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Commercial aquaculture and economic growth, poverty alleviation and food security

Assessment framework

Cover photographs:
Clockwise from top left:
A crocodile seeks haven in the waters below Murchison Falls on the Victoria Nile in northern Uganda. Credit: © FAO/17388/K. Dunn; In-house training ensures a consistent quality tilapia product for this manufacturer. Credit: courtesy of Lake Harvest Aquaculture (Pvt) Ltd; Correct handling and processing are vital to having quality products. Here, processing of tilapia takes less than 90 minutes, from live fish to chilled and ready for packing. Credit: courtesy of Lake Harvest Aquaculture (Pvt) Ltd; Farmed tilapia. Credit: courtesy of Lake Harvest Aquaculture (Pvt) Ltd

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Assessment framework

by

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Within the framework of its continued efforts to reduce food insecurity and alleviate poverty, the FAO Fisheries and Aquaculture Department encourages commercial or business-oriented aquaculture as a means of increasing food availability and accessibility, employment and income, and improving national economies, especially in developing countries. An issue for policy-makers is how to measure and compare the contribution of projects, including aquaculture, to their national economies, their poverty reduction efforts and to food security. This paper aims to help solve this problem by providing quantitative measures through an assessment framework and a useful methodology – the multiplier method. By estimating multipliers, a project's contribution to economic growth and therefore poverty alleviation can be measured; the method can also quantify all aspects of food security. It is a versatile tool and can be used with limited data. However, caution should be exercised because, as with all quantitative measures, reliability of results depends on the quality of data and underlying assumptions. Nonetheless, the multiplier is a valuable means of assessment and can be used as a first step if more sophisticated techniques are unavailable or are too costly. It is hoped that this tool will help policy-makers and development agents in their efforts to promote aquaculture. Although the focus of the document is on developing countries, where most aquaculture occurs, the analysis and methods are applicable everywhere.

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Abstract

This paper proposes some methods for quantifying the contribution of aquaculture to national economies, poverty alleviation and food security so as to improve the much needed political and financial support to the sector for its adequate development. Aquaculture's contribution to a country's economy can be measured by "aquaculture value-added multiplier", an indicator that represents the "increase in gross domestic product corresponding to a one-unit increase in aquaculture value-added. As alleviating poverty occurs by creating well paying jobs, evaluation of the contribution of aquaculture to poverty alleviation can be done through "aquaculture employment multiplier", the increase in the total employment for the entire economy corresponding to one extra job created in aquaculture. The contribution to food availability, one of the three dimensions of food security, can be assessed through the "net sum of protein-equivalent" (direct contribution) and the "ratio between the aquaculture net foreign exchange earning and the total value of food imports" (indirect contribution). "Aquaculture labour-income and employment multipliers" can be used to quantify aquaculture's contribution to food access, the second dimension of food security. Aquaculture tax multiplier and the "aquaculture ratio between the net foreign exchange earning" and the "whole economy net foreign exchange earning" can be used to estimate the sector's contribution to food utilization, the third dimension of food security.

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Foreword

This report aims at assisting countries to identify and quantify, where possible, the contribution of commercial aquaculture to economic growth, poverty alleviation and food security. Knowledge of this information is often needed by policy-makers when defining programmes for their national development agendas. We would like to acknowledge the invaluable contribution of Dr Junning Cai and Professor PingSun Leung, consultants for this project, and Nathanael Hishamunda of the FAO Fisheries and Aquaculture Economics and Policy Division, Development and Planning Service, who prepared this report. Professor Neil Ridler and Dr Jean Calvin N'Jock reviewed the manuscript while Rolf Willmann provided useful comments on an early draft.

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1. Introduction

1.1 BACKGROUND AND PURPOSE

Aquaculture has failed to develop adequately in many parts of the developing world, producing unsatisfactory and often ephemeral results. Experts agree that limited or lacking economic incentives for aquaculture activities has been one of the major causes of its poor, sluggish and short-lived performance. The Food and Agriculture Organization of the United Nations (FAO) believes that promoting aquaculture as a business could yield adequate and solid benefits from the sector, thereby leading to its sustainable development.

In 1999-2000, the FAO's Fisheries and Aquaculture Department, through its Development and Planning Service (FIEP), initiated the promotion of aquaculture as a self-sustained business, referring to it as sustainable commercial aquaculture. The primary targets were developing countries, especially from sub-Saharan Africa. A series of studies were conducted to understand the necessary conditions for commercial aquaculture to emerge and develop in a sustainable manner. Specifically, policies for the promotion of this type of aquaculture, economic feasibility and investment conditions as well as legal, regulatory and institutional frameworks were identified and made available to the targeted audience through a number of publications.

One of the lessons learned in this process is that promoting aquaculture as a business invariably calls for political support. Governments and funding institutions' will to support aquaculture is often a function of how they value the sector in terms of its contribution, real or potential, to food security and poverty alleviation. Both government and funding agencies make decisions on what level of support is provided to a sector based on its potential contribution to a nation's economy.

Unfortunately, more often than not, objective evaluation of the impact of aquaculture in general, and commercial aquaculture in particular, on countries' economies, poverty alleviation and food security, is sorely lacking. Where available, evaluation of the impact of aquaculture on these factors remains qualitative (Kennedy, 2003). Qualitative assessments are not always viewed by policy-makers as acceptable measures of a programme's relevance to the national development agenda, which may help explain the limited support provided to aquaculture in many countries. The objective of this study is to provide policy-makers with the necessary tools for the quantitative appraisal of the impact of aquaculture.

1.2 BASIC CONJECTURES

This study relies on several assumptions, including the definition and benefits of commercial aquaculture. These benefits represent the backbone of the models developed herein.

In this report, commercial aquaculture refers to "fish farming operations whose goal is to maximize profits, where profits are defined as revenues minus costs (perhaps discounted)". The distinction between commercial and noncommercial aquaculture as used in this document does not hinge on whether fish is sold or not. It relies primarily on the existence or absence of a business orientation, and on how factors of production such as labour will be paid (Ridler and Hishamunda, 2001).

Commercial aquaculture supplies aquatic products for consumption, generates business profits, creates jobs, pays labour incomes, including wages and salaries, and provides tax revenues.

Business profits, wages, salaries and taxes, which represent different levels of income from commercial aquaculture and related industries, contribute to the gross domestic product (GDP), which is a basic measure of economic performance. Business profits from commercial aquaculture provide funds for investments and hence stimulate economic growth. So do savings from commercial aquaculture employees.

By creating jobs and providing wages and salaries, commercial aquaculture helps alleviate poverty in general. Because this income can be used to purchase food items which would otherwise be inaccessible, commercial aquaculture can improve food security in particular. A significant contribution of commercial aquaculture to food security is its supply of nutritious aquatic food products. Seafood is an excellent source of high-quality protein. A 150 g single serving of seafood provides 50–60 percent of the daily protein needs for an adult. Seafood also contains various vitamins and minerals. It is typically low in saturated fats, carbohydrates and cholesterol (with the exception of prawns and squid). Evidence indicates that the consumption of two or more servings of seafood per week is associated with a lower prevalence of heart disease. Other health benefits of seafood include lowering blood pressure, possible improvement of symptoms of rheumatoid arthritis, improvement of eczema because of fish omega-3s and decreased incidence of depression (Seafood and Health Alliance, 2008).

Through employment creation an income generation, commercial aquaculture enables more people, especially those in rural areas whose employment opportunities are generally limited, to share the benefits of growth. Therefore, it contributes to the well-being of a country by providing intra-society equity. Tax revenues from commercial aquaculture constitute resources for stimulating growth, poverty alleviation and food security.

Despite the widely accepted importance of commercial aquaculture, systematic and quantitative evaluation of the impacts of commercial aquaculture on national economies, poverty reduction and food security is poorly documented, especially in developing countries (Charles *et al.,* 1997). Insufficiency of adequate data is one major cause of the problem. The lack of conceptual and data-amenable empirical frameworks exacerbates the issue. Yet, systematic and quantitative information about the economic and other impacts of commercial aquaculture is essential for governments and development agents to appreciate its merits. A proper assessment of these impacts allows for the formulation of suitable policies to help develop the sector into a mature and sustainable contributor to the economy and societal well-being. In recognition of this need, this study attempts to develop systematic conceptual and operational empirical frameworks for the assessment of commercial aquaculture's impacts on economic growth, poverty alleviation and food security. While these frameworks have been developed with commercial aquaculture in mind, they can also be applied to other forms of aquaculture, provided that adequate records are available.

1.3 STRUCTURE OF THE REPORT

Following the introduction (Chapter 1), the report is organized into three major chapters. Chapter 2 presents conceptual and empirical frameworks for assessing the contribution of commercial aquaculture to economic growth. Chapter 3 discusses conceptual and empirical frameworks for evaluating the contribution of the sector to poverty alleviation and food security. Chapter 4 presents illustrative examples on how these frameworks can be applied to measure the contributions of commercial aquaculture to the economy, poverty alleviation and food security in several selected countries in sub-Saharan Africa and Latin America. A short section recaps the main findings of this study and concludes the report.

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.

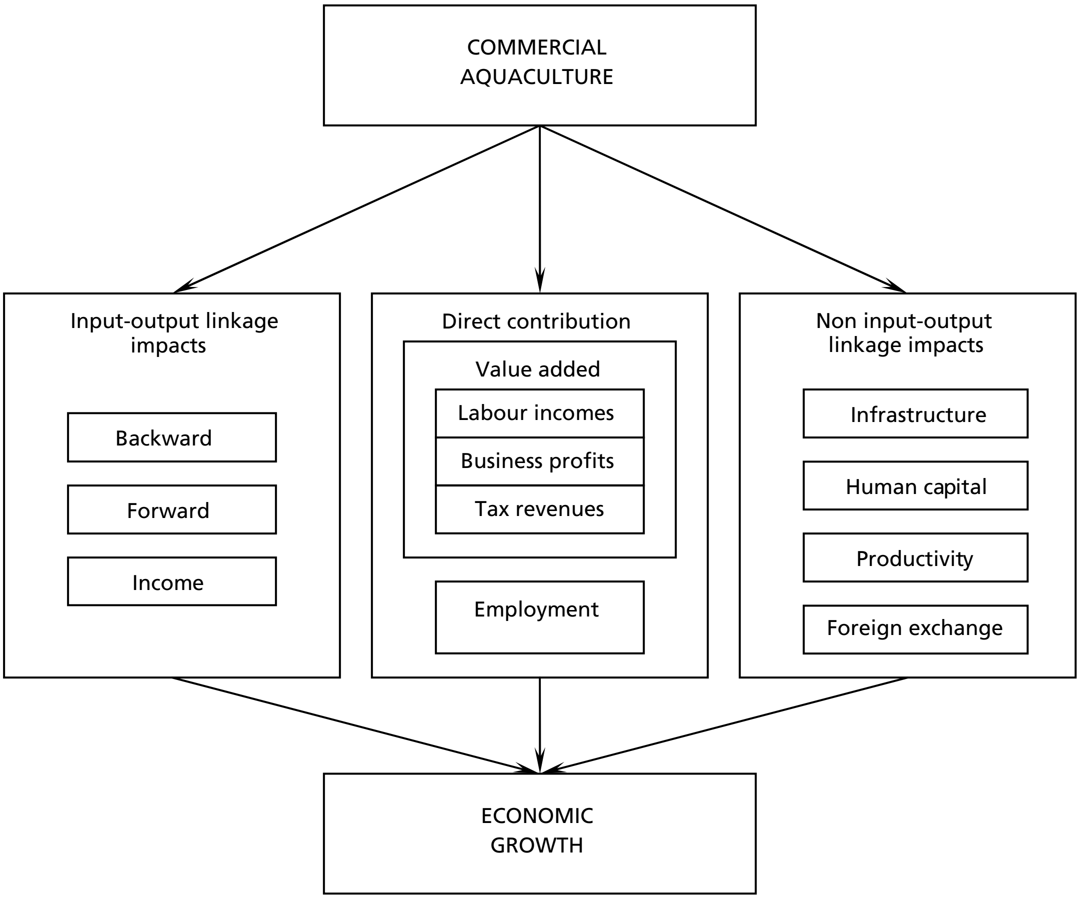
Foreign exchange
Foreign exchanges are valuable resources for developing countries that are often in need of imported goods (Johnston and Mellor, 1961; Timmer, 1992). Thus, foreign exchange earnings generated by exports of commercial aquaculture products constitute an additional contribution to economic 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
Δ = 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).

[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:

$$\mathrm{X}_1 = a_{11}X_1+a_{12}X_2+C_1+G_1+N_1 \quad (1)$$
$$\mathrm{X}_2 = a_{21}X_1+a_{22}X_2+C_2+G_2+N_2 \quad (2)$$

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.

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

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);
η = the ratio of the total consumption (value) to GDP;
θ = 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),

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

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

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] $$M_w = \frac{\varpi}{\omega} M_v,$$

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] $\Delta T_t^{ca} / \Delta T_t^{total}$
[4.3] T_t^{ca} / T_t^{ag}
[4.4] $\Delta T_t^{ca} / \Delta T_t^{ag}$

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] $$M_\tau = \frac{\varpi}{\tau} M_v,$$

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;
α = 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.

