, and the null hypothesis of no income effect could be rejected at very high probability. This suggests that fish consumption is sensitive to increases in income. In general, in low-income developing countries, the responsiveness of demand for food is high since a high proportion of total income is spent for food (Smith 1987). The strong effect of income could also be attributed to the low per-capita consumption of 9.27 kg per annum in 1988 (Table 2). The major function of income in driving the demand for fish suggests that demand will expand further with economic development in China.

Table 3. The specific model of fish demand for China.

Regressor	Coefficient	S.E.	T-value
Intercept	-8.66		
P	-0.23	0.123	-1.86
I	1.93	0.223	8.66
R^2	0.985	F-statistics	358
S.E.	0.048	DW-value	1.95

Price elasticity is estimated to be -0.23. This value is in the normal negative range, as expected. The ratio of the estimated coefficient to its standard error is -1.86. The null hypothesis of no-price effect, against the one-side

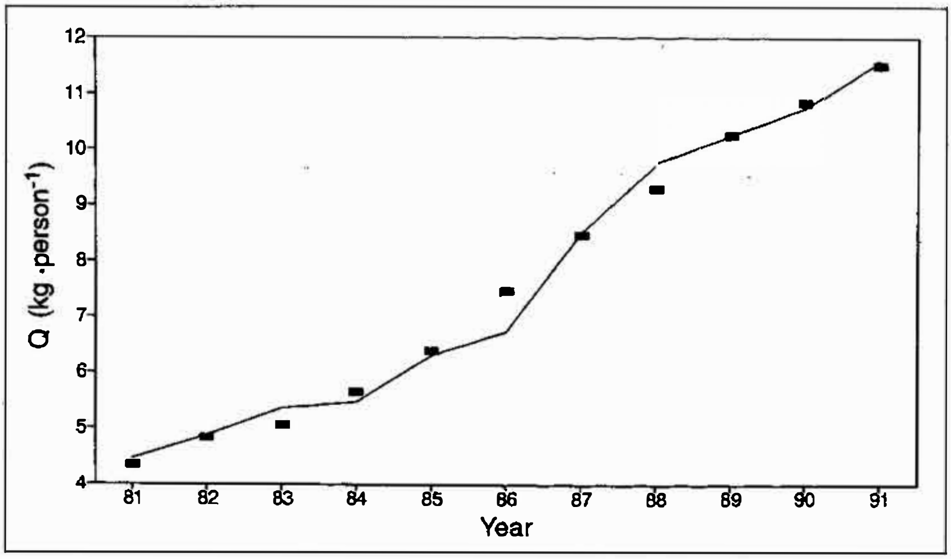

Fig. 1. The fit of the demand function for aquatic products. ■ data, - fit.

alternative hypothesis or a positive-price effect, would be rejected at the 10% level. The rejection of the null hypothesis tends to support the negative-price effect. The Durbin-Watson statistic for all variables is 1.95, consistent with no serial correlation in the regression residuals. The inelastic demand for fish may be related to low per-capita consumption.

From equation 3 and its fit (Table 3), it can be seen that the responsiveness of demand to income is much stronger than price. The high income elasticity suggests that fish is a superior commodity. With increase in income, people will spend more money on aquatic products. The low elasticity of demand to price hints at consumers' partiality for fish. These two features will lead to increased demand for fish in the near future.

Production Analysis for Fisheries

Fisheries consists of several different sectors: marine and freshwater capture fisheries, inland fisheries and mariculture. Each displays particular characteristics. For estimation of production, they are grouped into capture fishery and aquaculture.

Production Function for Aquaculture

China has a coastline of $1.8 \cdot 10^4$ km, and the area of the cultivable shallow seas and mud flats within the 10 m isobath is $1.33 \cdot 10^4$ km^2. However, the utilization rate prior to 1980 was only 9%. Kelp, laver and mussel were the major commodities, accounting for 98% of mariculture production. Aquaculture of marine fish, shrimp and others has been on the increase since 1980. Production increased from $45.0 \cdot 10^4$ tons in 1978 to $142.5 \cdot 10^4$ tons in 1988. Relative production of cultured fish, shrimp and other delicacies increased from 0.5% in

1978 to 27% in 1988. The total cultured area of mariculture increased from 1,500 km^2 in 1978 to 4,133 km^2 in 1988, a 2.8-fold expansion.

