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Assessment of comparative advantage in aquaculture

Framework and application on selected species in developing countries

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Background: A commercial aquaculture farm in Kigembe, Rwanda; courtesy of Nathanael Hishamunda.
Inset bottom left: Shrimp being cleaned for freezing in Manila, The Philippines; © FAO/Freeby Maimone.
Insert bottom right: Commercial aquaculture can help poor fishers increase food security;
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Within the framework of its continued efforts to alleviate poverty and enhance food security, the Fisheries and Aquaculture Department of the Food and Agriculture Organization of the United Nations (FAO) has initiated a number of studies to improve decision-making in both private and public sectors. This study provides two methodologies to estimate comparative advantage that can assist entrepreneurs and government policy-makers in developing countries in deciding which species and which export markets offer the most potential for commercial aquaculture.

While the methodologies can be applied anywhere, the focus of this report is on two case studies: the shrimp export market and farmed production of freshwater finfish. The studies were conducted within the Fisheries and Aquaculture Economics and Policy Division at FAO.

Abstract

International trade in fishery products has increased, together with the absolute and relative importance of aquaculture, as a source of fish production. Shrimp and salmon are two examples of species grown in developing countries that are traded internationally. How successful a country is in competing against other producers depends in part on transport and on satisfying food standards, but also on its costs of production. Comparative advantage is a means of comparing relative costs and indicating the species and markets where there is the greatest likelihood of success. There are problems with estimating comparative advantage: the method can be static rather than dynamic and may not indicate long-run opportunities. However, it is a useful tool for planners who devise aquaculture strategies and for individual fish farmers.

Two methods exist for estimating comparative advantage – both have been applied to aquaculture. The domestic resource cost (DRC) method relies on production cost data to compare efficiency. Distortions may require the estimation of shadow prices to reflect true social opportunity costs but, when adjusted, the country that has the lowest DRC has a comparative advantage. The DRC method is dynamic, providing useful information to decision-makers; however, cost data may be difficult to obtain and shadow pricing is problematic. The second method is revealed comparative advantage (RCA) whereby comparative advantage is inferred from an *ex post* assessment of actual trade and specialization. From trade statistics, estimates are obtained to examine whether a country exports a species to a particular country more than to the rest of the world; if so, it is judged to have a comparative advantage in that particular market. The RCA method is more descriptive and has less predictive potential than the DRC approach but it has the advantage of data availability.

This paper illustrates the concept of comparative advantage and some of its policy implications by presenting two case studies: the first one focuses on shrimp exporting countries while the second one is based on freshwater aquaculture production of carp, catfish and tilapia. The RCA method is used in both cases.

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Contents

Tables

Figures

Foreword

This report aims at assisting countries determine in which species and in which export markets they should specialize. Comparative advantage is a concept almost two-hundred years old suggesting that countries can trade and benefit from trade even if they have no absolute advantage. Thus even a country with limited resources and cost disadvantages can specialize and gain from trade just as the most efficient producer. For decision-makers, comparative advantage provides insights if they want to "pick winners" among the sectors of an economy.

The conclusions and methodologies in this report are not specific to any particular country and while data limitations may preclude the use of one method, both should apply consistently to all sectors. This report concentrates on the aquaculture sector with data coming from more than 100 countries. Case studies indicate which countries have a comparative advantage in shrimp production (for the export market) and freshwater production of fish.

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1. Introduction

The important role of aquaculture in food supply and economic growth has been well recognized (FAO, 2000; 2002; 2004; 2006). While aquaculture accounted for only 3.5 percent of the supply of aquatic products in the world during the early 1950s, the ratio had risen to 10 percent by the early 1980s, 35 percent by the early 2000s (FAO, 2004) and about 42 percent by 2006 (FAO, 2006). Increasing seafood demands driven by income and population growth under a situation of limited and depleting fisheries resources require aquaculture to play an even more important role in the future (FAO, 2006).

Fortunately, aquaculture is still a new and underdeveloped industry with great potential in many regions such as Africa (Kapetsky, 1994; Aguilar-Manjarrez and Nath, 1998) and Latin America (Kapetsky and Nath, 1997). Yet experience (especially in Africa) has shown that it is far from easy to realize these potentials (Machena and Moehl, 2001).

Successful aquaculture development depends on many factors; getting started on the right track is one of them. A special feature of aquaculture is that there are many species to choose from.[1] Even for the same species, there may be many markets to target. While skilled aquaculturists can make decisions based on their experience and visions, many entrepreneurs in aquaculture may need guidance to pick systems that could give them the greatest chances for long-run success. Similarly, in providing public support to aquaculture development, international funding agencies and local governments face the problem of "picking the winners". That is, they have to prioritize and allocate limited resources and aid to aquaculture activities with the most likelihood of achieving sustainable success. Thus, information on a country's "comparative advantage" in different aquaculture activities is important for both commercial and policy decision-making processes.

