2. Contribution of commercial aquaculture to economic growth: an assessment framework

As discussed earlier, there are no commonly accepted approaches of assessing the contribution of a given sector such as commercial aquaculture, to economic growth. Using previous studies, such as the one conducted by Timmer (1992), as a foundation, this chapter attempts to develop a framework for measuring this impact for commercial aquaculture. The assessment framework is developed in two steps. In the first step, a systematic conceptual/theoretical/qualitative framework for understanding the contribution of commercial aquaculture to economic growth is articulated. In the second step, the conceptual framework is converted into an empirical framework for quantitative evaluation of this contribution.

2.1 CONCEPTUAL FRAMEWORK

A sector's contribution to economic growth is the sum of contributions of each economic activity within the sector to the dynamic performance of the whole economy. The dynamic performance of an economy consists, for example, of the economy's national income (GDP) and employment. A sector can contribute directly and indirectly to the economy.

2.1.1 Direct contribution

A sector's direct contribution is the contribution of its own production to economic performance. It can be measured by the value added and employment generated by all production activities within the sector (Timmer, 1992). While the contributions of employment and labour income are straightforward, the concept of value added deserves some explanation.

In short, the value added of a production unit (firm) reflects the amount of economic value of primary inputs used in the firm's production process.

In general, there are two kinds of inputs used in every production process: primary and intermediate. While the former (primary) includes mainly labour and capital (land) attached to a firm, the latter includes imports and products purchased from other sectors but which are used as production inputs by the firm. The output value of the firm reflects the values of both kinds of inputs. Yet, while the value of the primary inputs is "created" during the production process, that of intermediate inputs, which is created by other sectors that produce them, is merely a "pass-on" value. Thus, in any firm, value added is measured by the difference between the value of the firm's output and the value of all inputs purchased from outside the firm (Gittinger, 1982). In other words, a firm's value added equals the firm's output value minus the value of the intermediate inputs used in the production process. Value is added to a firm's labour and capital (primary) inputs; not to purchased inputs as they are already other firms' products.

The sum of all the value added generated by a country's firms or the sum of all the value added generated by a country's economic sectors equals the country's total production or national income or gross national product (GDP). Likewise, the sum of all value added generated by all the firms which make up a sector, such as commercial aquaculture, represents the sector's value added or the sector's contribution to the

country's GDP or the sector's direct contribution to the country's economy in addition to the labour it employs and the employment it creates.

2.1.2   Indirect contribution

Sectors in an economy are interdependent. Thus, besides contributing to economic growth directly through own value added and employment created, an economic sector can also indirectly contribute to the economy through its impacts on other sectors.

Development in commercial aquaculture will not only increase its own output (and value added), create more jobs and pay more wages and salaries, but it can also stimulate output in other sectors. Very recently, Nigerian consumers' preferences have led to an ever-increasing demand for catfish over other fish species. One kilogram of fresh catfish sells for about 500 Naira (US$3.80) and 200 Naira (US$1.50) above the price paid for tilapia and chicken, respectively. The high price of catfish encouraged the development of an industry to such an extent that catfish farming as a commercial enterprise is picking up very rapidly and establishing as a dominant aquaculture industry (Hishamunda and Ridler, 2004). With the increasingly popular roadside restaurants locally known as "bukas", the development of commercial catfish farming is leading to a booming catfish specialized restaurant industry. Table fish is mainly sold at the farm gate by "market mammies" and wholesalers. Market mammies operate either individually or in loose groups and associations, often sharing transport costs and influencing the market price. Although mammies can sell a part of the produce to consumers at local urban markets and/or retailers, they sell the majority of the fish to street restaurants (bukas). Catfish is used as the main ingredient in pepper soup served in "bukas". Bukas have become large businesses owing to the development of commercial catfish farming.

From an *ex post* perspective, increases in "bukas" output due to the development in commercial catfish farming are the direct contribution of their own. From an *ex ante* perspective, however, such increases would not have happened without the development in commercial catfish farming. In this sense, increases in "bukas" output represent the indirect contribution of commercial catfish aquaculture to the restaurant industry in Nigeria and, therefore, to the Nigerian economy.

A sector's indirect contribution to economy depends on its "linkages" to other sectors of the economy. Because of their increasing importance in commercial aquaculture, these linkages need to be discussed. In this report, provided linkages can be conveniently analysed within the input-output framework, they will be discussed under the "input-output" linkages; otherwise, they will be analysed under "non input-output" linkages.

Input-output linkages
On the one hand, a sector in an interdependent economy may need to buy materials from other sectors as inputs for its own production. Where they are not fully vertically integrated, commercial aquaculture farms purchase feed and fertilizers from specialized feed and fertilizer companies. On the other hand, the sector's products may be sold to other sectors as inputs for their production. For example, some commercial aquaculture farms are specialized in bait production for the sport fishing industry. An aquaculture farm in Zambia, Kalimba Farms, grows crocodiles (and fish) essentially for their skin, which are exported to Singapore for belt, shoes and jacket production. The skin crocodile is Kalimba Farms' output and an input for belt/shoe/jacket producing firms in Singapore.

In addition, employees of commercial aquaculture farms may use their wages and salaries to purchase goods and services from other sectors, thereby stimulating these sectors' output. Such inter-sector relationships can be systematically analysed under the input-output framework (Miller and Blair, 1985). Thus, these linkages are referred

to as "input-output" linkages, which may include backward, forward and income linkages (Hirschman, 1958; Delgado, Hopkins and Kelly, 1998).

Backward linkages
A sector's *backward* linkage is its relationship with the rest of the economy through its direct and indirect *purchases* from other sectors of the economy.