Inland aquaculture displayed a similar expanding trend. Freshwater fish culture production, which was $76.0 \cdot 10^4$ tons in 1978 with a culture area of $2.738 \cdot 10^4$ km^2, increased to $398.7 \cdot 10^4$ tons in 1988 with a culture area of $3.895 \cdot 10^4$ km^2, an increase of 425 and 42%, respectively. The major production of inland aquaculture is from ponds, which accounted for 77% of production over the last decade.

Aquaculture is developing rapidly and becoming increasingly important in China. In 1978 it constituted only 26% to total fish production, but caught up with capture fishery production by 1988 (Fig. 2). Production from aquaculture is expected to increase at a rapid pace. Knowledge of the relationship between inputs and outputs will allow prediction of the future demand for inputs.

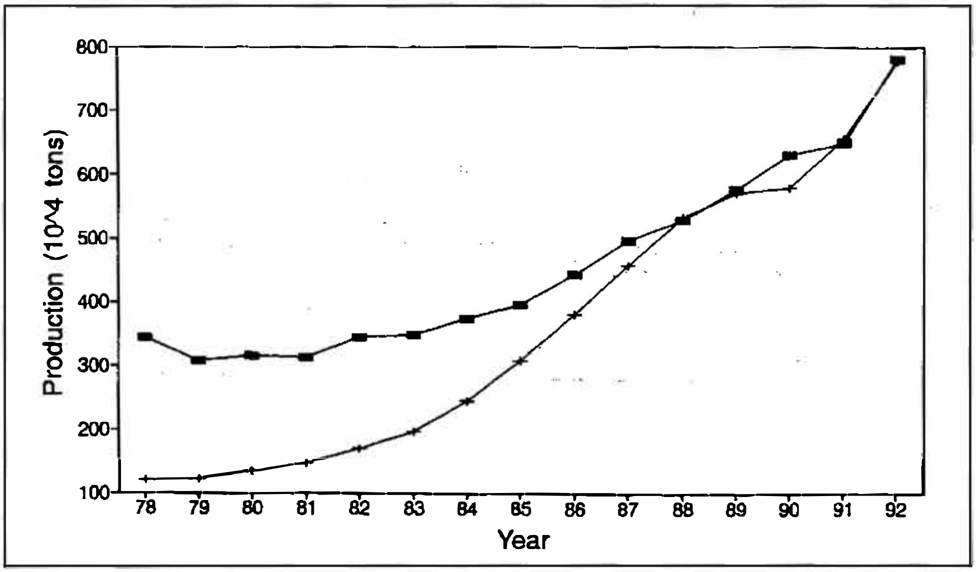

Fig. 2. Production history of the capture fishery and aquaculture. ■ capture fishery, + aquaculture.

A Cobb-Douglas type of function (Frankel 1962) is used

$$ln Q_t^c = a + \alpha \; ln A_t + \beta \; ln L_t + \gamma T_t, \qquad \text{...4)}$$

where Q^c : quantity of aquaculture production
A : area cultured
L : number of laborers involved in aquaculture
T : technical factor
a, α, β, γ : constants
t : year.

The technical factor is defined as production per unit area per laborer. Although technique is improving with time, productivity of waters that are not utilized would be lower than that of currently used waters. As aquaculture expands rapidly, both technique and quality of culture waters should be taken into account as a general technical factor.

Table 4. Data used for the estimation of aquaculture production function.

Year	Production (10^4 tons)	Area (10^4 km^2)	No. of laborers (10^4)	T (10^{-5})
1978	121.2	2.7757	133.7	3.27
1979	122.9	2.8556	155.3	2.77
1980	134.5	2.9992	190.0	2.36
1981	147.2	3.0203	220.2	2.21
1982	170.2	3.2148	265.1	2.00
1983	197.3	3.2709	305.6	1.97
1984	245.0	3.5039	380.4	1.84
1985	309.1	3.9226	463.9	1.70
1986	380.9	4.1152	588.1	1.57
1987	458.4	4.2307	661.4	1.64
1988	532.2	4.3104	712.7	1.73
1989	571.2	4.3108	745.1	1.73
1990	590.1	4.3362	847.0	1.57
1991	655.5	4.3168	879.4	1.73

Sources: Guan and Chen (1989), Zhang and Wu (1992), Chen and Wei (1993) and Zhang (1993).

