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Disaggregated projections on fish supply, demand and trade for developing Asia[1]

Madan M. Dey[2], U-Primo Rodriguez, Roehlano M. Briones and Chen Oai Li,

with Muhammad Sirajul Haque, Luping Li, Praduman Kumar, Sonny Koeshendrajana, Tai Shzee Yew, Athula Senaratne, Ayut Nissapa and Nguyen Tri Khiem

Introduction

Quantitative modelling of supply, demand, and trade for fish becomes very useful for evaluating development strategies and options if done for disaggregated fish types, production categories, and regions. With detailed analysis, one can identify priorities in terms of technologies for dissemination, research problems to address, regions on which to focus investments, and fish groups that contribute most to food security of the poor. Recently, a quantitative tool called the AsiaFish model (Dey et al. 2005a) has been developed for this purpose. This model is currently being applied to nine major fish-producing countries in Asia, namely Bangladesh, China, India, Indonesia, Malaysia, Philippines, Sri Lanka, Thailand and Vietnam.

Generating an outlook for fish in these countries is useful for at least three reasons. First, these countries account for a significant proportion of global production and consumption, contributing over 51% of output while absorbing 40% of consumption (FAO 2003; Delgado et al. 2003). Second, the growth performance of the fisheries sectors in these countries has been impressive: between 1991 and 2001, production in these countries growing at an average annual rate of 7.8%, more than twice the growth rate of world fish production. Fish consumption in these countries has also been rising rapidly; for example, the growth rates of consumption in China for 1985–1997 is 11.8%—over triple the global average of 3.3%. Third, fish is an important source of animal protein for these countries, with the share of fish in total spending on animal protein exceeding 70% for countries such as Thailand, China and Bangladesh (Dey et al. 2005b).

As argued in Dey et al. (2005a), existing food-sector models are ill-suited for the task of making fish-sector projections for these countries. With few exceptions, these models typically gloss over the heterogeneity of fish types, the presence of alternative production sources (i.e. capture versus culture), and the diversity of consumption demand across income groups or regions. The AsiaFish model addresses all these difficulties, as well as assorted data problems such as jointness of production and the mismatch of fish-type definitions in country-level data on production and consumption. This paper presents in summary form the method of, and results from, applying the AsiaFish model to the selected countries.

Modelling the fish sector in the selected countries

The AsiaFish model

The AsiaFish model is a multi-market equilibrium model for evaluating the effects of technology and policy changes on the prices, demand, supply and trade of various fish types. It is divided into producer, consumer and trade cores. The consumer and producer cores are

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[2] Corresponding author: Regional Director, The WorldFish Center; email: <m.dey@cgiar.org>.

essentially two sets of demand and supply equations. The producer core distinguishes between fresh and processed fish, with the assumption that a fixed ratio of fresh-fish output is allocated to processed fish. The supply of fresh fish is also distinguished by domestic production source.

The consumer core of the model describes the behaviour of households, which can be disaggregated by region and/or income class. The demand functions are derived from a three-stage budgeting framework. The first stage divides consumption expenditure into food and non-food spending. The second stage determines the representative household's demand for fish as a whole. The final stage captures the demands for different types of fish, using the quadratic form of the 'almost ideal demand system' (AIDS).

The trade core of the model is composed of a series of export supply and import demand equations.[3] In the tradition of applied general equilibrium (AGE) models, domestic and foreign goods are treated as differentiated products, which is the Armington assumption. One advantage of this formulation is that it allows a fish type to be exported and imported at the same time ('cross-hauling' in the trade data). The aggregation follows a functional form characterised by constant elasticity of transformation (in the case of exports) or constant elasticity of substitution (in the case of imports). Model closure is attained at simultaneous equilibrium among the three cores. The closure condition is, however, considerably complicated by the presence of mismatched fish-type definitions in the production and consumption data. To complete the matching, the model identifies demand or supply *composites*; that is, a demand (supply) composite is one that is matched to several fish types on the supply (demand) side. The model then disaggregates the demand (supply) composite based on a constant elasticity function (in imitation of the Armington technique).