3. Contribution of commercial aquaculture to poverty alleviation and food security: an assessment framework

3.1 BASIC CONCEPTS AND BACKGROUND

In addition to economic growth, economic development includes other dimensions such as income distribution, education, health, environment, poverty alleviation, food security, and so on (Johnston and Mellor, 1961; Timmer, 1992). As poverty and food security are two major issues in the regions of sub-Saharan Africa (SSA) and Latin America (LA), we will develop a framework for quantitatively assessing the contribution of commercial aquaculture.

3.1.1 Poverty alleviation

Poverty is a concept that has many dimensions (Maxwell, 1999; UNDP, 2000). In brief, poverty means poor living conditions; its immediate cause is lack of real, financial and other resources; its many symptoms include inadequate provisions (in terms of both quantity and quality) of food, housing, nutrition, health, education, etc.

As poverty is the major culprit for long-term, chronic food security problems, one consequence of commercial aquaculture's contribution to poverty alleviation will be to improve long-term food security. Thus, our assessment framework will be specifically designed for evaluating commercial aquaculture's contribution to food security; indicators used to measure aquaculture's contribution to long-term food security will also be used to measure contributions to poverty alleviation.

3.1.2 Food security

Food security is also a multi-dimensional concept. While long-term, chronic food access problems are a result of persistent poverty, other aspects (such as food availability, food utilization, and transitory food insecurity) require a broader perspective and examination.

3.1.3 Food insecurity in sub-Saharan Africa and Latin America

Lack of food security has been a major issue in the SSA region; conditions are not likely to improve in the near future. During 1998–2000, more than 40 percent of SSA populations were undernourished (FAO, 2002). According to the USDA (2003, p. 12), "fifty-four percent of sub-Saharan Africa's population is estimated to be hungry in 2002. This share is not projected to change during the next decade".

The food security situation for the LA (and Caribbean) region is more promising. Between 1998 and 2000, the shares of undernourished population were around 25% and 10% for the Caribbean area and South America respectively (FAO, 2002). In addition "food security in this region is projected to improve over the next decade, thanks to increasing export earnings and, thus, increased import capacity" (USDA, 2003).

3.1.4 Aquaculture's contribution to food security

The existing and potential contributions of aquaculture to food security have been well recognized. Tidwell and Allan (2001) provided some statistics as to the contribution of fish products to food supply: around one billion people worldwide rely on fish as their primary source of animal protein; fish supplies 17 percent of animal protein in Africa; over 36 million people are employed directly through fishing and aquaculture; consumption of food fish has increased from 40 million tonnes in 1970 to 86 million tonnes in 1998 (FAO, 1999); and fish consumption is expected to reach 110 million tonnes by 2010 (FAO, 2001).

As pointed out by Tacon (2001, p. 63), aquaculture is "an important domestic provider of much needed high-quality animal protein and other essential nutrition (generally at affordable prices to the poorer segments of the community)".

Ahmed and Lorica (2002, p. 125) found "clear evidence of positive income and consumption effects of aquaculture on households" in Asia's experience.

From the perspective of fish farmers, Edwards (1999a, 1999b, 2000) summarized aquaculture's contribution to the livelihoods of the rural poor into "direct" and "indirect" benefits, with the former including the provision of high-quality food, (self) employment, and incomes; and the latter including food supply to local markets, employment opportunities for local communities, efficient resource utilization, and enhancement of farm sustainability through infrastructure construction and (farming) technology innovations.

Brummett and Williams (2000, p. 197) pointed out that high population growth, low elasticity of demand for fish and static fishery production make aquaculture an important supply source for fish products.

3.1.5 Research on aquaculture's contribution to food security

Although the roles of aquaculture in poverty alleviation and food security improvement have been well recognized, there are few systematic and quantitative evaluations of aquaculture's contribution in these two respects, especially from a macroeconomic perspective (Charles *et al.*, 1997).

As pointed out by Tacon (2001), "little or no hard statistical information exists concerning the scale and extent of rural or small-scale aquaculture development within most developing countries and LIFDCs or concerning the direct/indirect impact of these and the more commercial-scale farming activities and assistance projects on food security and poverty alleviation".

In evaluating the state of aquaculture economics related to the Latin American and Caribbean region, Agüero and González (1997, p. 31) pointed out that "the social impact of aquaculture is usually regarded in the existing literature in terms of employment, foreign exchange generation or food supply. However, references to these impacts are descriptive and based on assumed positive impacts (i.e. increased production is assumed to be associated directly to improved community employment and incomes; increased export earnings are assumed to mean increased community welfare, etc.). Therefore, positive impacts are extrapolated from assumed factors and rarely based on in-depth analysis".

In evaluating the state of aquaculture economics related to the Africa and the Middle East region, Stomal and Weigel (1997, p. 22) pointed out that "the absence of economists in the field of African and Middle Eastern aquaculture is felt most strongly in the field of macro-economics. Broadly speaking, two features seem to be missing: a production and marketing chain approach, and an accounting for the direct and indirect effects of aquaculture development upon the local economy".

Some of the difficulties in this line of research include the lack of data, especially for the SSA region, and the lack of a generally accepted methodology (Charles *et al.*, 1997).

Given this background, in the following we attempt to first develop a conceptual and then a data-amenable empirical framework for assessing the contribution of commercial aquaculture to food security.

3.2 ASSESSING THE CONTRIBUTION OF COMMERCIAL AQUACULTURE TO FOOD SECURITY

3.2.1 A conceptual framework

The concept of food security

"Food security exists when all people, at all times, have physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life" (FAO, 1996).

Food security is a multidimensional concept and needs to be examined from different perspectives (Maxwell, 1996). Several evaluation frameworks have been used to evaluate the performance of specific food security programs sponsored by governments or development agents (USAID, 1995; Riely *et al*., 1999; Van Rooyen and Sigwele, 1998; Timmer, 1997; among others). Based on these experiences we will develop a framework for evaluating a specific sector's contribution to food security. Food security includes three major dimensions:

> *"(1) Availability of sufficient quantities of food of appropriate quality, supplied through domestic production or imports;*
> *(2) Access by households and individuals to adequate resources to acquire appropriate foods for a nutritious diet; and*
> *(3) Utilization of food through adequate diet, water, sanitation, and health care."*
> (USAID, 1995; USDA, 1996).

We will examine how commercial aquaculture can directly and indirectly contribute all these three dimensions of food security. It should be noted that these three dimensions are complementary yet not independent. For example, the improvement in food availability will tend to decrease food price and hence make food more accessible.

In general, factors that put food security in danger include chronic poverty, rapid population growth, declining per capita food output, poor infrastructure, ecological constraints, limited arable land, inappropriate policies, disease, poor water and sanitation, inadequate nutritional knowledge, civil war and ethnic conflicts, etc. (Riely *et al*. 1999; USAID, 1995). When evaluating commercial aquaculture's contribution to food security, we will consider how commercial aquaculture can enhance food security by reducing the elements that tend to cause food insecurity.

Contribution to economic growth as a general indicator

As economic growth (especially growth in agriculture) is one of the major elements for poverty alleviation and food security enhancement (Timmer, 1996; Lipton and Ravallion, 1994; Ravallion and Datt, 1996), the indicators for commercial aquaculture's contribution to economic growth discussed above can be taken as general indicators of its contribution to poverty alleviation and food security.

More specifically, commercial aquaculture can directly or indirectly contribute to all of the three major dimensions of food security, i.e. food availability, food access and food utilization.

Contribution to food availability

Two aspects of food availability are food quantity and quality. While food quantity provides a general, physical measure of the extent of food abundance or shortage, food quality is related to ultimate utility provided by food items to consumers.

Commercial aquaculture's contribution to food quantity includes its direct food supplies to domestic markets and its foreign exchange earnings that can be used for food imports. Food imports are vital for food security in many LA and SSA countries whose domestic food production usually cannot keep up with domestic population growth.

Commercial aquaculture's contribution to food quality depends on the characteristics of its products, which include nutrition contents, suitability to local taste, storability, etc. In general, aquatic products are an important source of high-quality animal protein for the LA and SSA countries (FAO, 1997; Tacon, 2004). Besides, aquatic food products generally suit the taste of the population in these countries.

Contribution to food access

Food availability is a necessary condition for food security, but not sufficient. Since households' own food supply may not be sufficient, households without sufficient resources for food purchases will be living in food insecurity, even when there is enough food available to feed all household members. Such a "paradox of plenty" is one example of food access problems.

The major aspect of food access is food affordability, which depends on food price and consumers' incomes.

Food supplies have major impacts on food prices – high food prices are usually caused by food shortage (Timmer, 1997; Haddad, 2000). Thus, aquatic food products supplied by commercial aquaculture to local markets will not only contribute to food availability, but also help food access by making aquatic products affordable to local households.

On the other hand, commercial aquaculture also contributes to food access by providing households with jobs and incomes. As discussed above, commercial aquaculture not only can provide wages (salaries) and jobs to its own employees, but it also stimulates income and job creation in the rest of the economy through its linkage impacts.

Besides affordability, food access is also "a function of the physical environment, social environment and policy environment, which determines how *effectively* households are able to utilize their resources to meet their food security objectives." (Riely *et al.*, 1999, p. 14, emphasis original). In this respect, commercial aquaculture's contribution stems from its investments in infrastructure, its impacts on community formation and its contribution to tax revenues.

Contribution to food utilization

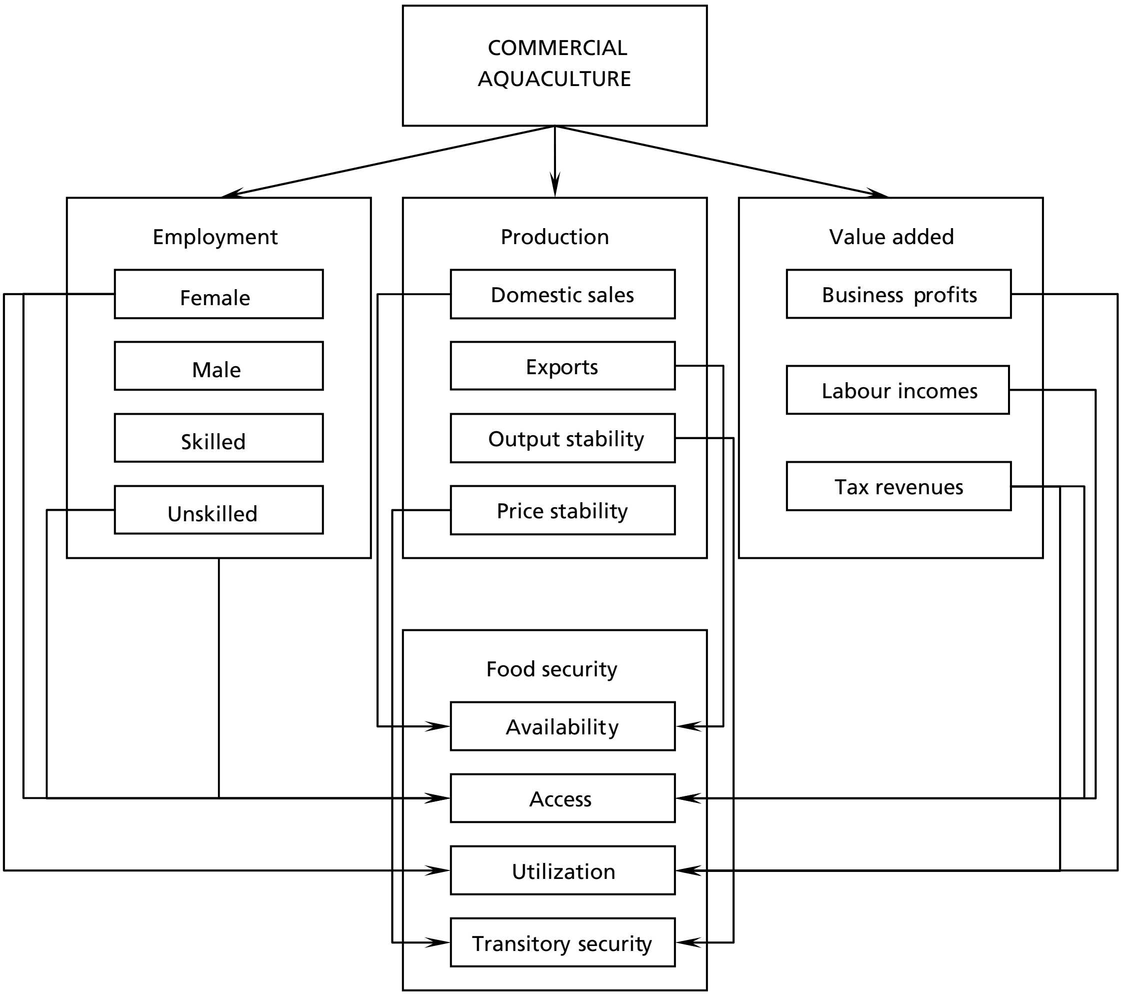
Food utilization is related to microdimensions of food security such as nutrition, food-preparing and sanitation knowledge, dietary habits, health conditions, etc. Commercial aquaculture can contribute to these issues indirectly. For example, commercial aquaculture's tax payments can help finance public health education and health care programmes, infrastructures for sanitation, etc. (Fan, Hazell and Thorat, 1999).