Table 5. The production model of fish for aquaculture.

Regressor	Coefficient	S.E.	T-value
Intercept	-8.38		
A	0.615	0.226	3.23
L	1.050	0.067	19.54
T	38627.9	1967.8	19.63
R^2	0.999	F-statistics	2,475
S.E.	0.016	DW-value	1.93

The data used in estimating production function is shown in Table 4. This model fits the data well (Table 5, Fig. 3). The coefficient for labor is 1.05, and 0.57 for the cultured area. The former means that a constant return to scale applies, and the latter indicates that marginal production will decrease as the cultured area increases because of the limitation of other resources.

Production Function for the Capture Fishery

Production from marine fisheries also showed an increasing trend over the last decade, from 2.75 million tons in 1979 to 4.63 million tons in 1988. An increase of 167.3% in fishing effort resulted in a 68% increase in

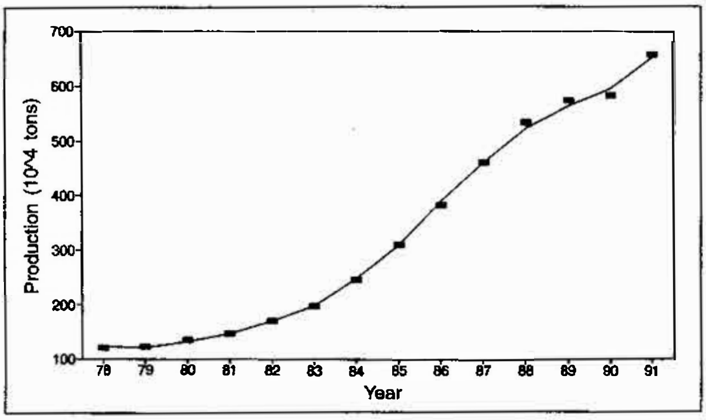

Fig. 3. The fit of the production model for aquaculture. ■ data, - fit.

fish production. The composition of marine catches has changed substantially. The production of pelagic fish and crustaceans has increased significantly, while landings of traditional marine fish such as hairtail, large yellow croaker, small yellow croaker and cuttle fish decreased.

Inland fishing has a different history. Its production peak, about 0.7 million tons, occurred in 1960. Measures to increase production through improved fisheries management, control of fishing intensity and establishment of closed seasons in open waters, has somewhat restored production to the 1950's level of 0.66 million tons. Production in 1988 reached 0.65 million tons, about 100% increase compared with 1978.

The ever increasing prices and demand for fish resulted in a rapid expansion of fishing effort. Does this raise the total catch? Although the history of the last decade showed that it did, the increase in catch did not have the same pace as effort. The collapse of four major traditional marine species of high economic value illustrated serious overfishing. While the urgent need to protect inshore fish resources has long been recognized, the problem of overfishing has worsened because of unregulated access to most species, constraints in implementation of management measures, and market pressure. Given the increasing demand for aquatic products, the estimation of future potential production may ensure correct long term decisions for management of natural fisheries and investment.

Capture fisheries differ from aquaculture. Production depends not only on investment, but also on abundance of fish resources. With the development of fishing, fishable stocks will decline. An excess in fishing effort will reduce catches in the longer term. Surplus production of fish stocks is a function of current biomass, which is determined by the developmental level of exploitation. If population dynamics follows Schaefer's model, such surplus production of all species as a whole could be described by a quadratic equation of single input, fishing effort as follows (Gulland 1983; Panayatou 1985).

$$Qf = aE_t - bE_t^2 \qquad ...5)$$

Table 6. Data used to estimate production function for capture fisheries.

Year	Catch (10^4 tons)	Effort (10^4 HP)
1979	307.4	312.9
1980	315.1	351.5
1981	313.3	382.8
1982	345.3	420.0
1983	348.6	454.4
1984	374.4	490.4
1985	396.0	551.5
1986	442.6	628.3
1987	496.8	726.2
1988	528.7	836.6
1989	577.1	916.6
1990	650.1	997.3
1991	649.3	1,087.3
1992	781.2	1,205.9

Sources: Guan and Chen (1989), Zhang and Wu (1992), Chen and Wei (1993) and Zhang (1993).