Traditionally, agriculture sectors are deemed as having limited backward-linkage impacts on the rest of the economy, because their major inputs are labour and lands (Hirschman, 1958). Yet, as it tends to adopt intensive or semi-intensive production technologies that require significant intermediate inputs, especially feed, commercial aquaculture is increasingly generating strong backward linkages. In modern aquaculture in Africa, feed generally represents between 60 and 65 percent of the variable costs and 45 to 63 percent of total costs (Hishamunda and Manning, 2002).

These linkages can be complex. A commercial seaweed farm in Zanzibar (Tanzania) may need to purchase a nitrogen-rich fertilizer from a fertilizer manufacturing company in Dar es Salaam (Tanzania's capital) for its seaweed production. The seaweed farm in Zanzibar will have a backward-linkage impact on the fertilizer manufacturing company in Dar es Salaam. One step further, the fertilizer manufacturing company in Dar es Salaam may need to purchase input materials needed to manufacture fertilizers from a chemical company in Mwanza (also in Tanzania). In this instance, through its impact on the fertilizer company in Dar es Salaam, the seaweed farm in Zanzibar will also have a backward-linkage impact on the chemical company in Mwanza even though it does not directly purchase any input from the chemical company. In addition, as the seaweed farm in Zanzibar needs to hire local transporters to take dried seaweed from the farm to the pharmaceutical plant in Dar es Salaam, it will have a backward-linkage impact on the local transportation sector. Because transportation requires fuel, the Zanzibar seaweed farm's backward linkage will extend further to the petroleum sector. All such relationships taken together will constitute the backward-linkage impact of the seaweed farm in Zanzibar on the rest of the Tanzanian economy.

As early as during its initial construction period, Aqualma, the largest commercial shrimp farm in Madagascar, began generating its backward-linkage impacts by significantly boosting local construction businesses. Even though they were imported, the number of bulldozers of local construction companies increased from five to 20. Around 300 construction jobs were created. Aqualma's backward-linkage impacts continued as the farm became fully operational. The company purchased at least 40 tonnes of lime per month from a local supplier. Sizable quantities of chicken manure to fertilize the ponds and food for the workers, including more than half a tonne of beef per month, rice, vegetables and other items were also purchased from local suppliers. In addition, the company's import demands represented about 50 percent of the activities in a nearby port (Karmokolias, 1997).

As commercial aquaculture develops in Africa, feeds and seeds, the two major inputs in commercial aquaculture that traditionally depend largely on imports, are progressively being supplied by local producers. In Zambia, the use of scientifically formulated fish feed was limited, primarily because of local unavailability or high import prices. However, as fish feed demand increased, owing to the increase in the number of commercial fish farms, Tiger Feeds (a local livestock feed mill company) diversified its business to include fish feed as one of its products since 2000. In Madagascar, shrimp farms still depend on feed imports from as far as Mauritius and Seychelles, Taiwan Province of China, and the United States of America (Hishamunda, 2000). With the rapid development of the shrimp industry, efforts from both the private and public sectors are underway to promote the local production of shrimp feed manufacturing (Hishamunda and Ridler, 2004). The forthcoming feed industry is

expected to significantly strengthen commercial aquaculture's backward linkages to the rest of the Malagasy economy.

Forward linkages

A sector's forward linkage represents its relationship with the rest of the economy through its direct and indirect sales to other sectors of the economy.

Take the Zanzibar seaweed farm as an example again. As some seaweed species contain pharmaceutical properties, seaweed produced by the farm in Zanzibar may be purchased by a pharmaceutical firm in Kigoma, Tanzania, as an input for medicine production. Thus, the seaweed farm in Zanzibar will have a forward-linkage impact on the pharmaceutical firm in Kigoma.

Because commercial aquaculture companies tend to process their own produces, the contribution of commercial aquaculture to economies through the processing of farm produces is not indirect, strictly speaking; it is direct because farm produces are not sold to other firms for use as production inputs. However, as far as the production structure is concerned, the processing of farm products falls under the forward-linkage impacts of commercial farming activities. It is worth noting that the processing of farm produces is one of the major activities in commercial aquaculture. Around 40 percent of Madagascar Aqualma's full-time employees are engaged in aquaculture produce processing activities (Hishamunda, 2000). Indian Ocean Aquaculture, a shrimp farming company in Mozambique, plans to employ at least 30 percent of its workforce in processing activities, with women expected to represent up to 90 percent of processing workers (Hishamunda and Ridler, 2004).

Income linkages

A sector's income linkage to the rest of the economy is established through wage (salary) payments to its employees. Employees of the Zanzibar seaweed farm will use their wages or salaries to buy different goods and services such as food, clothing, vacation bus or train tickets or medical services. Thus, by paying its employees, the seaweed farm will have income-linkage impacts on the food and clothing producing sectors and/or the transportation and medical-care companies. The creation of commercial shrimp farming companies in Madagascar induced the establishment of private retail shops and catering services to serve its workers and their dependents (Karmokolias, 1997). A clinic and other social amenities were also established in Mahajanga for the same purpose (Hishamunda, 2000).

Because of the high number of relatively well-paid workers at the Kigembe (Rwanda) fish station from the early 1980s to the early 1990s, local entrepreneurs opened small restaurants and bars in the farm surroundings to attract workers for lunch meals and evening gatherings. Not only did these new businesses contributed to the local economy through their own income, tax, and job generation, but also stimulated further the economy by purchasing local agriculture and other products. All of these multiplier effects represent Kigembe fish station's indirect contribution to the local economy through its income linkages.

Non input-output linkages

Besides input-output linkages, commercial aquaculture can also have other linkage impacts on the rest of the economy. These include investments in infrastructure and in human resources, and foreign exchange. Investments in infrastructure and human resources increase productivity, which ultimately drives economic growth and standards of living.