Disaggregation approach and data of the country models

On the demand side, most of the countries decided to disaggregate between rural and urban regions except India (no disaggregation) and Sri Lanka (disaggregated into rural, urban and estate regions.) The three-stage budgeting framework was generally followed by all the countries. As a whole, 27 'fish types' can be identified from the various models for the demand side. Table 1 shows the number of fish types incorporated in stage 3. The number of fish types ranges from five in China to 15 in Indonesia. Of these fish types, the most common are 'shrimp and prawns' and 'tilapia', which are explicitly modelled in eight and seven countries, respectively. The classification of disaggregation also incorporated by price (low and high value), size (small and large), source (capture and culture) and species groups (e.g. cephalopods, molluscs).

For the production side, the model distinguishes supply based on production source. The simplest is a distinction between capture and culture (as in India); source distinction can also be quite detailed, as in Indonesia (which has inland and marine capture, as well as inland, marine and brackish-water culture). Supply disaggregation by fish type usually follows the classification on the demand side. For five countries, the number of fish types in the supply side exceeds those on the demand side, mainly because the distinction by production source is also a distinction by supply fish type; the distinction, however, is not made on the demand side, hence the demand counterpart is a composite fish type. Among the countries, Thailand has the largest number of demand composites.

The country models require data on demand, supply, trade and prices for each fish type, as well as additional information for such variables as income, prices of non-fish food types, etc.

3 The need for explicit export-demand and import-supply equations is eliminated by the assumption that each country is a small open economy.

In order to ensure a consistent dataset, it was necessary organise the information for each fish type into a *balance sheet*. Each balance sheet assumes that the total supply of each fish type (S) is equal to imports (M) and the sum of outputs from capture fisheries (Q_{CF}) and aquaculture (Q_A). On the other side, total demand (D) is the sum of exports (X), intermediate demand (ID), rural household demand (HD_R) and urban household demand (HD_U). Finally, it must be the case that $S = D$ *or* $M + Q_{CF} + Q_A = X + ID + HD_R + HD_U$. Table 2 presents the aggregate balance sheets in summary form for each country.

Table 1. Demand fish types and composites of selected countries

Country	Number of fish types	Composites	Elements
Bangladesh	10	Indian major carp	Capture, culture
China	5	Other finfish Other fish Shrimp	Capture, culture Capture, culture Capture, culture
India	8	None	
Indonesia	15	None	
Malaysia	8	Crustaceans	High value (shrimp), low value
Philippines	9	Shells Other fish	Mussels and oysters, other shells Grouper, tuna, carp, catfish, other capture, other aquaculture
Sri Lanka	7	None	
Thailand	12	Shrimp Other high value Other low value	Capture, culture Freshwater, marine Freshwater, marine
Vietnam	9	None	

Table 2. Aggregate balance sheets for fish supply and demand for the selected countries

Country, year	Bangladesh 2002	China 2001	India 2000	Indonesia 2000	Malaysia 2000	Philippines 2000	Sri Lanka 2002	Thailand 2000	Vietnam 2000
Quantity ('000 t)									
Output	1,951.5	26,564.7	5,481.6	5,567.8	1,435.5	2,633.2	265.4	3,250.2	2,370.0
Imports	–	1,899.8	70.7	40.3	313.4	154.3	71.1	103.6	–
Exports	40.9	2,390.7	307.9	587.5	132.2	131.6	12.9	755.2	574.0
Consumption	1,727.6	15,103.9	5,244.4	4,400.5	665.1	1,355.5	253.0	2,437.4	1,619.0
Intermediate demand	183.0	10,969.9	–	620.0	951.5	1,300.4	70.6	161.2	177.0
Value (US$ million)									
Output	2,142.4	29,442.6	3,931.9	2,860.9	2,631.3	2,116.6	362.1	4,214.3	3,143.2
Imports	–	1,285.5	40.1	34.7	292.3	44.7	64.0	220.0	–
Exports	191.7	3,932.2	1,057.1	1,420.5	344.3	311.5	78.0	2,210.0	1,738.5
Consumption	1,750.4	12,111.5	2,915.0	1,262.9	781.8	1,025.8	251.2	2,103.3	1,372.6
Intermediate demand	200.3	14,684.4	–	212.2	1,797.5	823.9	97.0	121.1	32.1