Table 7. The Schaefer-type production model for capture fisheries.

Parameter	Value	S.E.	T-value
a	0.868	0.043	19.97
b	$-2.23 \cdot 10^{-4}$	$4.67 \cdot 10^{-5}$	-4.78
R^2	0.96		
S.E.	33.13		

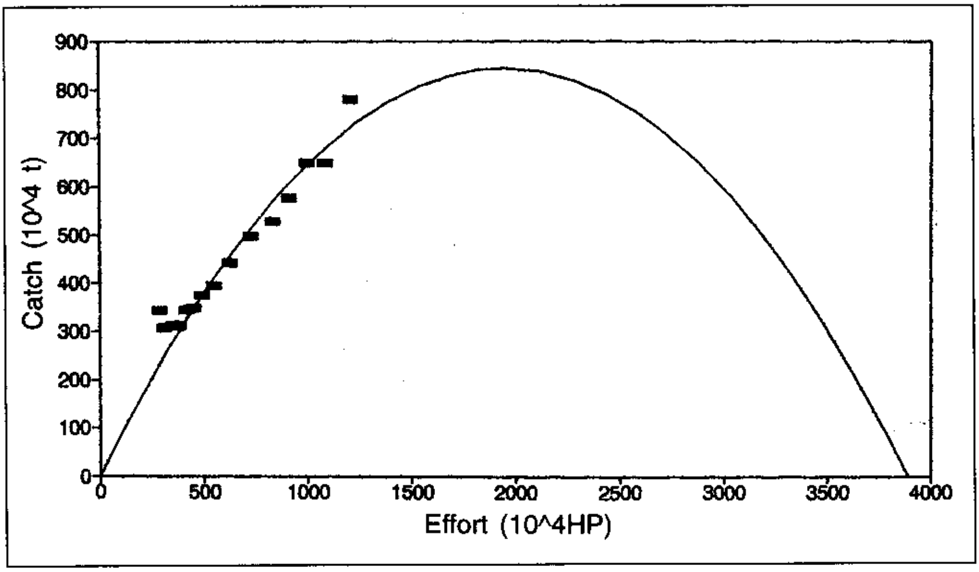

Fig. 4. The fit of the relationship between catch and fishing effort. ■ data, - fit.

where Q is production; E is fishing effort and is a composite input that can be broken down into its components: capital, labor, material and time spent on fishing; a and b are constants.

The data set used in this estimation is listed in Table 6. Equation 5 gives good fit to this set of time series data (Table 7, Fig. 4). R^2 is highly significant. Maximum production is 8.4 million tons and its corresponding fishing effort is 19.5 million HP. Production will decrease with over-investment in fishing. It is a top task for management of the capture fishery to control fishing effort at the level of maximum production.

Forecasts of Demand and Production by 2000

Predicting into the future with the econometric theory, which provides a systematic explanation of the past, is central to government decisionmaking. Total landings of fish in China over the last decade have been increasing. Although the total catch from capture fisheries has increased, catch per unit effort has been declining. Will demand for fish keep increasing, and what level will it attain by the end of this century? What is the market equilibrium of demand and supply? To answer these questions, forecasts of demand and production by year 2000 were made based on projections of exogenous variables which were used in previous demand and production functions.

Forecast of Demand for Fish by the Year 2000

Demand function (equation 3) consists of two variables, price and national income per person. The real price for aquatic products and per capita national income must be projected to forecast the future demand for fish. A simple projection model over time for real price could be used here

$$p = 336.47 + 105.12t$$

t-statistic 9.11

$R^2=0.87$ $\quad S.E.=174.1$

where p : price for aquatic products
t : year, with $t=1$ in 1978.

Fig. 5 shows the fit of the real price model to data. Some positive serial correlation appears. Although least squares slope estimates will be correct and unbiased, the least squares regression line fits the observed data points more closely than the true regression line and leads to an R^2 that gives an overly optimistic picture. More important, however, least squares will lead to an estimate of the error variance which is smaller than the true error variance. Serial correlation can be corrected by some methods, but both solutions to the serial correlation problem and the tests themselves have certain shortcomings. There are cases, for example, when the use of alternative procedures to deal with the serial correlation problem introduces inefficiencies which are greater than the inefficiency associated with serial correlation (Pindyck and Rubinfeld 1986).