Investments in infrastructure
Commercial aquaculture can catalyze investments in infrastructure such as roads and utilities that will benefit local businesses and communities. The Aqualma project in Madagascar contributed US$1.6 million in roads, utilities, communications, housing and amenities to the local economy (Karmokolias, 1997). In Zambia, Kafue Fish Farms contributed to road construction projects in the farm vicinity by means of financial and other mechanisms (Hishamunda and Manning, 2002).

Investments in human capital
Shrimp farming companies in Madagascar and Mozambique have trained biologists specializing in shrimp aquaculture; they also provided training to their laboratory personnel. Moreover, farm workers received on-the-job training by participating in instructional sessions on proper health and occupational practices (Karmokolias, 1997; Hishamunda and Ridler, 2004). The investments of commercial aquaculture in human capital help increase productivity, which is the ultimate driving force of long-term economic growth.

Productivity
From a "growth accounting" perspective, economic growth can be attributed to growth in factor inputs and in productivity (Barro, 1999). Growth theories indicate that, while factor input growth is important to the transition of an economy to its steady state, productivity growth is the major driving force of long-term (steady-state) growth (Solow, 1956; Koopmans, 1965; Romer, 1986). Therefore, productivity growth in the commercial aquaculture sector can contribute to economic growth by raising the total factor productivity (TFP) in the economy. However, Timmer (1992), and Block and Timmer (1994) found non-trivial contribution to TFP by agriculture in general. Studies on the TFP of aquaculture, including commercial aquaculture, are rare.

Foreign exchange
Foreign exchanges are valuable resources for developing countries that are often in need of imported goods (Johnston and Mellor, 1961; Timmer, 1992). Thus, foreign exchange earnings generated by exports of commercial aquaculture products constitute an additional contribution to economic growth. As a significant percentage of farm-raised aquatic products are for exportation, commercial aquaculture's contribution in this respect tends to be important. For example, net export earnings from shrimp farming in Madagascar were around US$55 million in 2001 (Coûteaux, Kasprzyk and Ranaivoson, 2003).

The conceptual framework discussed in this section is summarized in Figure 1.

2.2   EMPIRICAL FRAMEWORK
Based on the conceptual framework illustrated above, an empirical framework for quantitatively assessing the contribution of commercial aquaculture to economic growth is developed.

2.2.1   Contribution to gross domestic product (GDP)
Direct contribution to GDP
Indicators
As a basic measure of economic performance, value added can be used to gauge commercial aquaculture's contribution to economic growth. Specifically, we suggest the following indicators.

FIGURE 1
A conceptual framework for commercial aquaculture's contribution to economic growth
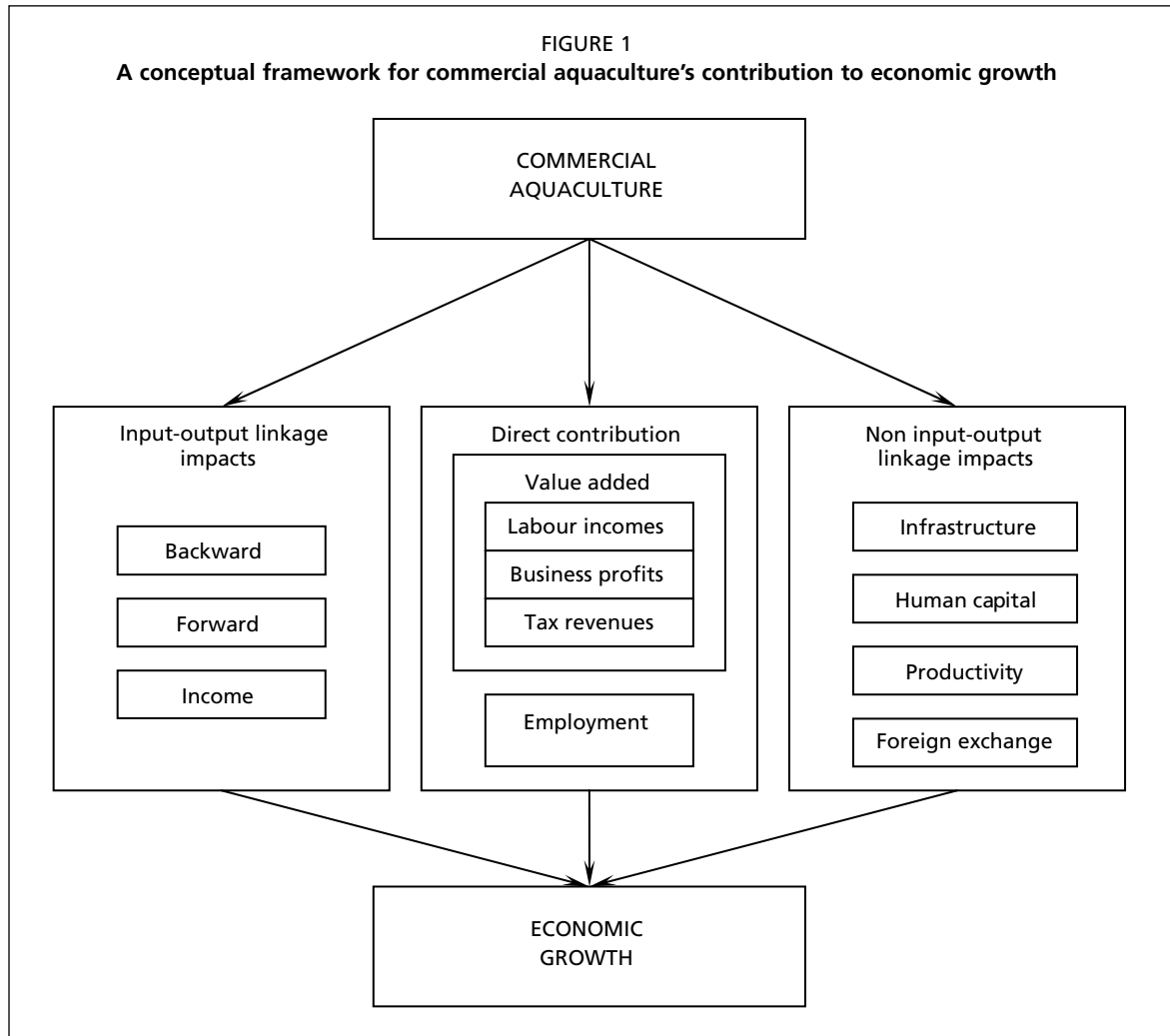
[1.1] VAD_t^{ca} / GDP_t
[1.2] $\Delta VAD_t^{ca} / \Delta GDP_t$
[1.3] VAD_t^{ca} / VAD_t^{ag}
[1.4] $\Delta VAD_t^{ca} / \Delta VAD_t^{ag}$