As in other food-sector modelling studies, considerable difficulties were confronted in constructing the balance sheets. One difficulty was that, in each country, there is no single source for all the data needed in the model. Second, some of the raw data had to be transformed in order to suit the requirements of the model. Third, in some countries there are credible studies that indicate inaccuracies in the raw data. For example, China's fish production figures may have been seriously overestimated; hence, some of the output data were adjusted downward.

Parameters of the model

The parameterisation approach was to estimate the relevant elasticities and response parameters for the consumer and producer cores, and to borrow elasticities for the trade core. Once obtained, these were transformed to suit the specification of the equations in Dey et al.

(2005a). The intercept terms of all the relevant equations were then calibrated to ensure that the model replicates the baseline dataset.

The estimation of the demand side yielded satisfactory results from the viewpoint of generating plausible values for the elasticities. In fact, elasticity estimates for the Philippines and India were used directly in the model, while those from Bangladesh and Malaysia required only minor modifications. In the cases of Sri Lanka, Thailand and Vietnam, estimates using national data were used in place of elasticities based on regional data. Lastly, demand-side elasticities from Indonesia and China relied heavily on estimates derived from a literature search and expert opinion. The initial estimates for these countries were not used for the projection exercises because (a) values did not perform well in simulation, and/or (b) problems in generating a disaggregation in the dataset for estimation that is consistent with that specified in the model.

Estimation of supply-side elasticities met with limited success. Except for Bangladesh, India and, to a lesser degree, Malaysia and Thailand, most of the supply-side elasticities were not satisfactory or did not perform well under simulation. Part of the explanation here lies in the incomplete data from which elasticities can be derived. The unavailability of reliable elasticity estimates for the supply side was addressed as follows. First, the country modellers attempted to borrow elasticities from the literature or other participants in the project. Second, for specific fish types for which such elasticities are not available elsewhere, it was decided to consult a panel of experts on plausible values for the elasticities.

Table 3 shows the average values of the elasticities used in the country models. Price elasticities for the supply side tend to be low; i.e. fish production is not very responsive to price changes. Price elasticities for aquaculture tend to be higher than their counterparts for capture fisheries. On the demand side, own-price and expenditure elasticities are higher for rural areas, implying a greater response to price and income changes in rural than in urban households.

Table 3. Summary of demand and supply elasticities for fish used in the country models

	Bangladesh	China	India	Indonesia	Malaysia	Philippines	Sri Lanka	Thailand	Vietnam
Supply									
Aquaculture	0.64	0.67	1.33	0.28	0.90	0.65	0.27	1.24	0.37
Capture	0.47	na	0.34	0.20	0.22	0.30	0.48	0.48	0.28
Demand									
Own price									
Rural	(2.55)	(0.80)	(0.98)	(1.20)	(1.21)	(1.43)	(0.89)	(0.56)	(1.11)
Urban	(0.37)	(0.45)	(0.98)	(1.18)	(1.21)	(1.37)	(0.89)	(0.62)	(1.33)
Estate							(0.89)		
Expenditure									
Rural	1.82	1.23	1.62	0.94	1.03	1.04	0.99	1.07	0.65
Urban	0.82	1.05	1.62	0.89	1.07	1.03	0.99	0.98	0.65

Note: Numbers in parentheses are negative.

Projections for supply, demand and trade

Detailed projections from 2005–2020 were made for each country. Information is available for trends in production of selected fish types by source, consumption of different fish types by region, trade by fish type, and prices of fish types in consumption and production. However, as the disaggregation of the fisheries sector varies from one country to the next, no attempt is made to present the results for the individual fish types in this paper. The focus instead is on the potential trends in selected aggregates for the fisheries sector.[4]

[4] Detailed country-level data and projections are available upon request from the authors.