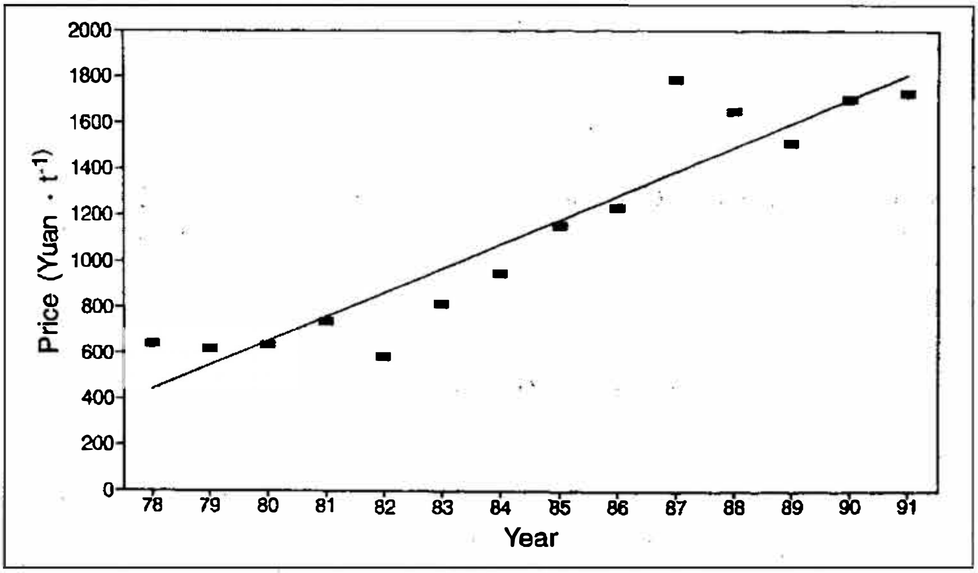

Fig. 5. The fit of the projection model for the real price of fish. ■ data, - fit.

A simple linear trend model is used here because of lack of data. It is also highly possible that serial correlation is caused by the high degree of correlation over time present in the cumulative effects of omitted variables in the regression model. So no further efforts were made to correct the serial correlation problem with this model.

The national income per person is projected by the following model

$I = 356.46 + 33.89t$
t-statistic 16.78
R^2=0.87 *S.E.*=30.95

where I : per capita national income
t : year, with t=1 in 1978.

The projection of national income per person is close to the increase rate, about 5% by the end of the century forecasted by the World Bank based on the long-term economic plan of the Chinese government (World Bank 1985). Based on these two projections of real price and income, the demand for aquatic products by the year 2000 is predicted at 19.3 kg per capita per annum, as against annual per capita consumption of 11.5 kg during 1991.

The demand function (equation 3) expresses demand as per capita consumption. To estimate the total amount of demand for aquatic products, a projection for population has been made using the model:

$pop = 946.73 + 15.25t$
t-statistic 21.1
R^2=0.97 *S.E.*=10.88

where *pop* : population size in millions
t : year, with t=1 in 1978.