Contribution to short-term food security

In addition to long-term, chronic food security problems, food security is also threatened by transitional shocks such as natural disasters, diseases, food price shocks in domestic or world markets and so on.

By providing diversified aquatic products, commercial aquaculture can increase the stability of domestic food supplies and hence increase the country's resistance to transitory shocks that have negative impacts on food security. In addition, stable commercial aquaculture production will help secure the incomes and jobs of its employees and hence increase the resistance of their households against transitory food insecurity.

FIGURE 2
A conceptual framework for commercial aquaculture's contribution to food security



Summary

The conceptual framework for understanding the contribution of commercial aquaculture to food security is summarized in Figure 2.

3.2.2 Indicators

Indicators for commercial aquaculture's contribution to food availability

Protein and other nutrient supplies

Since aquatic products are an important source of (animal) protein, a rudimental measure of commercial aquaculture's contribution to food availability is its protein supply:

$$[7.1] \quad CPS = \sum_i p_i X_i ,$$

where,

CPS = the protein supply of commercial aquaculture;
p_i = the protein content of a unit of commercial aquaculture product i;
X_i = the quantity of commercial aquaculture product i.

Data needed for calculating indicator [7.1] include the quantity (X_i) and protein content (p_i) of each commercial aquaculture product. Data on X_i are generally available from official statistical sources (such as FAO's FishStat). Data on p_i may be available from secondary resources.

Two extensions of indicator [7.1] are

[7.2] CPS / TPS

[7.3] CPS / APS

where,

TPS = total (actual or desired) protein supply for the entire economy;

APS = total (actual or desired) animal protein supply for the entire economy.

Indicators [7.2] and [7.3] measure the importance of commercial aquaculture as a source of protein in general and animal protein in particular. Data on *TPS* and *APS* are generally available from official statistical sources such as FAO's food balance sheets.

Similar to indicators [7.1]–[7.3], indicators for commercial aquaculture's contribution to other nutrient supplies can be constructed.

Direct and indirect food supplies

A portion of commercial aquaculture production may be exported and hence do not contribute to the domestic food supply directly. Yet, the foreign exchange earnings of commercial aquaculture's exports can indirectly contribute to the domestic food supply. Because of this complication, indicator [7.1] needs to be refined for countries that have non-trivial exports of commercial aquaculture products. We suggest the following two indicators.

[7.4] $CDPS = \sum_i p_i (X_i - Ex_i)$,

[7.5] $CIFS = NFE / FIM$,

where,

$CDPS$ = commercial aquaculture's direct protein supply;

Ex = commercial aquaculture's export quantity;

$CIFS$ = commercial aquaculture's indirect food supply;

NFE = commercial aquaculture's net foreign exchange earnings (defined in indicator [5]);

FIM = total value of food imports.

Indicator [7.4] measures the amount of protein that commercial aquaculture provides directly to domestic households. Despite its conceptual simplicity, one empirical difficulty in calculating indicator [7.4] is the lack of data on commercial aquaculture's exports. Although aquatic commodity export data are available from official statistics sources (e.g. FAO's FishStat or UN's Comtrade), these data may not be applicable directly here since they represent the total aquatic commodity exports that include both capture and culture products. Another problem is unmatched product categorizations for production data and export data. For example, the aquaculture production data in FishStat are categorized as "tilapia", "catfish", "shrimp", etc. Yet, the aquatic commodity trade data are categorized as "fillets", "freshwater fish", etc. Without matched data for production and export, indicator [7.4] cannot be calculated directly. One solution is to find out the export percentage for each commercial aquaculture product. Such information may be available from secondary sources. Otherwise, farm surveys may be necessary to obtain accurate data on the exports of commercial aquaculture products.

The rationale for indicator [7.5] deserves some explanation. *NFE* represents the net foreign exchange earnings of commercial aquaculture, which is equal to its foreign exchange revenues (from exports) minus its foreign exchange costs (for imported inputs). Even though the economy tends to have many other imported requirements besides food imports, indicator [7.5] measures commercial aquaculture's potential contribution to food imports if all of its net foreign exchange earnings are used for food imports. If data on the energy and nutrient contents of countries' food imports are available, we can calculate commercial aquaculture's indirect contribution to domestic food supply in terms of grain equivalents, calories, proteins, etc.

Note that, even though aquatic products *per se* may not be an important source for food energy (as compared to grain and root products) in the SSA and LA regions, commercial aquaculture can be a significant contributor to domestic food energy supply through its indirect food supplies.

Indicators for commercial aquaculture's contribution to food access

Labour income

Wages and salaries provided by commercial aquaculture directly and indirectly are important indicators of its contribution to food access.

[8.1.1] W^{ca}

[8.1.2] $W^{ca} * M_w$

[8.2.1] $w^{ca} = W^{ca} / E^{ca}$

[8.2.2] w^{ca} / w^{ag}

where,

W^{ca} = the total wage (salary) payments of commercial aquaculture to its employees;
M_w = the labour income multiplier defined in indicator [3.5];
E^{ca} = the total jobs provided by commercial aquaculture;
w^{ca} = the average wage (salary) income of commercial aquaculture employees;
w^{ag} = the average wage (salary) income of agriculture employees.

By measuring the labour incomes generated by commercial aquaculture directly or indirectly (through linkages), [8.1.1] and [8.1.2] serve as general indicators of contribution to food access. We assume the more labour income commercial aquaculture can generate, the greater its contribution to food access will be.

Indicators [8.1.1] and [8.1.2] deflated by food prices will reveal commercial aquaculture's "real" contribution to food access. This is especially important when the time series of the two indicators are used to assess commercial aquaculture's contribution to food access over time. For example, suppose commercial aquaculture's total labour income is US$10 million and US$15 million in 2003 and 2004 respectively; and the food price indices for the two years are respectively 1 and 2 (i.e. the food price has increased by 100% in 2004). Under this situation, even though commercial aquaculture provides a higher nominal labour income in 2004 than 2003, its real contribution to food accessibility in 2004, which is equal to US$7.5 million at 2003 prices, is nevertheless smaller because of inflation in food prices.

Indicator [8.2.1] measures the average wage rate in the commercial aquaculture sector; indicator [8.2.2] compares the average wage rate between commercial aquaculture and agriculture in general. A high wage rate of commercial aquaculture will make food more accessible to the families of its employees.

Employment

The jobs and wages (salaries) directly provided by commercial aquaculture are another important indicator of its contribution to food accessibility.

[8.3.1] E^{ca}

[8.3.2] E_j^{ca} / E^{ca}

[8.3.3] E_f^{ca} / E^{ca}

where,

E^{ca} = total jobs provided by commercial aquaculture;

E_j^{ca} = the number of commercial aquaculture's employees with educational level j;

j = no education; primary school graduate; secondary school graduate; etc.;

E_f^{ca} = the number of female employees hired by commercial aquaculture.

Indicator [8.3.1] measures the number of households whose food access will benefit from commercial aquaculture production.

Since populations with low skill levels are in general more likely to be food insecure, indicator [8.3.2] provides an in-depth measure of commercial aquaculture's contribution to food access. If a relatively large share of commercial aquaculture's employees belong to food-insecure-prone cohorts, its contribution to food access will be greater.

Indicator [8.3.3] measures the share of females in commercial aquaculture's labour force. Research has shown that households with female budget-planners tend to be more food secure – in general, female household heads demonstrate a stronger tendency to bring foods to the table rather than spending money in tobacco. Thus a large indicator [8.3.3] implies a greater contribution to food access.

Indicators for commercial aquaculture's contribution to short-term food security

From the perspective of food access, a measure of commercial aquaculture's contribution to short-term, transitory food security is the stability of its production, which will provide income and job security to its employees and hence enhance the food security of their households.

From the perspective of food supply, another measure of commercial aquaculture's contribution to short-term food security is the correlation between its food supply and the total domestic food supply and the price correlation between commercial aquaculture products and general food products. If the food supply of commercial aquaculture does not regularly move in the same direction as the total food supply, it plays a role in stabilizing the total food supply and hence contributes to transitory food security. Similarly, if the prices of commercial aquaculture products do not move regularly in the same direction as the general food price level, it contributes to food price stability, another dimension of short-term food security.

Variance

In general, the volatility of a variable can be measured by the deviations from its mean. Take commercial aquaculture's production as an example. Suppose $X_t = \overline{X}_t + \delta_{X_t}$, which implies that the actual production in time t (X_t) are determined by two factors: one is the mean $\overline{X}_t$ that represents the long-term trend of commercial aquaculture production; the other is a random variable δ_{X_t} that represents transitory shocks. The short-term volatility of X_t is caused by δ_{X_t} and can be measured by the following two indicators.

[9.1.1] $\sigma^2_{X_t} = \sum_t \frac{(X_t - \overline{X}_t)^2}{n}$

[9.1.2] $$\tilde{\sigma}^2_{X_t} = \sum_t \frac{(X_t / \overline{X}_t - 1)^2}{n}$$

where,

$\sigma^2_{X_t}$ = the magnitude variance of X_t;

$\tilde{\sigma}^2_{X_t}$ = the percentage variance of X_t;

X_t = the actual production or protein supply of commercial aquaculture in time t;

$\overline{X}_t$ = the mean production or protein supply of commercial aquaculture in time t;

Indicator [9.1.1] measures the average deviation of commercial aquaculture production from its underlying trend in a sample period whereas indicator [9.1.2] measures the average *percentage* deviation from trend. As opposed to indicator [9.1.1] measuring the magnitude of the fluctuations of commercial aquaculture production, indicator [9.1.2] measures the volatility *per se*. For example, the indicator [9.1.1] for agriculture tends to be always greater than that for commercial aquaculture. Yet it does not necessarily imply that commercial aquaculture production is more stable, but could merely reflect the large magnitude of agriculture production as compared to that of commercial aquaculture. Thus, by removing the scale element, indicator [9.1.2] provides a "weighted" measure of volatility.

Indicators [9.1.1] and [9.1.2] can be used to measure the volatility of commercial aquaculture's production, protein supply or other nutrient supplies. Measurements can be made for individual species or the total range of commercial aquaculture products.

While data for actual production X_t are available, the mean production $\overline{X}_t$ needs to be estimated. Suppose the time trend of X_t is linear; then the mean production $\overline{X}_t$ can be estimated by regressing the actual production X_t on time. Specifically, the regression model will be $X_t = a + bt + \delta_{X_t}$; the least-squares method can be used to estimate parameters a and b; thus, the estimation of $\overline{X}_t$ is equal to $a + bt$.

Similarly, price variability of aquaculture products can be measured by

[9.2.1] $$\sigma^2_{P_t} = \sum_t \frac{(P_t - \overline{P}_t)^2}{n}$$

[9.2.2] $$\tilde{\sigma}^2_{P_t} = \sum_t \frac{(P_t / \overline{P}_t - 1)^2}{n}$$

where,

P_t = the actual price of commercial aquaculture products;

$\overline{P}_t$ = the mean price of commercial aquaculture products;

$\sigma^2_{P_t}$ = the magnitude variance of P_t;

$\tilde{\sigma}^2_{X_t}$ = the percentage variance of P_t.

The interpretations of indicators [9.2.1] or [9.2.2] are similar to those of indicators [9.1.1] and [9.1.2].

Covariance and correlation

Another indicator of commercial aquaculture's contribution to short-term food security is its covariance and correlation with the total domestic food supply.

[9.3.1] $$\operatorname{cov}(x_t, y_t) = \sum_{t=1}^{n} \frac{(x_t - \bar{x})(y_t - \bar{y})}{n}$$

[9.3.2] $$\rho_{x,y} = \frac{\operatorname{cov}(x_t, y_t)}{\sigma_{x_t}\sigma_{y_t}}$$

where,

x = *CPS* (i.e. commercial aquaculture's total protein supply);
y = *TPS* (total protein supply for the entire economy);
$\rho_{x,y}$ or *APS* (total animal protein supply for the entire economy);
$\operatorname{cov}(x_t, y_t)$ = the covariance between x and y;
$\rho_{x,y}$ = the correlation between x and y.
σ_{x_t} = the standard deviation of x_t (as defined for indicator [9.1.1]);
σ_{y_t} = the standard deviation of y_t (as defined for indicator [9.1.1]);

Indicator [9.3.1] [i.e. $\operatorname{cov}(x_t, y_t)$] measures the extent to which x and y co-vary together. A positive indicator [9.3.1] implies that the protein supply of commercial aquaculture and the total domestic protein supply tend to deviate from their means in the same direction; a negative one implies that they tend to deviate in opposite directions. An indicator close to zero implies that there is no observable regularity between their deviations.

Indicator [9.3.2] (i.e. $\rho_{x,y}$) is a standardized covariance between x and y and measures their correlation. For example, suppose x-y covariance is greater than x-z covariance. This may not necessarily mean that x and y tend to deviate from their means in the same direction more often than x and z do, because the larger x-y covariance can also be a result of a larger variance for y than z. Therefore, by dividing the covariance between x and y by their respective variances, $\rho_{x,y}$ provides a measure of the likelihood of x and y deviating from their means in the same direction.