Overview

Projection results are highly dependent on the assumed changes in the exogenous variables. Table 4 summarises the ranges in which the projections fall for each variable category (i.e. fish types etc.) The country models in general used historical trends in projecting income, input prices, non-fish commodity prices and regional populations. Countries differ, however, on assumptions about future technological changes in the fisheries sector. At one extreme, the Philippines and Malaysia simulations assume no productivity changes during the projection period. As such, the projections for these countries should be interpreted as one in which technology in year 2020 is the same as it is at present. At the other extreme are India and Sri Lanka, for which it is assumed that technological progress will raise the productivity of aquaculture by 3–4% per year.

Projections for output

Projections for annual output increase over the period 2005–20 range from 0.21% in the Philippines to 3.57% in Sri Lanka (Table 5). The fastest growth rates are observed for Sri Lanka, India and China, while the slowest are in the Philippines and Indonesia. The relatively higher percentage increase in values suggests that fish prices as a whole are expected to rise over the projection period. Of the participating countries, the largest price increases are likely to be for India at approximately 6.2% (the difference between value and quantity growth).

Moreover, aquaculture is expected to expand for all countries, but especially China, Malaysia and Thailand. Overall, aquaculture production rises faster than capture production. All countries are expected to experience an expansion in capture fisheries, except for Bangladesh and the Philippines. The relatively high rates of increase for aquaculture output imply an increase in its share in total output. These changes are more pronounced for China, Bangladesh and Thailand. In the cases of China and Bangladesh, aquaculture is expected to account for roughly three-quarters of their total fresh fish in 2020. For China and Thailand, the increase in the share of aquaculture is mostly due to the relatively rapid growth of this source over the projection period. In Bangladesh, however, this is partly due to the projected output contraction in capture fisheries.

Projections for consumption

Projections for demand indicate rising aggregate consumption for all countries, but especially Malaysia (Table 6). The results are mixed at the regional level. Despite the decline in selected regions for the Philippines, China and Malaysia, total consumption is still expected to expand because of the relatively small initial share of the contracting region in total consumption. In the case of Malaysia, the positive aggregate response was also augmented by the relatively large expansion in rural consumption.

The expansion in aggregate consumption can be traced to a combination of population growth and higher per-capita consumption. In the cases of Indonesia, Bangladesh and the Philippines—see Rodriguez et al. (2005) and Dey et al. (2005b), the low average annual increase in aggregate consumption relative to population growth suggests that per-capita consumption in these countries is expected to decline over the projection period. That is, the increase in aggregate consumption for these countries is due solely to population growth. Unless these countries target higher productivity growth in fish supply, the traditional role of fish as a source of animal protein for poor households will be increasingly undermined.

Table 4. Assumed percentage changes in the exogenous variables for fish supply, demand and trade, selected Asian countries, 2005–2020

Variable	Bangladesh	China	India	Indonesia	Malaysia	Philippines	Sri Lanka	Thailand	Vietnam
Population	1.8	(2.3)–2.64	1.5	1.66–1.82	1.5–2	2.2 –2.35	(1.4)–2.9	1.0–1.1	1
Food price	3.1	0.375	6.7–9.0	4	1.5	4.33–7.77	1.2–2.5	3.5	1
Non-food price	3.1	0.375	8	na	3.08	8.85–8.98	4.3–7.4	3.5	Na
Input price	5	0.375	4.2–8.8	4.95	1.0–3.08	2.68–7.60	2–3.1	2.0–3.0	1
Export price	3.1	1	4.2–10.3	0.77	0.8	3.58–5.76	7.5–8.5	3.5	0.1
Import price	na	2	0	0.5	0.5	3.86–6.64	(4.2)–4.2	3.5	1
Per-capita income	6.2	4.5–5.5	5	8.77–8.96	3.29	8.85–8.98	4.0–11.0	6	9
No. of firms	0	0	0	0	0	0	1	0	1
Technology—capture	0	0	1.9	1	0	0	2	0	1
Technology—culture	0–5	1–5	3.8	2.0–3.0	0	0	1.6–3.0	1.0–2.0	1
Marketing margins	0	(2)	0	0	0	0	0.8–2.3	0	0.5

Note: Numbers in parentheses are negative.