where

$VAD^{ca} =$	the value added of commercial aquaculture;
$VAD^{ag} =$	the value added of agriculture;
$GDP =$	gross domestic product
$\Delta =$	the changes of variables over time;
$t =$	time subscript.

While indicator [1.1] measures commercial aquaculture's direct contribution to GDP at a certain point in time, [1.2] provides information about its direct contribution to the growth of GDP. For example, suppose a country's GDP in 2004 is US$1 billion whereas the value added of its commercial aquaculture sector is US$10 million. Thus we can say that commercial aquaculture directly contributes one percent (US$10 million divided by US$1 billion) of GDP in 2004. Suppose the US$1 billion GDP in 2004 is US$50 million higher than that in 2003 whereas commercial aquaculture's value added is higher by US$1 million. Then we can say that commercial aquaculture directly

contributes 2 percent (US$1 million divided by US$50 million) of GDP growth in 2004.

In contrast to indicators [1.1] and [1.2], which use the entire economy as reference point for evaluating commercial aquaculture's value added contribution, indicators [1.3] and [1.4] use the entire agriculture sector as reference point. Specifically, indicator [1.3] measures commercial aquaculture's contribution to agriculture value added whereas [1.4] measures its contribution to agriculture growth.

Empirical estimation of value added
Data needed to compute indicators [1.1] – [1.4] include GDP and the values added of agriculture and commercial aquaculture. While the former two are usually available from official statistical sources, the last one may need to be estimated based on data from field surveys or secondary sources.

As mentioned above, a sector's value added is the economic value created by its own production, which represents the economic value of the primary inputs (factors) used in the production. Thus, value added is equal to payments to factors (labour, capital, and land) plus tax payments to government; i.e.

[1]   *VAD* = **factor payments + tax payments**

Another formula for value added calculation is to deduct the total value of domestic intermediate and imported inputs from the output value; i.e.

[2]   *VAD* = **output value – domestic intermediate input value – imported input value**

Formulas [1] and [2] are constructed based on the input-output framework. Unfortunately, some developing countries may not have input-output tables; and for those who have, the tables may not be disaggregated enough to treat commercial aquaculture as a distinct sector. Rather, data available are likely to be accounting data with respect to the costs and revenues of commercial aquaculture operations. Thus, formulas [1] and [2] must be modified to suit the accounting data.

From a costs-revenues perspective, value added includes wages and salaries (as payments to labour), profits (as payments to "entrepreneur spirits"), and "fixed costs" that comprise rents (as payments to land), depreciation (as payments to capital), taxes (as payments to government), etc. Thus, value added can be calculated by the following formula:

[1']   *VAD* = **labour costs + profits + fixed costs,**

which is a counterpart of formula [1].

Since intermediate and imported inputs closely correspond to non-labour "variable costs", value added can also be estimated by another formula:

[2']   *VAD* = **revenues – non-labour variable costs,**

which is a counterpart of formula [2].

It should be noted that, based on different perspectives, input-output and accounting categorizations of input or cost items do not match perfectly. Although most of variable and fixed costs belong to intermediate and primary inputs respectively, exceptions do exist. For example, some types of taxes are variable costs in nature but belong to payments to primary inputs. On the other hand, interest payments to bank loans are sometimes accounted as fixed costs; yet they are payments to banks' services

TABLE 1
Production revenues and costs

Production revenues and costs	US$/ha
Revenues	25 224
Total costs	14 735
Fixed costs	1 120
Variable costs	13 615
Seed	2 315
Feed	2 723
Fertilizer and chemical	408
Labour	3 812
Other variable costs	4 221

Source: Hishamunda and Manning (2002).

as intermediate inputs. Thus, the terms "fixed cost" and "variable cost" in formulas [1']
and [2'] are used in a general sense; and practitioners ought to use the spirit of formulas
[1] and [2] as guidance for using formulas [1'] or [2'] in estimating value added.

An example of value added calculation
In Table 1 we provide an example of value added calculation based on the cost/
revenue data of a tilapia/catfish polyculture farm in Nigeria.

The business profit is US$10 498, equal to revenues minus total costs (US$25 224
– US$14 735). Thus, according to formula [1'], the value added is US$15 421, equal
to the sum of the business profit (US$10 498), fixed costs (US$1 120), and labour
costs (US$ 3 812). Or, according to the second formula, the value added can also be
calculated by deducting non-labour variable costs (US$9 803 = US$13 615 - US$3 812)
from revenues (US$25 224), which will give the same result (US$15 421).[1]

Note that the US$4 221 of "other variable costs" may contain value-added
components such as tax payments; and the US$1 120 of "fixed costs" may contain
non-value-added components such as interest payments for bank loans. Thus, the
estimation of value added can be more accurate if data on detailed breakdowns of the
two items are available.