The value of $\rho_{x,y}$ ranges between -1 and 1. A value close to -1 indicates a strong negative correlation between commercial aquaculture's protein supply and the total protein supply, which implies a greater contribution of commercial aquaculture to short-term food security. The reason is straightforward. The negative correlation means that commercial aquaculture's protein supply tends to be above its trend when the below-trend total protein supply is threatening short-term food security. On the contrary, a $\rho_{x,y}$ close to 1 indicates a strong positive correlation between commercial aquaculture's protein supply and the total protein supply, which implies a small contribution of commercial aquaculture to short-term food security.

Also, commercial aquaculture's contribution to food price stability can be measured by the covariance or correlation between the prices of commercial aquaculture products and the general food price index.

[9.4.1] $$\operatorname{cov}(p_t^{ca}, p_t) = \sum_{t=1}^{n} \frac{(p_t^{ca} - \bar{p}_t^{ca})(p_t - \bar{p}_t)}{n}$$

[9.4.2] $$\rho_{p^{ca},p} = \frac{\operatorname{cov}(p_t^{ca}, p_t)}{\sigma_{p_t^{ca}}\sigma_{p_t}}$$

where,

p_t^{ca} = the price of commercial aquaculture products in time t;
p_t = the food price index in time t;
$\operatorname{cov}(p_t^{ca}, p_t)$ = the covariance between p_t^{ca} and p_t;
$\rho_{p^{ca},p}$ = the correlation between p_t^{ca} and p_t.

4. Assessment of commercial aquaculture's contribution to economic growth and food security: examples

In the following we will use data collected from secondary sources to illustrate the applications of the assessment frameworks developed in the preceding sections. Appendix 5 provides a template of data needed for the assessment.

4.1 ASSESSING COMMERCIAL AQUACULTURE'S CONTRIBUTION TO ECONOMIC GROWTH

4.1.1 Commercial tilapia culture in Honduras

The upper half of Table 2 contains data on two commercial tilapia farms in Honduras (Green and Engle, 2000), which were used to estimate their economic contribution in terms of value added, labour income and employment. The estimation results are reported in the lower part of the table.

Value added

The export-oriented farm generates US$14 628 in value added per ha whereas the domestic farm generates US$4 949. The difference is mainly due to variations in production intensity: while the live-weight yield for the former is 20 233 kg/ha, yield is only 7 756 kg/ha for the latter. Note that the average tilapia weight for the export-oriented farm is 600 g whereas the domestic-oriented farm achieves a weight of 250 g.

The value added per kilo is US$0.72 for the export-oriented farm, higher as compared to the domestic-oriented farm (US$0.64). The difference reflects the extra value-added creation by fillet processing in the export-oriented farm.

The VAD/revenue ratio for the more intensive export-oriented farm is 0.35, a little smaller than that for the domestic-oriented farm (0.38). This mainly reflects a higher feed usage by the former. While feed costs represent 53 percent of the revenue for the export-oriented farm, they account for only 46 percent for the domestic-oriented farm. It should be noted that this does not necessarily imply a smaller contribution by the former because, should feed be domestically produced, value added contained in feeds will accrue to the farms' indirect contribution through linkages.

Labour income

Note that the salary of the farm manager accounts for a large portion of the two farms' labour incomes: For the export-oriented farm, the manager's salary is US$19 166 (37 percent of the total labour income), whereas the manager's salary is US$8 575 (63 percent of total labour income) for the domestic-oriented farm.

The average wage for labourers is US$1 413 for the export farm and US$1 240 for the domestic farm.

The labour income per hectare is US$2 153 and US$2 256 for the export and domestic farms, respectively. Excluding the manager's salary, the labourer's wage per hectare is US$1 354 and US$827 for the export and domestic farms, respectively.

TABLE 2
Annual production, revenues, costs and value added for tilapia production in Honduras

A 24-ha (pond area) farm		A 6-ha (pond area) farm	
Total production (live weight; kg)	485 585	Total production (live weight; kg)	46 535
Fillet (kg): $6.60/kg	135 502	Whole-dressed fish (kg):$1.85/kg	41 942
Whole-dressed fish (kg): $2.05/kg	52 519		
Revenues ($)	1 001 997	Revenues ($)	77 593
Total costs ($)	826 584	Total costs ($)	72 275
Fixed costs ($)	123 988	Fixed costs ($)	10 841
Variable costs ($)	702 596	Variable costs ($)	61 434
Seed ($)	11 382	Seed ($)	2 835
Feed ($)	534 160	Feed ($)	35 849
Fertilizer and Chemical ($)	n.a	Fertilizer and chemical ($)	n.a
Energy ($)	n.a.	Energy ($)	n.a.
Labour ($): 1 manager ($19 166) + 23 labourers ($1 413 each)	51 665	Labour ($): 1 manager ($8 575) + 4 labourers ($1 240 each)	13 535
Other variable costs ($)	105 389	Other variable costs ($)	9 215
Value added ($)	351 066	Value added ($)	29 694
VAD per ha ($)	14 628	VAD per ha ($)	4 949
VAD per kg live weight ($)	0.72	VAD per kg live weight ($)	0.64
VAD/revenue ratio	0.35	VAD/revenue ratio	0.38
Labour income ($)	51 665	Labour income ($)	13 535
Labour income per ha ($)	2 153	Labour income per ha ($)	2 256
Labour income per kg live weight ($)	0.11	Labour income per kg live weight ($)	0.29
Labour income/revenue ratio	0.05	Labour income/revenue ratio	0.17
Employment (No. of jobs)	24	Employment (No. of jobs)	5
jobs per ha	1.00	jobs per ha	0.83
jobs per tonne live weight	0.05	jobs per tonne live weight	0.11

Note: Currency shown is US$.
Source: Green and Engle (2000).

Employment

The 24-ha export farm hires one manager and 23 labourers, with an average of 1 employee per ha. The 6-ha domestic farm hires one manager and 4 labourers, with an average of 0.83 employee per ha.

For each tonne of live weight tilapia produced in the export (domestic) farm, 0.05 (0.11) jobs are created. For each million of revenue generated by the export (domestic) farm, 24 (64) jobs are created. The data indicate that the domestic farm is more labour intensive.

4.1.2 Commercial shrimp culture in Honduras

Data shown in Table 3 were obtained from a shrimp farm survey conducted in Honduras in 1997. The total pond area for the entire industry (78 farms) is 12 261 ha. Small, medium and large farms accounted for 2 551 ha, 4 621 ha and 5 089 ha, respectively.

Table 3 reports information on three representative farms with different sizes (73, 293 and 966 ha respectively) corresponding to small, medium and large farm scenarios.

Production and revenues

Reported annual yields were 675, 724 and 410 kg/ha for the small, medium and large farm scenarios, respectively. Thus the estimated total production quantity for the commercial shrimp culture sector is equal to

$$675 \text{ kg/ha} * 2\,551 \text{ ha} + 724 \text{ kg/ha} * 4\,621 \text{ ha} + 410 \text{ kg/ha} * 5\,089 \text{ ha} = 7\,154\,019 \text{ kg},$$

where the 2 551 ha, 4 621 ha and 5 089 ha are respectively the total area of small, medium, and large farms.

TABLE 3
Annual production, revenues, costs, value added, labour income and employment (per ha) for shrimp culture in Honduras (1997)

73-ha farm		293-ha farm		966-ha farm	
Yield (kg/ha):	675	Yield (kg/ha):	724	Yield (kg/ha):	410
Price ($/kg):	8.15	Price ($/kg):	7.92	Price ($/kg):	7.08
Revenues ($/ha)	5 504	Revenues ($/ha)	5 736	Revenues ($/ha)	2 902
Total costs ($/ha)	5 140	Total costs ($/ha)	4 446	Total costs ($/ha)	2 634
Fixed costs ($/ha)	1 023	Fixed costs ($/ha)	801	Fixed costs ($/ha)	216
Variable costs ($/ha)	4 118	Variable costs ($/ha)	3 646	Variable costs ($/ha)	2 420
Seed ($/ha)	1 309	Seed ($/ha)	1 496	Seed ($/ha)	844
Feed ($/ha)	986	Feed ($/ha)	723	Feed ($/ha)	574
Energy ($/ha)	168	Energy ($/ha)	204	Energy ($/ha)	258
Interest on operating capital ($/ha)	622	Interest on operating capital ($/ha)	258	Interest on operating capital ($/ha)	195
Labour cost ($/ha)	585	Labour cost ($/ha)	600	Labour cost ($/ha)	477
Other variable costs ($/ha)	448	Other variable costs ($/ha)	365	Other variable costs ($/ha)	72
Value added ($/ha)	2 593	Value added ($/ha)	2 948	Value added ($/ha)	1 154
VAD per kg ($/kg)	3.84	VAD per kg ($/kg)	4.07	VAD per kg ($/kg)	2.81
VAD/revenue ratio	0.47	VAD/Revenue ratio	0.51	VAD/Revenue ratio	0.40
Labour income ($/ha)	585	Labour income ($/ha)	600	Labour income ($/ha)	477
Labour income per kg	0.87	Labour income per kg ($/kg)	0.83	Labour income per kg ($/kg)	1.16
Labour income/ revenue ratio	0.11	Labour income/ revenue ratio	0.10	Labour income / revenue ratio	0.16
Total employment (No. of job equivalent)	n.a.	Total employment (No. of job equivalent)	n.a.	Total employment (No. of job equivalent)	190
full time (No. of positions):	n.a.	full time (No. of positions):	n.a.	full time (No. of positions): $3 668 per job	82
part time (hrs):	n.a.	part time (hrs):	n.a.	part time (hrs): 0.62 per hour	259 637
job per ha	n.a.	job per ha	n.a.	job per ha	0.20
jobs per tonne	n.a.	jobs per tonne	n.a.	jobs per tonne	0.48
Job/revenue ratio (job/$ million)	n.a.	Job/revenue ratio (job/$ million)	n.a.	Job/revenue ratio (job/$ million)	67.84

Note: Currency shown is US$.
Source: Valderrama and Engle (2001).

Estimated revenues (per ha) were, respectively, US$5 504, US$5 736, and US$2 902 for the small, medium, and large farms. Thus the estimated total production value for the commercial shrimp culture sector is equal to

US$5 504 * 2 551 + US$5 736 * 4 621 + US$2 902 * 5 089 = US$55 315 038.

Value added

The estimated value added (per ha) were US$2 593, US$2 948 and US$1 154 for the small, medium, and large farms, respectively. Thus the estimated total value added for the commercial shrimp culture sector is equal to

US$2 593 * 2 551 + US$2 948 * 4 621 + US$1 154 * 5 089 = US$26 110 157.

Labour income

The labour income (per ha) were US$585, US$600 and US$477 for the small, medium, and large farms, respectively. Thus the estimated total labour income for the commercial shrimp culture sector is equal to

US$585 * 2 551 + US$600 * 4621 + US$477 * 5089 = US$6 692 388.

On average, one-ha of shrimp culture can provide $546 in labour income.

Employment

Since Valderrama and Engle (2001) reported employment data only for the 966-ha farm, we estimated employment for the 73-ha and 293-ha farms.

Total employment for the 966-ha farm is 190 full-time equivalent jobs, including 82 full-time positions (with an average annual wage of US$3 668) and 259 637 hours of part-time positions (with an average hourly wage of US$0.62) equivalent to 108 full-time jobs (assuming a full-time job is 8 hours per day and 300 days per year). Thus, the 966-ha farm provides 82 + 108 = 190 full time equivalent jobs. Therefore, on average, one ha of large size farms will provide 190/966 = 0.20 jobs.

The total labour income for the 966-ha farm is

US$3 668 * 82 + US$0.62 * 250 637 = US$460 559.

Thus the average wage rate is US$460 559/190 = US$2 424.

Employment estimates can be derived for the medium and small farms from their labour incomes, assuming the same wage rate estimated for the large farms.

The total labour income for the 73-ha farm is US$585 * 73 = US$42 705. Thus the estimated employment is US$42 705/US$2 424 = 18 (jobs); 0.24 jobs per ha on average.

The labour income for the 293-ha farm is US$600 * 293=US$175 800. Thus the estimated employment is US$175 800/US$2 424 = 73 (jobs), 0.25 jobs per ha on average.

Therefore, the estimated total employment provided by the shrimp farming industry is 0.24 * 2 551 + 0.25 * 4 621 + 0.20 * 5 089 = 2 785 (jobs).

4.1.3 Commercial salmon culture in Chile

Table 4 shows data on Atlantic salmon culture in Chile in 2000. The data on yields and revenues were obtained from FishStat (FAO, 2006) whereas the data on production costs are as reported by Bjorndal (2002).

Table 4 shows that around 61 percent of total revenues correspond to value added. Specifically, one kilo of cultured Atlantic salmon can generate US$3.4 in revenue and US$2.07 in value added. Total revenues and value added for Atlantic salmon culture were US$567 449 800 and US$345 059 548, respectively. According to FishStat, total revenue for coho salmon is US$345 650 300. Assuming coho salmon has the same VAD/revenue ratio as Atlantic salmon, then the estimated value added for coho salmon culture would be equal to

US$345 059 548 * US$345 650 300/US$567 449 800 = US$210 185 900.

Therefore, the estimated total value-added for Chile's salmon industry is equal to

US$345 059 548 + US$210 185 900 = US$555 245 448.