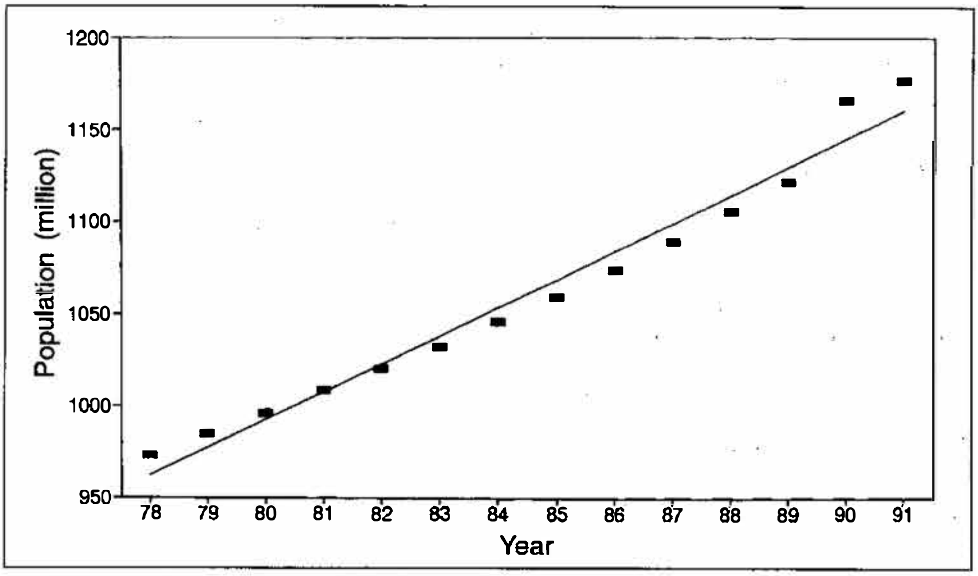

Fig. 6. The fit of the projection model for the population of China. ■ data, - fit.

The fit of this projection model to data is shown in Fig. 6. Substituting these three projections into the demand function puts the total fish demanded by year 2000 at 25.04 million tons, which is higher than 18 million tons, targeted by the government of China (Anon. 1992). The study points out that even if the planned production is achieved, China will still face an excess of demand over supply. To meet the demand, an average annual growth rate of 7.1% by the year 2000 must be achieved. This growth rate is quite high, but lower than the mean growth rate of 9.96% during the last 14 years.

Production of the Capture Fishery

Production of capture fisheries depends mainly on reproductivity of fish resources. When the dynamics of populations are known, production is a function of fishing effort (equation 5). In practice, it has been found that the fit of the observed catch and effort data is often better in terms of the combined total of all species, than it is in terms of species taken individually (Gulland 1983).

Although fishing effort has increased during the last decade, catch per unit effort is on a steady decline. With further development of fishing, production of capture fisheries may decrease rather than increase. Equation 5 gives an estimate of maximum production at 8.4 million tons. Xia (1982) estimates maximum production from the capture fishery at about 8 million tons on the basis of primary production. To obtain maximum sustainable production, a fishing effort of 19.5 million HP is required. Overdevelopment would reduce production. During 1979-92, average annual increase in effort was about 10%. If this trend continues, the effort corresponding to maximum production will be reached in 5 years. Production would decrease with increase in fishing effort. Definitely, stringent control over fishing effort is needed to maximize production. Suppose regulations and laws are put into practice to tune the exploitation of fish resources to a reasonable level, at best the supply from the capture fishery would be 8.4 million tons.

Aquaculture Required

The estimated maximum production of 8.4 million tons from the capture fishery can meet only 33.5% of the estimated demand by the year 2000. The remaining 66.5% which amounts to 16.64 million tons has to be covered by aquaculture if market demand is to be met, which is 2.5 times the production in 1991.

The production equation for aquaculture provides the possibility to assess the investment required, but first the forecasts of the three exogenous variables in the production function (equation 4) must be made. The technical factor has remained at about $1.73 \cdot 10^{-5}$ for the last 4 years (Table 4). It is assumed here that T will remain at this level before the year 2000. The ratio of labor to culture area is extrapolated by the following equation:

$$L/A = 24.95 + 12.7t$$
t-statistic 33.20
$R^2 = 0.99$ $S.E. = 5.77$

where L/A stands for ratio of labor to culture area; t is year with t=1 in 1978. The fit of this projection model to data is shown in Fig. 7. With this model, it is easy to estimate ratio and then production for the year 2000. To produce 16.64 million tons of aquatic products, 22.7 million laborers and $7.2 \cdot 10^4$ km^2 of culture area will be needed. Compared with 1991, the labor force must increase by 159%, and culture area by 66%.