Also note that profits and value added are indicators of farm performance from
different perspectives. While the former evaluates the competitiveness and viability of
the farm from a business perspective, the latter evaluates the contribution of the farm
to the wellbeing of the economy from a social perspective.

Total contribution to GDP
Being rudimental indicators of commercial aquaculture's contribution to economic
performance and growth, indicators [1.1] – [1.4] nevertheless do not capture the
sector's indirect contribution through linkage impacts.

To assess a sector's "total" (i.e. direct plus indirect) contribution to economic
growth, a general methodology is to simulate its potential (or counterfactual) impacts
on economic performance in economy-wide models.

In general, such simulations include three steps. First, a simulation model needs to
be constructed to capture commercial aquaculture's linkages to the rest of the economy.
Then the model can be used to simulate the (dynamic) reactions of the economy to
hypothetical shocks (say a US$1 increase in commercial aquaculture production).

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[1] With sufficient cost/revenue information, both formulas are applicable here. Yet there could be situations
where available information may allow one formula to be used but not the other.

Finally, based on the simulated impacts, indicators (such as a variety of multipliers) can be calculated to measure the sector's total contribution to growth.

In the spirit of this methodology, three approaches have been used to assess a sectors' total contribution to growth.

Macroeconomic models
One approach is to conduct dynamic simulations in macroeconomic models (Cavallo and Mundlak, 1982; Mundlak, Cavallo and Domenech, 1989; Block and Timmer, 1994). The first step is to specify an empirical model in which each equation represents a certain relationship among aggregate variables (such as GDP, consumption, investment, capital stock, etc.). The second step is to use historical data to calibrate each equation separately to determine parameters therein. With all parameters estimated, a model for the economy is in shape; its fitness can be tested by comparing a simulated growth path to the actual path. If the fitness is acceptable, the model can be used to conduct counterfactual simulations to provide information regarding the sectors' total contribution to growth.

For example, in examining the linkage impacts of Kenya's agriculture, Block and Timmer (1994) assumed a (counterfactual) 100 million-pound increase in agriculture's value added at a certain point of time, and then used a model built according to the above method to estimate the impacts of the shock on GDP over time. They used the ratio between the total increase in GDP over time and the 100 million-pound initial increase in agriculture's value added as a measure of the impact of Kenya's agriculture on GDP growth.

This dynamic simulation approach can provide valuable information regarding sectors' contribution to growth over time beyond their direct contribution. However, one limitation is the lack of solid theoretical foundation for underlying model specifications. A model may be "fit" in the sense that it can replicate the actual growth path with acceptable accuracy; yet, this does not guarantee that the model is also fit in counterfactual experiments or out-of-sample estimations. In other words, without theoretical justifications, the parameter-stability assumption essential to this approach may be a concern. Moreover, intensive time-series data requirements may limit its practical applicability.

Input-output or CGE models
An alternative approach involves input-output or computable general equilibrium (CGE) models to conduct simulations. As opposed to macroeconomic models specified ad hoc and estimated econometrically from time-series data, CGE models are usually constructed with the aid of a Social Accounting Matrix (SAM) that provides detailed structural information regarding intersectoral relationships within an economy.

With a dynamic CGE model, a sector's impacts on growth can be simulated by following the same method specified for macroeconomic models. With a static CGE model, linkage multipliers can be estimated to reveal a sector's potential impact on growth. The first step is to specify a hypothetical shock (e.g. a one-dollar increase in commercial aquaculture's output) and then the impacts of the shock can be estimated in the CGE model. Then the value added multiplier of commercial aquaculture can be measured by the amount of GDP increase caused by a one-dollar increase in commercial aquaculture's value added.

Based on SAM (or input-output tables), CGE models have more solid microfoundation than macroeconomic models. However, as pointed out by Delgado, Hopkins and Kelly (1998, p. 15), restrictive assumptions required to close a CGE model may not always be realistic. An additional limitation of the CGE approach is the (un)availability of SAM or input-output tables. Even if available, parameterization of a CGE model is certainly not a trivial task and oftentimes is prohibitive. Furthermore,

SAM or input-output tables may not be detailed enough to have commercial aquaculture as a distinct sector.

Simplified input-output model

A third approach, which demands less data, is to use simplified models in the input-output spirit to derive growth multipliers. One example is the "semi-input-output" models widely used in the "growth linkage" literature (Delgado, Hopkins and Kelly, 1998).

In general, semi-input-output models are essentially simplified input-output (Type II) models that capture the interactions between the sector in interest (e.g. tradable sector) and the rest of the economy (e.g. non-tradable sector). Usually the coefficients in a semi-input-output model is not from input-output tables but estimated from aggregate data. As compared to CGE models wherein prices are usually endogenously determined, one major limitation of semi-input-output models is the assumption of fixed prices (Delgado, Hopkins and Kelly, 1998).

Summary

In summary, the underlying methodology of the above approaches is the same: linkage impacts are estimated in (counterfactual or forecasting) experiments based on certain models that capture intersectoral and other relationships within the economy. Their major differences are in the levels of model sophistication, the methods for model construction, the data and methods for model parameterization, and the indicators used to gauge linkage impacts.

Example: a two-sector model

As data on the commercial aquaculture sector in developing countries are limited, the third approach may currently be the most applicable tool for evaluating the sector's total contribution to GDP.

In the following we illustrate a two-sector model that can be used to calculate the value added multiplier of commercial aquaculture. Labour income and employment multipliers can also be calculated in a similar way; they will be discussed later.