TABLE 4
Production, revenues, costs, value added, labour income and employment for Atlantic salmon culture in Chile (2000)

Yield (tonnes):	166 897.00
Price ($/kg):	3.40
Revenues (1000$)	567 449.80
Total costs ($/kg)	1.62
Fixed costs ($/kg)	0.23
Variable costs ($/kg)	1.39
Seed ($/kg)	0.31
Feed ($/kg)	0.79
Labour cost ($/kg)	0.06
Other variable costs ($/kg)	0.24
Value added	
Total VAD	345 059 547.50
VAD per kg ($/kg)	2.07
VAD/revenue ratio	0.61
Labour income	
Total labour income	9 596 577.50
Labour income per kg	0.06
Labour income/revenue ratio	0.0169

Note: Currency shown is US$.
Source: Bjorndal (2002).

4.1.4 Commercial tilapia culture in sub-Saharan Africa

Table 5 presents information on three commercial tilapia farms in SSA; ZAM1 is a 32-ha polyculture (tilapia and carp) farm integrated with pig farming in Zambia; ZAM2 is a 5-ha integrated (tilapia, pigs and ducks) farm in Zambia; and NIG2 is a 3.7-ha polyculture (tilapia and catfish) farm in Nigeria.

On average, ZAM1 produces 3 125 kg/ha/year of tilapia and 1 560 kg/ha/year of carp, generating US$3 960/ha of value added and US$375/ha of labour income. ZAM2 produces 5 000 kg/ha/year of tilapia and generates US$2 900/ha of value added and US$2 186/ha of labour income. NIG2 produces 10 000 kg/ha/year of tilapia and 5 000 kg/ha/year of catfish, and generates US$15 421/ha of value added and US$3 812/ha of labour income.

4.1.5 Commercial catfish culture in sub-Saharan Africa

Table 6 shows data on catfish culture in the Central African Republic and the Democratic Republic of the Congo during the 1980s (de Graaf and Janssen, 1996).

One hectare of monoculture catfish generates US$12 281 in value added, US$7 018 in labour income and 6.7 jobs. One hectare of polyculture catfish (and tilapia) farming generates US$10 271 in value added, US$7 018 in labour income and 6.7 jobs.

4.1.6 Commercial shrimp culture in Madagascar

Table 7 shows information on two shrimp farms in Madagascar (Hishamunda and Manning, 2002). Farm MD1 has a 640-ha production area and produces 5 000 kg/ha of *Penaeus monodon*. Annually, it directly generates US$20 million in value added, US$529 000 in labour income, and 407 jobs. On average, one hectare of production

TABLE 5
Annual production, revenues, costs, value added, labour income and employment for tilapia

ZAM1: 32-ha (production area) farm		ZAM2: 5-ha (production area) farm		NIG2: 3.7-ha (production area) farm	
Yield (kg/ha):	4 685	Yield (kg/ha):	5 000	Yield (kg/ha): 10 000 tilapia + 5 000 catfish	15 000
Price ($/kg):	1.00	Price ($/kg):	1.04	Price ($/kg):	1.68
Revenues ($/ha)	4 688	Revenues ($/ha)	5 198	Revenues ($/ha)	25 224
Total costs ($/ha)	2 254	Total costs ($/ha)	4 619	Total costs ($/ha)	14 735
Fixed costs ($/ha)	1 152	Fixed costs ($/ha)	131	Fixed costs ($/ha)	1 120
Variable costs ($/ha)	1 102	Variable costs ($/ha)	4 488	Variable costs ($/ha)	13 615
Seed ($/ha)	672.22	Seed ($/ha)	260.30	Seed ($/ha)	2 315
Feed ($/ha)	11.02	Feed ($/ha)	1 606.70	Feed ($/ha)	2 723
Fertilizer and chemical ($/ha)		Fertilizer and chemical ($/ha)	4.49	Fertilizer and chemical ($/ha)	408.45
Electricity ($/ha)		Electricity ($/ha)	17.95	Electricity ($/ha)	
Labour cost ($/ha)	374.68	Labour cost ($/ha)	2 185.66	Labour cost ($/ha)	3 812.20
Other variable costs ($/ha)	33.06	Other variable costs ($/ha)	408.41	Other variable costs ($/ha)	4 220.65
Value added		Value added ($/ha)		Value added ($/ha)	
Total VAD	126 742	Total VAD	14 478	Total VAD	57 058
VAD per ha ($/ha)	3 961	VAD per ha ($/ha)	2 896	VAD per ha ($/ha)	15 421
VAD per kg ($/kg)	0.85	VAD per kg ($/kg)	0.58	VAD per kg ($/kg)	1.03
VAD/revenue ratio	0.84	VAD/revenue ratio	0.56	VAD/revenue ratio	0.61
Labour income		Labour income		Labour income	
Total labour income ($)	11 990	Total labour income ($)	10 928	Total labour income ($)	14 105
Labour income per worker ($/job)		Labour income per worker ($/job)		Labour income per worker ($/job)	
Labour income per ha ($/ha)	375	Labour income per ha ($/ha)	2 186	Labour income per ha ($/ha)	3 812
Labour income per kg	0.08	Labour income per kg ($/kg)	0.44	Labour income per kg ($/kg)	0.25
Labour income/ revenue ratio	0.08	Labour income/ revenue ratio	0.42	Labour income/ revenue ratio	0.15
Employment		Employment		Employment	
Total jobs		Total jobs	35	Total jobs	
Jobs per ha		Jobs per ha		Jobs per ha	
Jobs per tonne		Jobs per tonne		Jobs per tonne	
Job/revenue ratio (job/$ million)		Job/revenue ratio (job/$ million)		Job/revenue ratio (job/$ million)	

Note: Currency shown in US$.
Data source: Hishamunda and Manning (2002).

area generates US$33 000 in value added, US$827 in labour income, and 0.64 jobs. Farm MD2 has a 138-ha production area and grows 9 058 kg/ha of *P. monodon*. Annually, it directly generates US$5.8 million in value added, US$475 000 in labour income, and 301 jobs. On average, one ha of production area generates US$42 000 in value added, US$3 443 in labour income, and 2.18 jobs.

4.1.7 Commercial aquaculture's contribution to GDP in 14 sub-Saharan African countries

Using the VAD/revenue ratios estimated in the preceding examples in tandem with data on production value provided by FishStat (FAO, 2006), the annual value added of commercial aquaculture was estimated for 14 SSA countries from 1984 to 2000. These estimates were subsequently used to calculate the annual share of commercial aquaculture's value-added in the GDP of each country. Results are reported in Table 8.

The species covered include tilapia, catfish, shrimp and trout, which are representative for most of the countries. Exceptions include Tanzania, which has large seaweed production, and Cameroon, Kenya, Madagascar and Rwanda which have non-trivial carp culture.

TABLE 6
Production, revenues, costs, value added, labour income and employment for catfish culture in SSA

	Monoculture	Polyculture: catfish + tilapia
Pond size (ha):	0.04	0.04
Yield (kg):	720.00	468.00
Price ($/kg):	2.81	1.98
Revenues ($)	2 021.05	926.26
Total costs ($/kg)		
Fixed costs ($/kg)		
Variable costs ($/kg)	1 810.53	796.14
Seed ($/kg)	252.63	53.56
Feed ($/kg)	1 061.05	344.84
Labour cost ($/kg)	280.70	280.70
Other variable costs ($/kg)	216.14	117.04
Value added		
Total VAD ($)	491.23	410.82
VAD per ha ($/ha)	12 280.70	10 270.53
VAD per kg ($/kg)	0.68	0.88
VAD/revenue ratio	0.24	0.44
Labour income		
Total labour income	280.70	280.70
Labour income per ha ($/ha)	7 017.54	7 017.54
Labour income per kg	0.39	0.60
Labour income/revenue ratio	0.14	0.30
Employment		
Total working days	80.00	80.00
Wage rate ($/day)	3.51	3.51
job per ha	6.67	6.67
jobs per tonne	0.37	0.57
Job/revenue ratio (job/$ million)	13.19	28.79

Note: Currency shown is US$.
Data source: de Graaf and Janssen (1996).

The VAD/revenue ratios needed in the estimation were obtained from the examples discussed in previous sections. According to section 4.1.3, the VAD/revenue ratio for salmon culture in Chile is 61 percent, which is used as a representative VAD/revenue ratio for trout. The average VAD/revenue ratio for the three tilapia farms in section 4.1.4 is 67 percent, which is used as a representative VAD/revenue ratio for tilapia. Similarly, the representative ratios for catfish and shrimp are respectively 34 and 61 percent, which are calculated based on the example farms in section 4.1.5 and 4.1.6 respectively. Note that, since these "representative" ratios may not be really representative for every country in every year, results in Table 8 may not be accurate. We present them for illustration purposes only.

The bold (colour) numbers in Table 8 represent VAD/GDP ratios that are higher than previous years. For easier visualization, we calculate the average VAD/GDP ratios for the 14 countries in the sample period and plot them in Figure 3. For comparison purposes, the corresponding output/GDP ratios are also shown in Figure 3.

TABLE 7
Annual production, revenues, costs, value added, labour income and employment for shrimp culture in Madagascar

MD1: 640-ha (production area) farm		MD2: 138-ha (production area) farm	
Yield (kg/ha):	5 000	Yield (kg/ha):	9 058
Price ($/kg):	9.65	Price ($/kg):	8.46
Revenues ($/ha)	48 269.00	Revenues ($/ha)	76 644.00
Total costs ($/ha)	22 235.00	Total costs ($/ha)	39 390.00
Fixed costs ($/ha)	5 703.00	Fixed costs ($/ha)	1 137.00
Variable costs ($/ha)	16 532.00	Variable costs ($/ha)	38 252.00
Seed ($/ha)	2 149.16	Seed ($/ha)	4 207.72
Feed ($/ha)	9 919.20	Feed ($/ha)	24 863.80
Fertilizer and chemical ($/ha)	661.28	Fertilizer and chemical ($/ha)	382.52
Electricity ($/ha)	1 322.56	Electricity ($/ha)	3 442.68
Labour cost ($/ha)	826.60	Labour cost ($/ha)	3 442.68
Other variable costs ($/ha)	1 818.52	Other variable costs ($/ha)	2 295.12
Value added		Value added ($/ha)	
Total VAD	20 840 704	Total VAD	5 773 186
VAD per ha ($/ha)	32 564	VAD per ha ($/ha)	41 835
VAD per kg ($/kg)	6.51	VAD per kg ($/kg)	4.62
VAD/revenue ratio	0.67	VAD/revenue ratio	0.55
Labour income		Labour income	
Total labour income ($)	529 024	Total labour income ($)	475 090
Labour income per worker ($/job)	1 300	Labour income per worker ($/job)	1 578
Labour income per ha ($/ha)	827	Labour income per ha ($/ha)	3 443
Labour income per kg	0.17	Labour income per kg ($/kg)	0.38
Labour income/revenue ratio	0.02	Labour income/revenue ratio	0.04
Employment		Employment	
Total jobs	773	Total jobs	482
No. of jobs for farming	407	No. of jobs for farming	301
No. of jobs for processing	366	No. of jobs for processing	181
Farming jobs per ha	0.64	job per ha	2.18
Farming jobs per tonne	0.13	jobs per tonne	0.24
Farming job/revenue ratio (job/$ million)	13.17	job/revenue ratio (job/$ million)	28.46

Note: Currency shown is US$.
Data source: Hishamunda and Manning (2002).

Table 8 and Figure 3 shows that – we should stress again that the results may not be accurate – although commercial aquaculture's direct contribution to GDP is small (less than 0.05%), it is on an upward trend since the 1990s. Note that the similarity between the dynamics of the VAD/GDP ratio and the output/GDP ratio results primarily from our assumption of a constant VAD/revenue ratio for each species, meaning that potential changes in VAD/revenue ratio over time are disregarded. Yet the estimations do capture the change in the composition of aquaculture products over time, which explains why the VAD/GDP ratio went down from 1995 to 1996 whereas the output/GDP ratio was up.

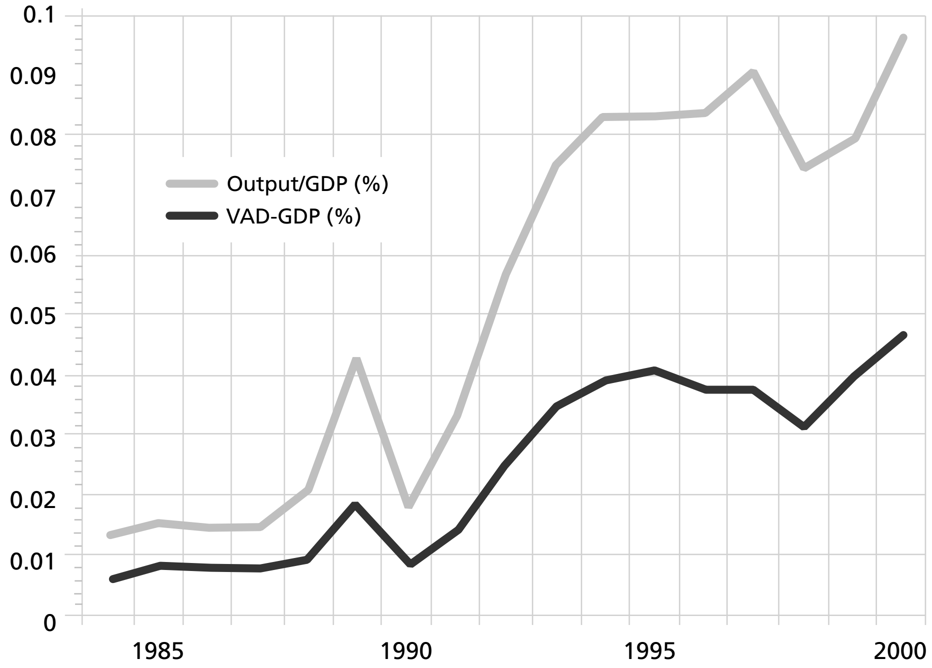
Recall that commercial aquaculture's VAD represents only its direct contribution to GDP. An example showing total (direct and indirect) contribution is presented in the next section.