Table 5. Projected growth in the output of fresh fish, 2005–2020, by country

	Value (%)	Quantity (%)	Aquaculture (%)	Capture (%)
Bangladesh	2.06	1.34	2.77	(2.02)
China	6.22	3.04	4.69	–
India	9.33	3.14	3.99	1.99
Indonesia	2.19	0.88	1.80	0.83
Malaysia	5.74	1.49	4.45	1.12
Philippines	4.52	0.21	2.17	(0.17)
Sri Lanka	6.39	3.57	3.60	3.33
Thailand	6.43	1.75	4.01	0.46
Vietnam	2.68	2.01	2.01	2.01

Note: Numbers in parentheses are negative.

Table 6. Projected growth in fish consumption and consumption per capita, 2005–2020, by country

	Consumption			Consumption per capita	
	Total (%)	Rural (%)	Urban (%)	Rural (%)	Urban (%)
Bangladesh	0.22	0.06	0.82	(1.74)	(0.98)
China	2.53	(2.00)	3.62	0.30	0.98
India	2.47	na	na	0.97	0.97
Indonesia	1.05	0.12	1.92	(1.54)	0.10
Malaysia	9.95	12.55	(1.85)	11.05	(3.85)
Philippines	0.50	(1.56)	1.38	(3.91)	(0.87)
Sri Lanka	3.91	4.45	0.42	1.55	1.82
Thailand	1.83	2.07	1.37	0.97	0.27
Vietnam	1.73	1.91	1.33	0.91	0.33

Note: Numbers in parentheses are negative.

Projections for trade

Meanwhile for trade, imports and exports of fish are projected to increase except for Malaysia and the Philippines (Table 7). The results also point to the rising importance of foreign markets for South Asia and China. With the exception of Malaysia, the value of net exports is expected to be higher in 2020. This is consistent with the earlier finding that the value of production would tend to rise faster than the value of consumption.

Table 7. Projected growth of fish exports and imports, 2005–2020, by country

	Quantities		Values	
	Exports (%)	Imports (%)	Exports (%)	Imports (%)
Bangladesh	8.68	na	12.10	na
China	2.92	1.82	6.69	4.10
India	3.69	0.94	14.18	0.96
Indonesia	0.64	1.44	1.74	1.99
Malaysia	(2.67)	15.72	(1.38)	15.48
Philippines	0.24	(3.85)	5.08	2.77
Sri Lanka	4.69	7.32	10.12	7.32
Thailand	1.91	3.40	6.36	6.99
Vietnam	2.23	na	2.38	na

Note: Numbers in parentheses are negative.

Projections under different scenarios

For impact analysis, we simulate the outcomes of faster technical progress. In the selected countries this is a realistic scenario for aquaculture. Globally, aquaculture is recognised as the primary source of growth in the fish sector (Delgado et al. 2003). Moreover, the presence of modern technologies and farming inefficiencies implies a potential for raising output without meeting fundamental resource constraints, such as limited farm area. This is in contrast to the case of capture fisheries which, in the selected countries, are found to be fully or over-exploited (Silvestre et al. 2004). Scenario 1 refers to faster productivity growth in freshwater aquaculture, while scenario 2 refers to faster productivity growth in brackish-water or marine systems.[5] This distinction may be roughly associated with higher productivity of low-value aquaculture (scenario 1) versus higher productivity of high value aquaculture (scenario 2), as brackish-water and marine aquaculture tends to produce the relatively more expensive fish products. This distinction can then be linked to food security, as poor households tend to consume low-value fish in greater proportion.