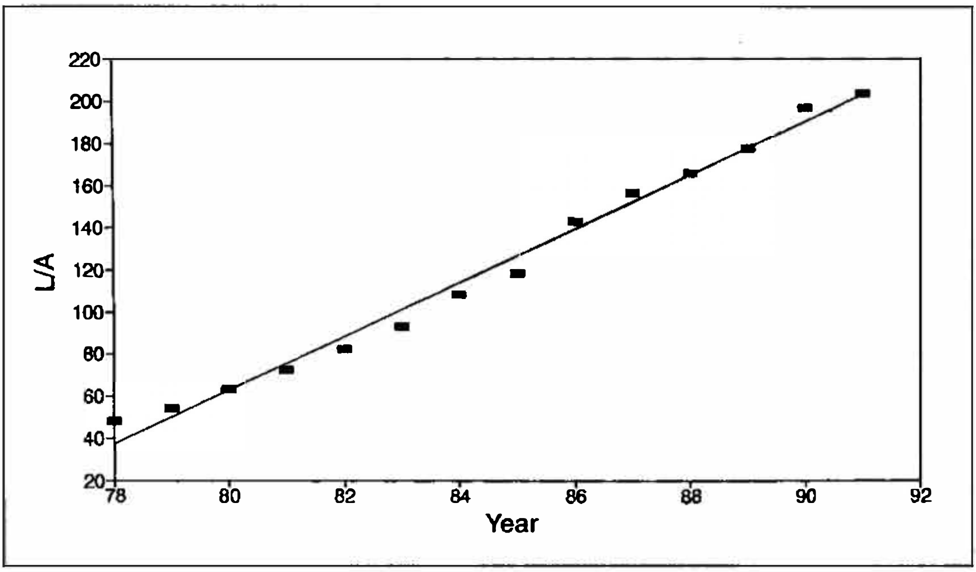

Fig. 7. The fit of the projection model for the ratio of labor to culture area. ■ data, - fit.

To achieve this production, the key factor is water for culture, as labor may migrate from agriculture. There are $8 \cdot 10^4$ km^2 of water area. The present area under culture is only a little over $2 \cdot 10^4$ km^2; calculating the area within the 10-m isobath, there are about $1.33 \cdot 10^4$ km^2 of shallow seas and mudflats, of which only 4,133 km^2 have been utilized (31%); there are about $3 \cdot 10^4$ km^2 of lowlands and saline-alkali wastelands available for cultivation, where fish production bases could be constructed (Guan and Chen 1989). It is unreasonable to expect that the waters that have not been utilized so far can produce the same yield as the currently cultured waters (Cunningham et al. 1985). A breakthrough in aquaculture techniques may be essential if aquaculture is to develop further.

Another potential for increasing production comes from improving production efficiency. Inland pond production is a major part of aquaculture, accounting for 77%. The average yield per square kilometer was 207 tons in 1988. This contrasts with a yield of 756 tons per km^2 in Shunde county, Guangdong province with 173.3 km^2 of ponds. By the turn of the century, the average production may be expected to attain 375 tons per km^2 (Guan and Chen 1989)

Conclusions

The demand analysis gives the income elasticity of 1.93. This suggests that fish consumption is sensitive to increases in income. The strong effect of income on demand for aquatic products could be attributed to the high proportion of total income committed to food and the low level of per capita consumption of fish. The major function of income in driving the market demand for fish suggests that demand will expand further with economic development in China.

Production for aquaculture is expressed as a function of culture area, labor force and technical factor. Decreasing return to scale applies to the culture area, but a constant return is found for labor. Production from capture fisheries is a function of a single variable, fishing effort. This function illustrates the principle that excess in fishing effort will reduce the production of natural fisheries. Effective regulations must be implemented to tune exploitation to a level that will maximize production.

The demand for aquatic products will reach 25.04 million tons by the end of this century. The maximum supply from the capture fishery is only 8.4 million tons. In order not to depress market demand with high prices, aquaculture has to supply 16.64 million tons of fish by the end of this century. This will require 22.7 million laborers and $7.2 \cdot 10^4$ km^2 of culture area. China has the potential natural resources to meet this requirement, but technical development seems critical.

The highly income-led fish demand suggests that market demand will increase continually with economic development. However, production potential from capture fisheries is limited. Although there may be some potential to develop new fisheries, the main opportunities for increasing fishery yields are through "fine tuning" regulations on stocks that are fully exploited, and through rehabilitation programs for stocks that have been overexploited. Aquaculture has to develop substantially and play a dominant role in order to preclude demand depressions due to price, and to supply markets with sufficient aquatic products. The emphasis of future fishery managment policies should be on preventing overfishing of capture fisheries and stimulating the development of aquaculture.