TABLE 8
Commercial aquaculture's value-added as a percentage of GDP: 14 SSA countries 1984–2000 *(in percentage)*

Year	Cameroon	Central African Republic	Democratic Republic of the Congo	Congo	Côte d'Ivoire	Ghana	Kenya	Madagascar	Malawi	Nigeria	Rwanda	United Republic of Tanzania	Zambia	Zimbabwe
1984	0.0020	0.0444	0.0012	0.0025	0.0002	0.0064	0.0055	0.0114	0.0062	0.0087	0.0021	n.a.	0.0179	0.0055
1985	0.0009	0.0445	0.0027	0.0032	0.0006	0.0051	0.0053	0.0096	0.0093	0.0138	0.0017	n.a.	0.0263	0.0058
1986	0.0007	0.0331	0.0097	0.0050	0.0022	0.0038	0.0048	0.0064	0.0084	0.0157	0.0024	n.a.	0.0295	0.0057
1987	0.0008	0.0159	0.0113	0.0053	0.0024	0.0041	0.0039	0.0069	0.0078	0.0149	0.0032	n.a.	0.0278	0.0052
1988	0.0010	0.0136	0.0092	0.0044	0.0017	0.0047	0.0108	0.0066	0.0076	0.0202	0.0021	0.0003	0.0191	0.0046
1989	0.0011	0.0133	0.0052	0.0034	0.0015	0.0037	0.0123	0.0060	0.0070	0.0566	0.0019	0.0048	0.0187	0.0041
1990	0.0010	0.0135	0.0047	0.0029	0.0011	0.0039	0.0112	0.0086	0.0054	0.0158	0.0101	0.0061	0.0273	0.0039
1991	0.0008	0.0143	0.0057	0.0036	0.0025	0.0047	0.0113	0.0151	0.0057	0.0348	0.0029	0.0060	0.0586	0.0035
1992	0.0008	0.0358	0.0066	0.0124	0.0030	0.0053	0.0106	0.0598	0.0075	0.0524	0.0023	0.0061	0.1115	0.0044
1993	0.0008	0.0310	0.0058	0.0217	0.0053	0.0066	0.0196	0.1225	0.0071	0.0787	0.0024	0.0043	0.1823	0.0048
1994	0.0006	0.0295	0.0082	0.0124	0.0015	0.0083	0.0193	0.1452	0.0113	0.0659	0.0075	0.0035	0.2379	0.0047
1995	0.0008	0.0120	0.0086	0.0093	0.0034	0.0075	0.0195	0.2116	0.0094	0.0641	0.0056	0.0044	0.2607	0.0049
1996	0.0007	0.0088	0.0084	0.0062	0.0084	0.0074	0.0070	0.2587	0.0057	0.0403	0.0070	0.0036	0.3830	0.0043
1997	0.0008	0.0064	0.0135	0.0063	0.0033	0.0058	0.0013	0.3710	0.0055	0.0473	0.0065	0.0028	0.2280	0.0044
1998	0.0008	0.0061	0.0071	0.0087	0.0056	0.0241	0.0009	0.2769	0.0081	0.0462	0.0066	0.0026	0.1324	0.0064
1999	0.0007	0.0121	0.0081	0.0088	0.0066	0.0377	0.0018	0.3537	0.0219	0.0571	0.0134	0.0025	0.1358	0.0073
2000	0.0005	0.0127	0.0074	0.0071	0.0092	0.1122	0.0054	0.4421	0.0226	0.0533	0.0123	0.0019	0.1374	0.0056
2001	0.0005	0.0134	0.0070	0.0083	0.0086	0.1270	0.0105	0.4099	0.0257	0.0430	0.0168	0.0032	0.1211	0.0050

Note: n.a. = not available.

FIGURE 3
Average commercial aquaculture's VAD/GDP (output/GDP) ratios for 14 SSA countries (1984–2000)



4.1.8 Total economic contribution of fishing and fish farming in Tanzania

Data

With the aid of the social accounting matrix (SAM) for Tanzania (Thurlow and Wobst, 2003), the total (direct and indirect) contribution of fishing and fish farming to Tanzania's economy was estimated – part of the data and estimation results are reported in Table 9. Since the available SAMs do not disaggregate fishing and fish farming, additional data are needed to estimate the economic contribution of commercial aquaculture. Yet the methodology will be the same.

Similar to input-output tables, a social accounting matrix is a consistent data framework for describing the intersectoral relationships of an economy, which allows us to apply the two-sector model developed in section 2.2.1 to estimate the contribution of fishing and fish farming through their own production and linkage impacts.

Data availability allows us to estimate the contribution of fishing and fish farming to Tanzania's economy in each of the four years in the period 1998–2001 and hence evaluate its contribution to economic growth.

Contribution to GDP

The real GDP growth rates for Tanzania in 1999, 2000 and 2001 were 7.78, 5.54 and 7.92 percent, respectively.

The value added generated by own production of fishing and fish farming was 4.26, 4.28, 4.18 and 4.09 percent of GDP in 1998, 1999, 2000 and 2001, respectively. When linkage impacts are taken into consideration, the total "contribution" of the sector is 15.28, 15.53, 14.73 and 14.23 percent of GDP in 1998, 1999, 2000 and 2001, respectively.

Fishing and fish farming directly contributed 4.53, 2.36 and 2.93 percent of GDP growth in 1999, 2000 and 2001, respectively. When linkage impacts are taken into consideration, the sector contributed (directly and indirectly) 18.73, 0.32 and 7.93 percent of GDP growth in 1999, 2000 and 2001, respectively.

TABLE 9
Economic contribution of fish and fish farming in Tanzania (1998–2001)

Year	1998	1999	2000	2001
Entire economy				
Consumer price index (1995 = 100)	158.42	170.92	181.04	190.34
Total output (million Tanzania shillings)	10 217.83	11 812.46	13 197.75	14 861.86
GDP (million Tanzania shillings)	5 140.31	5 977.10	6 681.85	7 581.22
GDP growth	n.a.	7.78%	5.54%	7.92%
Total labour income (million Tanzania shillings)	3 048.55	3 556.88	3 952.55	4 502.89
Total labour income growth	n.a.	8.14%	4.91%	8.36%
Total consumption (million Tanzania shillings)	4 905.31	5 662.28	6 065.65	6 911.30
Total employment	?	?	?	?
Agriculture				
Agri output (million Tanzania shillings)	3 084.28	3 573.57	3 960.89	4 456.54
Agri value added (million Tanzania shillings)	2 491.58	2 885.65	3 175.36	3 569.87
Agri labour income (million Tanzania shillings)	1 757.24	2 029.46	2 181.58	2 469.49
Agri consumption (million Tanzania shillings)	1 924.72	2 238.74	2 390.94	2 701.68
Agri employment	?	?	?	?
Commercial fishing and fish farming				
Fish output (million Tanzania shillings)	243.08	282.87	310.37	346.11
Fish VAD (million Tanzania shillings)	219.14	255.96	279.38	310.03
Fish labour income (million Tanzania shillings)	115.40	135.55	144.45	161.77
Fish consumption (million Tanzania shillings)	190.44	225.67	241.78	271.37
Fish sector's intermediate purchases from ROE (million Tanzania shillings)	21.69	23.39	27.20	31.41
Fish sector's intermediate sales to ROE (million Tanzania shillings)	3.33	6.01	10.54	9.40
v_1 (fish sector's VAD/output ratio)	0.9015	0.9049	0.9001	0.8957
v_2 (ROE VAD/output ratio)	0.4934	0.4962	0.4968	0.5009
a_{21} (fish sector's intermediate purchases from ROE/output ratio)	0.0892	0.0827	0.0876	0.0908
a_{22} (ROE intra-industry transaction/output ratio)	0.3535	0.3595	0.3762	0.3639
$_t$ (total consumption/GDP ratio)	0.9543	0.9473	0.9078	0.9116
$_q$ (share of fish products in total consumption)	0.0388	0.0399	0.0399	0.0393
$_v$ (share of fish VAD to GDP)	0.0426	0.0428	0.0418	0.0409
$_w$ (share of fish labour income in total labour income)	0.0379	0.0381	0.0365	0.0359
$_e$ (share of fish employment in the total employment)				
Fish sector's multipliers				
Fish sector's VAD multiplier	3.58	3.63	3.52	3.48
Fish sector's labour income multiplier	4.04	4.07	4.03	3.96
Fish sector's employment multiplier	?	?	?	?
Fish sector's economic contribution				
Contribution to value added				
direct contribution to VAD (million Tanzania shillings)	219.14	255.96	279.38	310.03
percentage to GDP	4.26%	4.28%	4.18%	4.09%
direct VAD growth	n.a.	8.26%	3.05%	5.55%
direct contribution to GDP growth	n.a.	4.53%	2.36%	2.93%
total contribution to VAD (million Tanzania shillings)	785.42	928.16	984.25	1 078.89
percentage to GDP	15.28%	15.53%	14.73%	14.23%
direct + indirect VAD growth	n.a.	9.53%	0.12%	4.26%
direct + indirect contribution to GDP growth	n.a.	18.73%	0.32%	7.93%
Contribution to labour income				
direct contribution to labour income (million Tanzania shillings)	115.40	135.55	144.45	161.77
percentage to total labour income	3.79%	3.81%	3.65%	3.59%
direct labour income growth	n.a.	8.88%	0.61%	6.52%
direct contribution to total labour income growth	n.a.	4.13%	0.47%	2.85%
total contribution to labour income (million Tanzania shillings)	465.80	552.33	582.22	640.81
percentage to total labour income	15.28%	15.53%	14.73%	14.23%
direct + indirect labour income growth	n.a.	9.90%	-0.48%	4.69%
direct + indirect contribution to total labour income growth	n.a.	18.59%	-1.52%	8.26%
Contribution to employment				
direct contribution to employment	?	?	?	?
percentage to total employment	?	?	?	?
total contribution to employment	?	?	?	?
percentage to total employment	?	?	?	?

Data source: Thurlow and Wobst (2003).

Contribution to total labour income

The growth rates of real labour income for Tanzania in 1999, 2000 and 2001 were 8.14, 4.91 and 8.36 percent, respectively.

Labour incomes generated by own production of fishing and fish farming were 3.79, 3.81, 3.65 and 3.59 percent of total labour income in 1998, 1999, 2000 and 2001, respectively. When linkage impacts are taken into consideration, the total "contribution"

TABLE 10
Energy and protein contents of several aquatic products

Species	Edible content per kilo of live weight (kg)	Protein content per kilo of fillet (kg)	Protein content per kilo of live weight (kg)	Energy content per kilo of fillet (kcal)	Energy content per kilo of live weight (kcal)
Common carp	0.35	0.15	0.053	1 270	445
Tilapia	0.25	0.19	0.048	1 230	308
Catfish	0.30	0.16	0.048	1 350	405
Shrimp	0.48	0.20	0.096	1 060	509
Rainbow trout	0.35	0.21	0.074	1 380	483
Salmon (Atlantic)	0.40	0.20	0.080	1 830	732
Salmon (coho)	0.40	0.21	0.084	1 600	640

Data sources: Billard (1999); Fontaínhas-Fernandes *et al.* (1999); NFI (2008); USDA/ARS (2008).

of the sector was 15.28, 15.53, 14.73 and 14.23 percent of total labour income in 1998, 1999, 2000 and 2001, respectively. Note that the ratios are identical to the sector's total GDP contribution. This results from aggregating the rest of the economy as one sector in the two-sector model.

Fishing and fish farming directly contributed 4.13, 0.47 and 2.85 percent of labour income growth in 1999, 2000 and 2001, respectively. When linkage impacts are taken into consideration, the sector contributed (directly and indirectly) 18.59, 1.52 and 8.23 percent of labour income growth in 1999, 2000 and 2001.

Contribution to total employment

Since the social accounting matrices provided in Thurlow and Wobst (2003) do not provide employment information, other sources must be consulted to estimate fishing and fish farming's contribution to employment, which is yet to be completed. However, the above estimations imply that the shares of the sector's direct and indirect employment as a contributors to total employment will be identical to the shares of direct and indirect GDP (or labour income) contribution; that is, 15.28, 15.53, 14.73 and 14.23 percent for 1998, 1999, 2000 and 2001.