The model

The economy can be divided into sectors 1 and 2, with sector 1 representing commercial aquaculture (CA) and sector 2 representing the rest of the economy (ROE). The input-output linkages between these two sectors can be captured by the following two equations:

$$X_1 = a_{11}X_1 + a_{12}X_2 + C_1 + G_1 + N_1 \tag{1}$$
$$X_2 = a_{21}X_1 + a_{22}X_2 + C_2 + G_2 + N_2 \tag{2}$$

where,

$X_i =$ the output (value) of CA ($i = 1$) or the ROE ($i = 2$);

$C_i =$ the domestic private consumption (value) of CA's ($i = 1$) or the ROE's products ($i = 2$);

$G_i =$ the government consumption (value) of CA's ($i = 1$) or the ROE's ($i = 2$) products;

$N_i =$ the net export (value) of CA's ($i = 1$) or the ROE's ($i = 2$) products;

$a_{11} =$ the ratio of CA's intrasectoral trade to CA's output;

$a_{21} =$ the ratio of CA's intermediate purchases (from the ROE) to CA's output;

$a_{12} =$ the ratio of CA's intermediate sales (to the ROE) to the ROE's output;

$a_{22} =$ the ratio of the ROE's intrasectoral trade to the ROE's output.

Equation (1) shows that the total output of commercial aquaculture (X_1) is sold to itself by the amount $a_{11}X_1$, to the ROE by the amount of $a_{12}X_2$, to domestic private consumption by the amount of C_1, to government by the amount of G_1, and to the net export by the amount of N_1 – note that N_1 would be negative if the country is a net importer of commercial aquaculture products. Symmetrically, equation (2) shows the various destinations of the ROE's output.

According to equation (2), an increase in the production of commercial aquaculture (i.e. a higher X_1) will stimulate the ROE's production (i.e. a higher X_2). Besides, the increases in X_1 and X_2 will generate extra incomes for domestic consumers, who will tend to increase their consumption (C_1 and C_2). This will further stimulate the production in the rest of the economy (X_2).

According to equation (1), the increases in the ROE's production (X_2) and domestic consumption of aquatic products (C_1) will require more commercial aquaculture products (X_1), which could exceed the initial increase in X_1 and hence further stimulate the development of commercial aquaculture. Yet, since the task here is to estimate the impact of commercial aquaculture on the rest of the economy, we do not consider such feedback effects.

According to equation (2), the impact of commercial aquaculture on the rest of the economy through intersectoral purchases (i.e. the backward linkage) depends on the coefficient a_{21} and a_{22}. A high a_{21} implies a large purchase of commercial aquaculture from the rest of the economy, while a high a_{22} implies a strong intersectoral linkage within the rest of the economy.

To calculate the impact of commercial aquaculture on the rest of the economy through the income linkage, we will first calculate how production increases in commercial aquaculture and the rest of the economy affect GDP, and then use the relationship between GDP and consumption to calculate the impact on consumption, which, according to equation (2), will further stimulate the ROE's production (X_2). The following equations capture such relationships.

$$V_1 = v_1 X_1 \tag{3}$$
$$V_2 = v_2 X_2 \tag{4}$$
$$Y = V_1 + V_2 \tag{5}$$
$$C = \eta Y \tag{6}$$
$$C_1 = \theta C \tag{7}$$
$$C_2 = (1-\theta)C \tag{8}$$

where,

$Y =$ GDP;
$C =$ the total consumption to the entire economy;
$V_i =$ the value added of CA ($i = 1$) or the ROE ($i = 2$);
$v_i =$ the ratio of value added to output for CA ($i = 1$) or the ROE ($i = 2$);
$\eta =$ the ratio of the total consumption (value) to GDP;
$\theta =$ the share of the consumption of aquatic products in the total consumption.

Equations (3), (4) and (5) together describe the relationship between production and GDP. Specifically, equations (3) and (4) represent the relationship between output and value added for sector 1 and 2 respectively; and equation (5) is an accounting identity (i.e. GDP is equal to the sum of the value added of all the sectors in the economy). Equation (6) describes the relationship between GDP and the total consumption. Equation (7) and (8) describe the distribution of the total consumption between CA's products (C_1) and the products provided by the rest of the economy (C_2).

Value-added multiplier
The simultaneous equation system comprised by equations (1) to (8) allows us to calculate the value-added multiplier (denoted as M_v) of commercial aquaculture, which is defined as the increase in GDP corresponding to a one-unit increase in commercial aquaculture's value added; i.e., $M_v = dY/dV_1$.

According to equations (1) to (8),

$$[1.5] \quad M_v = \frac{(1-a_{22}) + a_{21}(v_2/v_1)}{1 - a_{22} - \eta(1-\theta)v_2},$$

which implies that a one-unit increase in the value added of commercial aquaculture corresponds to an increase in GDP by the amount represented by indicator [1.5]. Derivations of indicator [1.5] are provided in Appendix 1.

Commercial aquaculture's value added multiplier provides an indicator of the sector's total contribution to GDP. Yet, it should be noted that the multiplier should not be interpreted as implying that one unit of value-added change in commercial aquaculture will "cause" certain units of change in GDP. Indeed, both changes are ultimately driven by a change in the production of commercial aquaculture. Similar cautions also apply to the "employment" and "labour-income" multipliers that will be discussed later.

Empirical estimation of value-added multiplier
To calculate the value-added multiplier, parameters v_1, a_{21}, v_2, a_{22}, η, and θ need to be specified.

- v_1 represents the VAD/output ratio for the commercial aquaculture sector. The estimation of commercial aquaculture's value added was discussed previously; data on commercial aquaculture's output may be available from field surveys or secondary sources.
- a_{21} represents the ratio of commercial aquaculture's domestic intermediate input value to its output value, which can be directly calculated if data on the domestic intermediate input value are available. Otherwise, it can be calculated with the following formula:

$a_{21} = 1 - v_1 - m_1$,

where,

m_1 = CA's import costs/CA's output.