Results are reported in terms of average deviation from the baseline projection. Higher productivity of freshwater aquaculture leads to faster overall growth of output (Table 8). Of course the output growth tends to be higher in aquaculture, as it is the directly affected sector. The results for exports are, however, mixed; only in Malaysia do we observe a significant export boost from more rapid technical progress in aquaculture. On the other hand, only in Malaysia is there a zero impact of productivity growth on consumption; in the other countries, consumption tends to rise. This probably implies a welfare gain especially for the poor.

The results for scenario 2 are broadly similar to those of scenario 1. Higher productivity of high-value fish also leads to faster growth of output, especially in aquaculture (Table 9). In contrast, the export effects tend to be positive and larger, as brackish-water and marine culture tends to be more export-oriented than freshwater aquaculture. Lastly, we expect growth of total consumption for all the countries, though somewhat milder than that

5 In the case of Thailand, productivity growth also rises for capture fisheries.

observed in scenario 1, as brackish-water or marine-cultured fish tend to be less important in the consumption basket. The results of these two scenarios suggest that, if a nation is aiming at improved food security, it is better-off targeting productivity growth in low-value aquaculture. If this comes at the expense of investments in high-value aquaculture, however, it may have to forgo some of the export growth attributable to the latter.

Table 8. Scenario of higher productivity of freshwater aquaculture: deviations from baseline growth rate, 2005–2020, by country. Values are percentages.

	Percentage rise in productivity growth	Total output	Aquaculture output	Quantity of exports	Total consumption
Bangladesh	1.0	0.20	0.27	(0.05)	0.28
India	5.0	0.03	0.01	(0.30)	0.08
Indonesia	3.0–5.0	0.19	1.20	0.00	0.21
Malaysia	1.0	0.66	2.94	2.55	0.00
Philippines	5.0	0.68	2.47	0.18	0.88
Thailand	1.0	0.14	0.77	(0.48)	0.31
Vietnam	1.0	0.17	0.51	0.21	0.13

Note: Numbers in parentheses are negative.

Table 9. Scenario of higher productivity of high-value fish in aquaculture: deviations from baseline, 2005–2020, by country

		Total output	Aquaculture output	Quantity of exports	Total consumption
Bangladesh	1.0	0.39	0.50	1.30	0.06
India	1.0	0.07	0.01	(0.16)	0.08
Indonesia	1–3	0.10	0.66	0.13	0.10
Malaysia	1.0	0.07	0.04	0.07	(0.18)
Philippines	1.0	0.06	0.21	0.21	0.04
Thailand	0.01 to 2.0	0.02	0.15	(0.07)	0.05
Vietnam	1.0	0.00	0.06	0.00	0.00

Note: Numbers in parentheses are negative.

Concluding remarks

The AsiaFish model is a quantitative tool for analysing the supply and demand outlook and impact of policies, at a disaggregated level, to provide detailed guidance on the design of development strategies for the fish sector. The model has been applied to nine major fish producers in Asia to generate projections to 2020. Our results indicate that, with rising population and income, fish demand will continue to grow. Supply will also rise, with the bulk of the increase coming from aquaculture.

Growth of supply will, however, be slower, implying the long-run increase of fish prices. Nevertheless, in most cases fish consumption per person will continue to be maintained or perhaps even increase. The exceptions are Indonesia, the Philippines and Bangladesh, where a long-term decline in per-capita consumption is projected, unless reversed by aggressive productivity improvements. In our alternative scenarios, faster productivity growth will indeed increase output and raise total consumption.

The disaggregated nature of our model allows more targeted types of analysis. We have, for example, differentiated productivity growth between low-value aquaculture and high-value aquaculture. With this tool, we confirm as well as quantify the expectation that consumption increase is higher for the former, though export increases are higher for the latter.

The results presented so far are depicted in general terms due to the need to make succinct, cross-country comparisons. With the AsiaFish country models, however, we can generate disaggregated projections by fish type, production source and region, for fish supply, demand

and trade. Moreover, we can devise detailed shock scenarios. In future work we intend to customise the impact scenarios to evaluate a wide range of policy options towards increasing and sustaining benefits from fisheries and aquaculture to poor households.

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