4.2 EXAMPLES OF CONTRIBUTION TO FOOD SECURITY

4.2.1 Contribution to food availability (protein supply)

Data

We have gathered data on the energy and protein content of several common aquaculture species from a variety of sources. Table 10 summarizes this information.

In addition to statistics on commercial aquaculture production, data in Table 10 allow us to estimate commercial aquaculture's contribution to food energy and protein supply. Since aquatic products are not a major source of food energy supply, focus is made on its contribution to protein supply.

Results

Table 11 shows the results of the estimation. We consider commercial aquaculture's contribution to protein supply in 14 SSA countries during three time periods: 1986–1990, 1991–1995, and 1996–2000.

Data for aquaculture production were obtained from FishStat (FAO, 2006). We considered only the species covered in Table 10, which generally include most of aquaculture production. Data on the countries' total fish and animal protein supplies come from FAO's food balance sheets (FAO, 2008).

To measure the importance of fish as a source of proteins, we calculated the contribution of fish to the total supply of animal protein (first set of columns in Table 11). Fish is a fairly important animal protein source in the 14 SSA countries: on average, around 30 percent of animal protein supply comes from aquatic products.

TABLE 11
Aquaculture's share of fish and animal protein

Countries	Fish/animal protein ratio (%)				Aquaculture percentage of total fish protein			Aquaculture percentage of total animal protein		
	1986–1990	*1991–1995*	*1996–2000*	*Average*	*1986–1990*	*1991–1995*	*1996–2000*	*1986–1990*	*1991–1995*	*1996–2000*
Ghana	63	59	64	62	0.04	0.05	0.29	0.03	0.03	0.19
Congo	61	48	48	52	0.09	0.10	0.08	0.06	0.05	0.04
Malawi	48	42	40	43	0.05	0.03	0.17	0.02	0.01	0.07
Côte d'Ivoire	43	39	37	40	0.08	0.19	0.31	0.03	0.08	0.12
United Republic of Tanzania	37	32	33	34	0.02	0.04	0.02	0.01	0.01	0.01
Democratic Rep. of the Congo	34	33	32	33	0.12	0.11	0.08	0.04	0.04	0.03
Nigeria	36	26	23	28	0.61	0.82	0.58	0.22	0.22	0.13
Cameroon	28	24	25	26	0.04	0.02	0.02	0.01	0.01	0.01
Zambia	27	25	23	25	0.72	2.25	2.45	0.19	0.56	0.57
Madagascar	15	16	15	15	0.12	1.46	4.28	0.02	0.23	0.65
Kenya	10	11	10	10	0.28	0.45	0.11	0.03	0.05	0.01
Central African Republic	12	10	8	10	0.33	0.78	0.37	0.04	0.08	0.03
Zimbabwe	7	10	11	9	0.37	0.24	0.24	0.02	0.03	0.03
Rwanda	3	5	5	4	1.25	0.66	1.89	0.04	0.03	0.09
Average	**31**	**28**	**26**	**29**	**0.31**	**0.44**	**0.51**	**0.06**	**0.09**	**0.10**

One notable fact is that the contribution of fish to the animal protein supply decreased from 31 percent during the second half of the 1980s to 26 percent during the second half of the 1990s. Unfortunately, this does not imply a shift to superior protein sources. Rather, the protein supply in SSA countries declined during the period under study; the declining fish/animal protein ratio implies that fish protein supply has been falling at even a faster rate.

The last two column sets in Table 11 show the contribution of aquaculture to fish and animal protein supply, respectively. Because aquaculture is severely underdeveloped in the region, it contributes less than one percent of total fish protein supply. Nevertheless, these findings highlight the importance of aquaculture development. As population growth in the region places increased pressure on food supply in general and fish supply in particular, capture fisheries will eventually not be able to meet the full demand for fish protein; hence aquaculture must assume an important role in filling the protein gap. A positive development in this regard is that aquaculture's contribution has been increasing during the sample period.

4.2.2 Contribution to food access

To estimate aquaculture's contribution to food access, we calculated aquaculture's labour income indices for 11 SSA countries during 1986–2000. First we estimated total labour income provided by aquaculture activities in each year. We used the labour income-revenue ratios estimated from the examples in sections 4.14–4.16 together with the revenue data provided by FishStat to estimate labour incomes. Limited by the availability of labour income-output ratios, we considered only tilapia, catfish and

TABLE 12
Real labour income as an indicator of aquaculture's contribution to food access

Year	Central African Republic	Congo	Ghana	Kenya	Madagascar	Malawi	Nigeria	Rwanda	United Rep. of Tanzania	Zambia	Zimbabwe
1986	146	55	9	45	8	75	19	51	21	40	116
1987	73	63	11	43	10	65	40	61	21	44	99
1988	69	53	13	133	10	65	41	40	11	27	100
1989	71	47	10	149	10	63	127	37	151	21	100
1990	73	40	11	151	12	51	43	185	185	26	98
1991	79	52	15	132	11	59	103	58	181	64	110
1992	184	198	18	109	93	64	229	49	193	97	91
1993	161	227	25	187	101	67	182	43	138	145	80
1994	162	159	33	163	187	88	116	64	114	192	83
1995	68	120	27	205	145	80	76	78	143	214	82
1996	48	91	29	129	146	57	47	98	118	285	86
1997	33	88	23	20	315	57	52	97	101	182	89
1998	33	92	96	15	168	86	41	90	93	99	124
1999	72	112	165	37	219	234	217	237	96	102	130
2000	76	150	569	92	235	258	262	221	79	114	101

shrimp, which are the most important species in most of the sample countries. An additional problem is that the ratios may not be representative; hence the estimated labour incomes may not be accurate.

Since the estimated labour incomes are in nominal terms, we deflated them with food price indices to provide a measure of their food purchasing power. These labour income indices can then be interpreted as indicators of aquaculture's contribution to food access.

Results are shown in Table 12. Labour incomes have fluctuated over time, with a recent trend towards increasing incomes.

4.2.3 Contribution to short-term food security

We used the average percentage deviation from an estimated trend as a measure of the volatility of aquaculture's protein supply, which is one indicator of its potential contribution to short-term food security.

We first estimated aquaculture's protein supply in the sample periods. Then we used least-squares regression to determine a linear time trend for the data. The differences between actual supply and the supply trend were viewed as random transitory shocks. The ratio between the residuals and the corresponding supply trend prediction provided percentage deviations; averages were subsequently computed based on the absolute values of the percentage deviations over the sample periods. The resulting volatility measure is similar to $\tilde{\sigma}_{X_t}$ in indicator [9.1.2].

The first column in Table 13 shows the average volatility (during 1990–2000) of commercial aquaculture's production value in 12 SSA countries. In aggregate, the average volatility is 28 percent. Yet, the dispersion is uneven: the Central African Republic, Kenya, Rwanda and Zambia have large production volatility; the Democratic

TABLE 13
Aquaculture's contribution to transitory food security (1990-2000)

Countries	Average percentage deviation from trend		Correlations among different sources of protein supply	
	Commercial aquaculture's production value *(%)*	Commercial aquaculture's protein supply *(%)*	Aquaculture and total fish protein	Aquaculture and total animal protein
Cameroon	14.61	17.72 (-)	0.93	0.87
Central African Republic	44.73	36.64 (+)	-0.58	-0.10
Democratic Rep. of the Congo	6.57	3.29 (+)	0.24	0.26
Congo	34.91	26.76 (-)	0.65	0.19
Côte d'Ivoire	32.10	38.04 (+)	0.09	0.27
Kenya	61.90	52.10 (+)	0.43	0.08
Madagascar	3.57	23.93 (-)	-0.21	-0.08
Nigeria	17.90	25.27 (+)	-0.73	-0.68
Rwanda	54.79	47.30 (+)	0.10	-0.79
United Rep. of Tanzania	12.72	23.31 (+)	0.19	0.17
Zambia	49.22	18.88 (-)	0.64	0.68
Zimbabwe	5.18	4.92 (+)	-0.10	0.47
Average	**28.18**	**26.51**	**0.14**	**0.11**

Republic of the Congo, Madagascar and Zimbabwe have low production volatility. Low volatility implies stable incomes and jobs for employees and hence a greater contribution to the food-access dimension of short-term food security.

The second column in Table 13 shows the average volatility for commercial aquaculture's protein supply, with an average 27 percent deviation from the trend for the 12 countries. To examine whether commercial aquaculture contributes to stabilize total animal protein supply, we calculated the average volatility for total animal protein supply with and without commercial aquaculture. A positive (negative) sign in the parentheses in the second column indicates that commercial aquaculture makes the total protein supply less (more) volatile. Results show that commercial aquaculture plays a stabilizing role in the supply of animal protein in most of the sample countries except Cameroon, Congo, Madagascar and Zambia.

Another measure of the role of commercial aquaculture in stabilizing protein supply is provided by the correlations between its own protein supply and the total supply of fish protein or animal protein (last two columns in Table 13). On average, the correlations are small (0.14 and 0.11 for total fish and animal protein supply, respectively), which implies a general stabilizing role for commercial aquaculture. Again, the dispersion across countries is large. Nigeria and Rwanda have correlations between commercial aquaculture protein supplies and total animal protein supplies close to -1, which implies a potentially large contribution to short-term food security. On the contrary, Cameroon, Zambia and Zimbabwe show correlations close to 1 and hence imply a potentially small contribution from aquaculture to short-term food security.

Note that Madagascar's commercial aquaculture has been identified (in the second column of Table 13) as a destabilizing factor for total animal protein supply whereas a negative correlation is shown in the fourth column, which implies otherwise. This is not a contradiction. The negative correlation in the fourth column implies a high frequency for commercial aquaculture and total animal protein supplies to deviate from their trends in opposite directions in a given period. Yet, if the magnitudes of their low-frequency, positively-correlated deviations are sufficiently large, commercial aquaculture will still play a destabilizing role for total protein supply.

Another caveat is in order. We assumed linear trends during the sample period. However, if the trends are not linear for reasons such as structural changes in commercial aquaculture or other protein supply sources, then we would have interpreted changes in long-term trends as short-term volatilities. Therefore, an adequate choice of sample periods is essential.

5. Summary

This document presents conceptual and empirical frameworks for assessing the contribution of commercial aquaculture to economic growth, poverty alleviation, and food security. Conceptually, we focused on value added (as contribution to GDP), labour income and employment as three major dimensions of economic growth, and examined how commercial aquaculture contributes to them via its own production as well as its linkage impacts on the rest of the economy. Other dimensions include commercial aquaculture's contribution to tax revenues, investments in human and non-human capital, productivity, foreign exchanges, among others.

Commercial aquaculture's contribution to economic growth is a general measure of its contribution to poverty alleviation and food security. Specifically, we developed a conceptual framework that focuses on commercial aquaculture's contribution to long-term food security (including food availability, access, and utilization as three major dimensions) as well as its contribution to short-term, transitory food security through stable production (prices) and diversified food supplies.

Based on the conceptual frameworks established, we developed indicators for quantitative assessments of the many dimensions of commercial aquaculture's economic contributions, explained the rationales behind them, discussed the data needed to operationalize them, and provided some illustrative examples of their applications. Table 14 provides a summary of the indicators used for the assessment.

TABLE 14
Indicators for commercial aquaculture's economic contribution

Indicators for commercial aquaculture's economic contribution

Dimensions	Index	Indicators	Notes
Gross domestic product			
	[1.1]	VAD_t^{ca} / GDP_t	share of CA's value added in GDP
	[1.2]	$\Delta VAD_t^{ca} / \Delta GDP_t$	CA's contribution to GDP growth
	[1.3]	VAD_t^{ca} / VAD_t^{ag}	share of CA's VAD in agriculture VAD
	[1.4]	$\Delta VAD_t^{ca} / \Delta VAD_t^{ag}$	CA's contribution to agriculture VAD growth
	[1.5]	M_v	VAD multiplier
Employment			
	[2.1]	E_t^{ca} / E_t^{total}	share of CA employment in total employment
	[2.2]	$\Delta E_t^{ca} / \Delta E_t^{total}$	CA's contribution to total employment growth
	[2.3]	E_t^{ca} / E_t^{ag}	share of CA employment in total agriculture employment
	[2.4]	$\Delta E_t^{ca} / \Delta E_t^{ag}$	CA's contribution to agriculture employment growth
	[2.5]	M_e	employment multiplier
Labour income			
	[3.1]	W_t^{ca} / W_t^{total}	share of CA's labor income in total labor income
	[3.2]	$\Delta W_t^{ca} / \Delta W_t^{total}$	CA's contribution to total labor income growth
	[3.3]	W_t^{ca} / W_t^{ag}	share of CA's labor income in total agriculture labor income
	[3.4]	$\Delta W_t^{ca} / \Delta W_t^{ag}$	CA's contribution to agriculture labor income growth
	[3.5]	M_w	labor income multiplier
Tax revenues			
	[4.1]	T_t^{ca} / T_t^{total}	share of CA's tax payments in total tax revenues
	[4.2]	$\Delta T_t^{ca} / \Delta T_t^{total}$	CA's contribution to total tax revenue growth
	[4.3]	T_t^{ca} / T_t^{ag}	share of CA's tax payments in total agriculture tax payments
	[4.4]	$\Delta T_t^{ca} / \Delta T_t^{ag}$	CA's contribution to agriculture tax payment growth
	[4.5]	M_τ	tax multiplier
Foreign exchange			
	[5]	NFE	net foreign exchange earning
Productivity			
	[6.1]	CA output per worker	CA's labor productivity
	[6.2]	CA output per ha	CA's land productivity
	[6.3]	*TFP*	Total factor productivity based on structural models
	[6.4]	ln(*TFP*)	Total factor productivity based on index analysis
Food availability			
	[7.1]	*CPS*	CA's protein (or other nutrients) supply
	[7.2]	*CPS* / *TPS*	share of CA's protein supply in total protein supply
	[7.3]	*CPS* / *APS*	share of CA's protein supply in total animal protein supply
	[7.4]	*CDPS*	CA's direct protein supply
	[7.5]	*CIFS*	CA's indirect food supply
Food access			
	[8.1.1]	W^{ca}	CA's direct contribution to labor income
	[8.1.2]	$W^{ca} * M_w$	CA's total contribution to labor income
	[8.2.1]	w^{ca}	CA's average wage rate
	[8.2.2]	w^{ca} / w^{ag}	wage level comparison between CA and agriculture
	[8.3.1]	E^{ca}	CA's employment
	[8.3.2]	E_j^{ca} / E^{ca}	CA's employment composition
	[8.3.3]	E_f^{ca} / E^{ca}	female share in CA's employment
Transitory food security			
	[9.1.1]	σ_x^2	magnitude deviation of production (protein supply) from trend
	[9.1.2]	σ_x^2 (tilda)	percentage deviation of production from trend
	[9.2.1]	σ_p^2	magnitude deviation of price from trend
	[9.2.2]	σ_p^2 (tilda)	percentage deviation of price from trend
	[9.3.1]	cov (x, y)	covariance between x and y
	[9.3.2]	$\rho_{x,y}$	correlation between x and y