- Recall that output value is equal to domestic intermediate input value plus imported input value plus value added. Thus, since v_1 and m_1 represent respectively the VAD/output ratio and the ratio of import input to output, $1 - v_1 - m_1$ is equal to the ratio of domestic intermediate input to output (i.e. a_{21}).
- v_2 represents the VAD/output ratio for the rest of the economy (ROE). While the ROE's value added can be calculated by deducting commercial aquaculture's value added from GDP, data for the output of the rest of the economy can be found in input-output tables (or social accounting matrices). If input-output tables are not available, the tax base of a country (which accounts for total transactions in the country) can be used as a proxy of its total output. Alternatively, one direct estimation method is to collect output data regarding major sectors from different

sources, the sum of which would approximate the total output of the whole economy.

- a_{22} represents the ratio of the ROE's intersectoral trade value to its total output value, which can be easily calculated if input-output tables are available. Otherwise, it can be calculated by using the following formula:

$$a_{22} = 1 - v_2 - m_2,$$

where,

m_2 = ROE's import costs/ROE's output.

- The value of the ROE's (or the entire economy's) total imported intermediate goods is needed for calculating m_2.
- η represents the ratio between total consumption and GDP. Data on total consumption and GDP should be available from official statistical sources.
- θ represents the share of commercial aquaculture products in total consumption. Data needed to calculate θ include the total domestic consumption and domestic consumption on commercial aquaculture products. While the former should be available from official statistical sources, the latter can be approximated by the commercial aquaculture's domestic sales plus the total import value of the same products.

Extension

The treatment of the rest of the economy as one sector in the above two-sector model is a simplification that does not allow us to see the details of commercial aquaculture's impacts on the rest of the economy.

For countries that have input-output tables or social accounting matrices (e.g. Brazil, Malawi, Tanzania, Zambia and Zimbabwe), the two-sector model can be extended into full-blown input-output models. Alternative techniques can be used to estimate commercial aquaculture's linkage impacts on the rest of the economy (Cai and Leung, 2004; Leung and Pooley, 2002).

2.2.2   Contribution to employment
Direct contribution to employment

Similar to indicators [1.1] – [1.4], commercial aquaculture's direct contribution to employment can be measured by the following indicators.

[2.1] E_t^{ca} / E_t^{total}
[2.2] $\Delta E_t^{ca} / \Delta E_t^{total}$
[2.3] E_t^{ca} / E_t^{ag}
[2.4] $\Delta E_t^{ca} / \Delta E_t^{ag}$

where,

E^{ca} =   the employment provided by commercial aquaculture during period t;
E^{ag} =   the employment provided by agriculture during period t;
E^{total} =   the employment for the entire economy during period t.

Data on E^{total} and E^{ag} are generally available from official statistics sources; those on E^{ca} may be available from detailed employment statistics or comprehensive farm surveys. Note that part-time, seasonal labour hired by commercial aquaculture ought to be converted into full-time equivalent employment (i.e. 300 days per year).

If data on E^{ca} are not available, one method is to use the scale of commercial aquaculture production to estimate its employment. The first step is to estimate the average employment-output ratio for each commercial aquaculture product; then the sector's employment can be calculated by the following formula:

$$E^{ca} = \sum e_i\, X_i^{ca}$$

where,

X_i^{ca} = the output of commercial aquaculture product *i* (such as shrimp, tilapia, catfish, and so on);

e_i = the average employment-output ratio for product *i*.

Data on X_i^{ca} can come from official statistical sources or may need to be collected in the field. Data on e_i may exist in secondary sources; otherwise, survey data on typical farms are needed to estimate e_i.

It should be noted that employment tends to vary dramatically for commercial aquaculture operations producing different final products. For example, if final products are fillets for export, a large proportion of employment will tend to be devoted to product processing. Yet, if products are mainly supplied to local consumers, most of employment will be in farming. In addition, farming employment can also vary dramatically depending on the farming technology adopted. For example, the employment-output ratio is generally smaller for farms that adopt more intensive farming technologies. In other word, the proper choices of e_i require detailed information regarding commercial aquaculture sectors in the sample countries.

Total contribution to employment

Similar to the value-added multiplier (indicator [1.5]), the employment multiplier of commercial aquaculture (denoted as M_e), which is defined as the increase in total employment for the entire economy corresponding to one extra job provided by commercial aquaculture, can be used to measure commercial aquaculture's total contribution to employment. According to the derivations provided in Appendix 2, the employment multiplier in the two-sector model is given by

$$[2.5]\quad M_e = \frac{\varpi}{\varepsilon} M_v,$$

where,

M_e = commercial aquaculture's employment multiplier;

M_v = commercial aquaculture's value-added multiplier;

ϖ = VAD^{ca} / GDP; i.e. the share of commercial aquaculture's value added in GDP;

ε = E^{ca} / E^{total}; i.e. the share of commercial aquaculture employment in total employment.

Data for calculating indicator [2.5] include the employment of the commercial aquaculture sector, the total employment of the entire economy, the value added of commercial aquaculture and GDP. Issues on the availability of these data have been discussed previously.

2.2.3   Contribution to labour income
Direct contribution to labour income
Labour income is one component of value added. The reason for distinguishing labour income as a separate indicator is due to the fact that it is closely related to the well-being of domestic consumers whereas business profits may belong to foreign capital and be repatriated.

Similar to indicators [1.1] – [1.4], commercial aquaculture's direct contribution to labour income can be measured by the following indicators.

[3.1] W_t^{ca} / W_t^{total}
[3.2] $\Delta W_t^{ca} / \Delta W_t^{total}$
[3.3] W_t^{ca} / W_t^{ag}
[3.4] $\Delta W_t^{ca} / \Delta W_t^{ag}$

where,

$W^{ca} =$ the total wages and salaries provided by commercial aquaculture;
$W^{ag} =$ the total wages and salaries provided by agriculture;
$W^{total} =$ the total wages and salaries for the entire economy.