The forecasting exercises carried out in this study are based on models fitted from past data. If any significant structural changes occur and thus alter the future movement of the time series, then the model must be revised in order to make sensible forecasts. An important target of further research in this area is to improve the availability of data and update the models when new data become available.

Acknowledgments

The author thanks Prof. John Beddington, Imperial College, UK, for his valuable guidance and support during production of my Ph.D. thesis on which this paper is based. I am also indebted to Mr. Vardis Maximilianos Tsontos and Dr. Graeme Parkes for useful discussions, and two anonymous referees for their valuable comments. Financial support from the Marine Education and Conservation Trust, and the ORS award of the Committee of Vice-Chancellors and Principals of the Universities of the UK are gratefully acknowledged.

References

Anon. 1989. Almanac of China's prices Editorial Committee, China Commerce Publishing House, Beijing. 351 pp.

Anon. 1992. China became the largest fisheries country in the world. People's Daily (overseas edition) No. 2583. 8 pp.

Bell, F.R. 1986. The pope and the price of fish. The American Economic Review 58: 1346-1350.

Bird, P.J.W.N. 1986. Econometric estimation of world salmon demand. Marine Resource Economics 3 (2): 169-182.

Chen, Y. and G. Wei. 1993. Analysis of 1992's Chinese fishery statistics. China Fishery Economics Research 4: 23-25.

Cunningham, S., M.R. Dunn and D. Whitmarsh. 1985. Fisheries economics: an introduction. Mansell Publishing Ltd., London. 372 pp.

Devoretz, D. 1980. The demand for salmon in the United States. Discussion Paper 80-03-2. Simon Fraser University, Burnaby, British Columbia. 23 pp.

Devoretz, D. 1982. An econometric demand model for Canadian salmon. Canadian Journal of Agricultural Economics 30: 49-60.

FAO. 1988. Yearbook of fishery statistics: commodities. Vol. 67. Food and Agriculture Organization, Rome. 397 pp.

Frankel, M. 1962. The production function in allocation and growth: a synthesis. The American Economic Review 52 (5): 995-1022.

Guan, R. and Y. Chen. 1989. Reform and development of the fisheries of China. FAO Fisheries Circular 822. 33 pp.

Gulland, J.A. 1983. Fish stock assessment: A manual of basic methods. Wiley Interscience, New York. 223 pp.

Hendry, D.F. 1979. Predictive failure and econometric modelling in microeconomics: the transactions demand for money. In: Economic modelling (ed. P. Heinemann). Macmillan Press, London. 373 pp.

Panayatou, T. 1985. Small-scale fisheries in Asia: Socioeconomic analysis and policy. International Development Research Centre, Ottawa. 283 pp.

Pindyck, R.S. and D.L. Rubinfeld. 1986. Econometric models and economic forecasts. McGraw-Hill, Singapore. 596 pp.

Smith, P. 1987. Future demand for fish in Southeast Asia. Symposium on the Exploitation and Management of Marine Fishery Resources in Southeast Asia, Darwin: 28-42.

Walters, A.A. 1970. An introduction to econometrics (2nd ed). Macmillon, London. 437 pp.

World Bank. 1985. China: long term development issues and problems. The World Bank, New York. 48 pp.

Xia, S. 1982. On ways to build the optimal eco-economic system of marine fisheries in China. Proceedings of the China Society of Ecology 1983: 179-192.

Ye, Y. 1994. Bioeconomic analysis of the harvesting of fishery resources. University of London. 296 pp. Ph.D. thesis.

Zhang, H. 1993. A study on the developmental law of fish production in China. Modern Fisheries Information 8 (12): 1-5.

Zhang, G. and W. Wu. 1992. The current and future situations of the supply of marine fish products in China. Chinese Fishery Economics Research 4: 11-17.

Zhao, Q. 1986. Report on the investigation of fishery resources in the East China Sea. In: Investigation and division of fish resources in the East China Sea (ed. Fisheries Bureau, Agricultural Ministry of China). Teachers University of East China Press, Shanghai: 206-602.

Manuscript received 10 May 1994; accepted 4 March 1996.