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Appendix 1

Derivation of the value added multiplier M_v

By total differentiating simultaneous equations (1) – (8), we obtain

$$dX_1 = a_{11}dX_1 + a_{12}dX_2 + dC_1 + dG_1 + dN_1 \quad \text{(A.1)}$$
$$dX_2 = a_{21}dX_1 + a_{22}dX_2 + dC_2 + dG_2 + dN_2 \quad \text{(A.2)}$$
$$dV_1 = v_1 dX_1 \quad \text{(A.3)}$$
$$dV_2 = v_2 dX_2 \quad \text{(A.4)}$$
$$dY = dV_1 + dV_2 \quad \text{(A.5)}$$
$$dC = \eta dY \quad \text{(A.6)}$$
$$dC_1 = \theta dC \quad \text{(A.7)}$$
$$dC_2 = (1-\theta)dC \quad \text{(A.8)}$$

We first derive dY/dX_1, which measures the change in GDP (dY) caused by a one-unit change in commercial aquaculture's output ($dX_1 = 1$).

Using equations (A.6) and (A.8) to replace dC, we obtain

$$dC_2 = \eta(1-\theta)dY \quad \text{(A.9)}$$

Using equations (A.3), (A.4) and (A.5) to replace dV_1 and dV_2, we obtain

$$dX_2 = v_2^{-1}dY - v_2^{-1}v_1 dX_1 \quad \text{(A.10)}$$

Assume that the change in commercial aquaculture's production (i.e. dX_1) does not affect government's consumption of the ROE's products (i.e. $dG_2 = 0$) and the net export of the ROE's products ($dN_2 = 0$). Then equation (A.2) can be reduced to

$$dX_2 = a_{21}dX_1 + a_{22}dX_2 + dC_2 \quad \text{(A.2')}$$

Substituting equation (A.9) and (A.10) into (A.2'), we obtain
which can be rearranged into

$$(1-a_{22})(v_2^{-1}dY - v_2^{-1}v_1 dX_1) - a_{21}dX_1 - \eta(1-\theta)dY = 0$$

We now derive the value added multiplier $M_v = dY/dV_1$, which measures the change

$$\frac{dY}{dX_1} = \frac{(1-a_{22})v_1 + a_{21}v_2}{1-a_{22}-\eta(1-\theta)v_2} \quad \text{(A.11)}$$

in GDP (dY) that corresponds to a one-unit change in aquaculture's value added ($dV_1 = 1$).

$$M_v = \frac{dY}{dV_1}$$
$$= \frac{dY}{v_1 dX_1} \quad \text{(using A.3)} \quad \text{(A.12)}$$
$$= \frac{1-a_{22}+a_{21}(v_2/v_1)}{1-a_{22}-\eta(1-\theta)v_2} \quad \text{(using A.11)}$$

Appendix 2
Derivation of the employment multiplier M_e

The employment multiplier $M_e = dE^{total}/dE^{ca}$ measures the change in total employment for the entire economy (dE^{total}) that corresponds to a one-unit change in commercial aquaculture's employment ($dE^{ca} = 1$).

Let

$$e^{total} = Y / E^{total} \tag{A.13}$$

denote GDP per worker.

Let

$$e^{ca} = X_1 / E^{ca} \tag{A.14}$$

denotes output per worker for commercial aquaculture.
Assume e^{total} and e^{ca} are constant; then we obtain

$$\begin{aligned} M_e &= \frac{dE^{total}}{dE^{ca}} \\ &= \frac{e^{ca}}{e^{total}}\frac{dY}{dX_1} && \text{(using A.13 and A.14)} \\ &= \frac{e^{ca}}{e^{total}} v_1 M_v && \text{(using A.12)} \\ &= \frac{X_1 / E^{ca}}{Y / E^{total}}\frac{V_1}{X_1} M_v && \text{(using A.13, A.14 and the definition of } v_1\text{)} \\ &= \frac{\varpi}{\varepsilon} M_v \end{aligned} \tag{A.15}$$

where $\varpi = V_1 / Y$ measures the share of commercial aquaculture's value added in GDP; and $\varepsilon = E^{ca} / E^{total}$ measures the share of commercial aquaculture employment in total employment.

Appendix 3
Derivation of the labour income multiplier M_w

The labour income multiplier $M_w = dW^{total} / dW^{ca}$ measures the change in total labour income for the entire economy (dW^{total}) that corresponds to a one-unit change in commercial aquaculture's labour income ($dW^{ca} = 1$).

Let

$$l^{total} = W^{total} / Y \tag{A.16}$$

denote the share of labour income in GDP.

Let

$$l^{ca} = W^{ca} / V_1 \tag{A.17}$$

denotes the share of labour income in value added for commercial aquaculture.
Assume l^{total} and l^{ca} are constant; then we obtain the following.

$$\begin{aligned}
M_w &= \frac{dW^{total}}{dW^{ca}} \\
&= \frac{l^{total}}{l^{ca}} \frac{dY}{dV_1} && \text{(using A.16 and A.17)} \\
&= \frac{W^{total} / Y}{W^{ca} / V_1} M_v && \text{(using A.12, A.16 and A.17)} \qquad \text{(A.18)} \\
&= \frac{V_1 / Y}{W^{ca} / W^{total}} M_v \\
&= \frac{\varpi}{\omega} M_v
\end{aligned}$$

where $\varpi = V_1 / Y$ measures the share of commercial aquaculture's value added in GDP and $\omega = W^{ca} / W^{total}$ measures the share of commercial aquaculture labour income in total labour income.

Appendix 4
Derivation of the tax multiplier M_t

The tax multiplier $M_\tau = dT^{total} / dT^{ca}$ measures the change in total tax revenues for the entire economy (dT^{total}) that corresponds to a one-unit change in commercial aquaculture's tax payment $(dT^{ca} = 1)$.

Let

$$t^{total} = T^{total} / Y \tag{A.19}$$

denote the share of tax revenues in GDP.

Let

$$t^{ca} = T^{ca} / V_1 \tag{A.20}$$

denotes the share of tax payments in value added for commercial aquaculture.
Assume t^{total} and t^{ca} are constant; then we obtain the following:

$$\begin{aligned} M_\tau &= \frac{dT^{total}}{dT^{ca}} \\ &= \frac{t^{total}}{t^{ca}} \frac{dY}{dV_1} && \text{(using A.18 and A.19)} \\ &= \frac{T^{total}/Y}{T^{ca}/V_1} M_v && \text{(using A.12, A.18 and A.19)} \\ &= \frac{V_1/Y}{T^{ca}/T^{total}} M_v \\ &= \frac{\varpi}{\tau} M_v \end{aligned} \tag{A.21}$$

where $\varpi = V_1 / Y$ measures the share of commercial aquaculture's value added in GDP; and $\tau = W^{ca} / W^{total}$ measure the share of commercial aquaculture's tax payments relative to the total tax revenues for the entire economy.

Appendix 5
Data template

The following is a template of data needed for assessing commercial aquaculture's contribution to economic growth, poverty alleviation and food security.

CA contribution to growth, poverty alleviation and food security (data template)

Aggregate							
	General:	Value	Quantity	Price			
1	Aggregate output	?	—	—			
2	Gross national product (GNP)	√?	—	—			
3	Aggregate employment	—	√?	—			
4	Aggregate labour Income	√?	—	—			
	Aggregate consumption	√?	—	—			
	Savings rate	√?	—	—			
Agriculture							
	General:	Value	Quantity	Price			
5	Agriculture output	?E	—	—			
6	Agriculture VAD	?	—	—			
7	Agriculture employment	—	E	—			
8	Agriculture labour income	?	—	—			
	Major agriculture products:	Value	Quantity	Price			
	Item I	?E	?	?			
	Item II	?E	?	?			
	Item N	?E	?	?			
9	Total	?E	—	—			
Commercial aquaculture (CA)							
	Basic:	**CA Product I, II, III…**			**Total**		
		Value	Quantity	Prices	Value	Quantity	Price
10	Output	E	?	?	E	—	—
11	Value added	?E	—	—	E	—	—
12	Employment	—	?E	?E	—	E	—
13	Labour income	?E	—	—	E	—	—
	Sales:	**CA Product I, II, III…**			**Total**		
		Value	Quantity	Prices	Value	Quantity	Price
14	Domestic sales	E	?	?	E	—	—
15	Domestic intermediate sales	E	?	—	E	—	—
16	Domestic consumption	E	E	—	E	—	—
17	Exports	√?	√?	?E	E	—	—

Symbols: **?** (to be collected); √ (high availability); **E** (to be estimated or calculated); **—** (unnecessary)

Data template (continued)

Commercial aquaculture (CA)

	Cost structure:	**CA Product I, II, III…**			**Total**		
		Value	Quantity	Prices	Value	Quantity	Price
18	Fixed costs	?E	?	?	E	—	—
19	Variable costs	?E	?	?	E	—	—
20	Labour costs	?E	?	?	E	—	—
21	Profits	?E	—	—	E	—	—

	Productive capital structure:	**CA Product I, II, III…**			**Total**		
		Value	Quantity	Prices	Value	Quantity	Price
22	Land	?E	?	?	E	E	—
23	Ponds	?E	?	?	E	E	—
24	Equipments	?E	?	?	E	E	—
25	Infrastructure	?E	—	—	E	—	—

	Intermediate input structure:	**CA Product I, II, III…**				**Total**			
		Value	Quantity	Prices	Import content	Value	Quantity	Price	Import content
26	Feed	?E	?	?	?	E	—	—	E
27	Seed	?E	?	?	?	E	—	—	E
28	Fertilizer and chemicals	?E	?	?	?	E	—	—	E
29	Fuel	?E	?	?	?	E	—	—	E
30	Electricity	?E	?	?	?	E	—	—	E
31	Water	?E	?	?	?	E	—	—	E
32	Others	?E	?	?	?	E	—	—	E

	Investments:	Value
33	Infrastructures	?
34	Employment training	?

Others

	Food imports:	Value	Quantity	Price	Calorie	Protein
	Item I	E	√?	√?	E	E
	Item II	E	√?	√?	E	E
	Item N	E	√?	√?	E	E
35	Total	E	—	—	E	E

	Food supply:	Total	Domestic	Import
36	Calorie	√?E	?	?
37	Protein	?	?	?

Symbols: **?** (to be collected); √ (high availability); **E** (to be estimated or calculated); **—** (unnecessary)

There is ample evidence that, when properly conducted, especially as a business (commercial) activity, aquaculture can make significant contribution to national food security, poverty alleviation and economies, factors which often determine policy makers' support to any sector. Yet, quantitative evaluation of these merits is poorly documented, particularly in developing countries, which often limits the much needed political and financial support to the sector for its adequate development. This paper suggests to measure aquaculture's contribution to a country's economy through the "aquaculture value-added multiplier" and its contribution to poverty alleviation through "aquaculture employment multiplier". It also suggests to use the "net sum of protein-equivalent" and the "ratio between the net foreign exchange earning of aquaculture and the total value of food imports" to assess the direct and indirect contributions of the sector to food availability (one of the three dimensions of food security), the "aquaculture labour-income and employment multipliers" to quantify the sector's contribution to food access (second dimension of food security) and the "aquaculture tax multiplier" and the "Ratio between the Aquaculture Net Foreign Exchange Earning and the Whole Economy Net Foreign Exchange Earning" to estimate aquaculture's contribution to food utilization (the third dimension of food security). While the document refers to "commercial aquaculture" throughout, the methodology developed can be applied to aquaculture in general.

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