While W^{total} and W^{ag} are generally available from official statistical sources, W^{ca} may require detailed survey data or need to be estimated. One method is to use the following formula:

$$W^{ca} = w^{ca} * E^{ca},$$

where,

$w^{ca} =$ the average wage rate in the commercial aquaculture sector;
$E^{ca} =$ the employment provided by commercial aquaculture during period t.

Accuracy in the estimation of total wages (W^{ca}) is dependent on the estimation of E^{ca}. If employment classification according to skill levels is available, different wage rates should be used for jobs with different skill levels, which will make the estimation of W^{ca} more accurate.

Total contribution to labour income
Similar to the value-added multiplier (indicator [1.5]), the labour-income multiplier of commercial aquaculture (denoted as M_w), which is defined as the increase in total labour income for the entire economy corresponding to one extra unit of labour income provided by commercial aquaculture, can be used to measure commercial aquaculture's total contribution to labour income. According to the derivations provided in Appendix 3,

[3.5] $M_w = \dfrac{\varpi}{\omega} M_v ,$

where,

$M_w =$ commercial aquaculture's labour-income multiplier;
$M_v =$ commercial aquaculture's value-added multiplier;

ϖ = VAD^{ca} / GDP; i.e. the share of commercial aquaculture's value added in GDP;
ω = W^{ca} / W^{total}; i.e. the share of commercial aquaculture's labour income in total labour income for the entire economy.

Data on total labour income for the entire economy may be available from official statistical sources. Data availability for other variables has been discussed previously.

2.2.4   Contribution to tax revenues
Direct contribution to tax revenues
As another component of value added, tax payments can help finance government programs that stimulate growth
Similar to indicators [1.1] – [1.4], commercial aquaculture's direct contribution to tax revenues can be measured by the following indicators.

[4.1] T_t^{ca} / T_t^{total}
[4.2] ΔT_t^{ca} / ΔT_t^{total}
[4.3] T_t^{ca} / T_t^{ag}
[4.4] ΔT_t^{ca} / ΔT_t^{ag}

where,

T^{ca} =   commercial aquaculture's tax payments;
T^{ag} =   agriculture's tax payments;
T^{total} =   total tax revenues for the entire economy.

While data on T^{total} and W^{ag} are generally available from official statistical sources, T^{ca} can be estimated by using commercial aquaculture's revenues or value added as a base in addition to information on tax regimes in the studied countries.

Total contribution to tax revenues
Similar to the value-added multiplier (indicator [1.5]), the tax multiplier of commercial aquaculture (denoted as M_τ), which is defined as the increase in the total tax revenues for the entire economy corresponding to one extra unit of tax payment provided by commercial aquaculture, can be used to measure commercial aquaculture's total contribution to tax revenues. According to the derivations provided in Appendix 4,

[4.5] $M_\tau = \dfrac{\varpi}{\tau} M_v$,

where

M_τ =   commercial aquaculture's tax multiplier;
M_v =   commercial aquaculture's value added multiplier;
ϖ = VAD^{ca} / GDP; i.e. the share of commercial aquaculture's value added in GDP;
τ = T^{ca} / T^{total}; i.e. the share of commercial aquaculture's tax payments as a component of total tax revenues for the entire economy.

Data availability for calculating indicator [4.5] was discussed previously.

2.2.5   Other contributions
Foreign exchange
Commercial aquaculture's contribution to economic growth through "foreign exchange" linkages can be measured by the following indicator:

[5] $NFE = ER - IC$

where,

$NFE =$ net foreign exchange earnings of commercial aquaculture;
$ER =$ export revenue of commercial aquaculture;
$IC =$ import costs of commercial aquaculture.

Data for calculating indicator [5] include the export revenues of commercial aquaculture and the costs of its imported inputs.

Productivity

The productivity of commercial aquaculture production can be measured by two basic indicators:

[6.1] CA output per worker,

and

[6.2] CA output per ha (or other measures of capital).

While indicator [6.1] measures the labour productivity in commercial aquaculture production, [6.2] measures the productivity of land or capital. The time trends of the two indicators will reveal the growth of factor productivity along time.

While indicators [6.1] and [6.2] measure the productivities of different factors separately, the growth of commercial aquaculture's total factor productivity (TFP) can be measured by

[6.3] $TFP = g_y - [\alpha g_k + (1-\alpha)g_l]$,

where,

$g_y =$ the growth rate of commercial aquaculture's output;
$g_k =$ the growth rate of capital stock (e.g. land) used in commercial aquaculture production;
$g_l =$ the growth rate of labour input used in commercial aquaculture production;
$\alpha =$ the capital share in commercial aquaculture's production function.

An alternative approach is to use the ratio between output and input indices to measure TFP growth (Coelli *et al*., 2005, chapter 4), i.e.

[6.4] $\ln TFP = \ln(output\ index) - \ln(input\ index)$

where the output and input indices measure the growth of output and input values respectively, and can be constructed via various methods (Coelli *et al*., 2005).

Data for calculating indicators [6.1] – [6.4] include the quantities and prices of commercial aquaculture's outputs and inputs over time. Should indicator [6.3] be used, the capital share α needs to be estimated or assumed. Even though they represent more appropriate measures of productivity, the TFP indicators [6.3] and [6.4] may not be practical given the difficulties in obtaining data on commercial aquaculture's inputs (let alone time-series data).

Investments in infrastructure and human capital
Commercial aquaculture's investments in infrastructure and expenditures in employee trainings are additional indicators of its contribution to economic growth.