The objective of this study is to develop a basic, yet systematic framework for assessing countries' comparative advantages in competing aquaculture activities, discuss how this framework can help entrepreneurial and policy decision-making in aquaculture development, and illustrate the practical application of the framework.

This report is organized in five sections. Following these introductory remarks, Section 2 discusses two approaches commonly used in the economics literature for assessing comparative advantage. One is the domestic resource cost (DRC) or benefits-costs (BC) approach; the other is the revealed comparative advantage (RCA) approach. A discussion on the respective merits and limitations of each of these two complementary approaches and on how the two methods can be used to guide policy is provided at the end of this section.

Sections 3 and 4 illustrate two empirical applications of the assessment framework developed in section 2, with a focus on the RCA approach. Because of a lack of data on aquaculture production costs, the report does not illustrate the application of the DRC method, which is nevertheless well established and documented in the literature. More specifically, Section 3 evaluates the comparative advantage of major shrimp farming countries in exporting frozen cultured shrimp to three major international markets (Japan, the United States of America and the European Union). In section 4, the revealed comparative advantage in the production of three freshwater finfish

[1] Production data for 103 fish species, 21 crustacean species and 43 mollusc species were reported to FAO in 1994 (FAO, 1996).

species (tilapia, catfish, and carp) by countries in three regions (Asia, Latin America and the Caribbean and sub-Saharan Africa) is assessed. A comparative advantage study of shrimp farming in these three regions will also be conducted when data become available.

Section 5 summarizes the major findings of the study and the most relevant implications for entrepreneurs and policy-makers.

2. Comparative advantage in aquaculture: an assessment framework

2.1 CONCEPT OF COMPARATIVE ADVANTAGE

The concept of comparative advantage was first expressed by Robert Torrens in 1815 in his paper titled *Essay on the external corn trade*. However, the theory is usually attributed to David Ricardo who created its systematic explanation in his book on *"Principles of political economy and taxation"* in 1817. Using a two-nations (Portugal and England) and two-commodities (wine and cloth) model, Ricardo argued that trade would be beneficial even if Portugal held an *absolute* cost advantage over England in both commodities (Suranovic, 2008). Hence, Ricardo provided insight that free trade allows countries to gain from increasing specialization in activities in which they have (strong) comparative advantage under autarky.

More generally, comparative advantage is a concept commonly used to explain specialization and trade patterns. It refers to an entity (country, region, company, individual)'s ability to produce a good or service at a lower cost, relative to other goods or services, compared to another entity. In economic jargon, an entity has a comparative advantage over another in the production of a good or service if it can produce it at a lower opportunity cost, meaning that it has to give up less labour and other productive resources that could be used in the production of other goods or services, in order to produce it (Thompson, 2006).

The concept of comparative advantage has two aspects: normative and positive. Normatively, it is in an entity's interest to highly specialize (as compared to other countries) in the production of goods or services in which it has a strong comparative advantage. Positively, under perfect competition and undistorted markets, an entity has a tendency to highly specialize in and export goods or services in which it has a strong comparative advantage while it imports those goods in which it has a weak comparative advantage.

Comparative advantage can be analysed from two different perspectives: static and dynamic. In a static sense (the Ricardian sense), comparative advantage is a concept used to compare entities' current optimal specialization and trade patterns. Thus, by stating that country A has a strong comparative advantage in tilapia farming, it is implied that the country's current optimal specialization level (that is, the specialization level that reflects efficient resource allocation) in tilapia farming is higher than those of other countries. In a dynamic sense, the concept is used to compare entities' future optimal specialization and trade patterns by recognizing that an entity's relative ability to competitively produce certain goods and services can be eroded or enhanced with time, in response to a variety of endogenous and exogenous factors such as changes in factor endowments and their opportunity costs (physical capital, human capital/labor, land), changes in production and marketing technologies and changes in world input and output prices.

It is very important to distinguish these two dimensions of comparative advantage because they have different policy implications. For example, stating that country A has a strong comparative advantage in tilapia farming in the *static* sense implies that the activity is important for the country but does not necessarily imply that it should

be promoted any further. If the country's actual specialization level in tilapia farming is already optimal, then an attempt to further increase the specialization could be counterproductive. However, stating that a country has a strong comparative advantage in tilapia farming in the *dynamic* sense implies that the country should have a tendency to increase its specialization in tilapia farming.

Regarding general statements such as "country A has a comparative advantage in activity X", two other factors need to be clarified. First, when making such statements, it is important to clarify *what other activities* is country A's "comparative" advantage in activity X relative to. For example, country A's comparative advantage in tilapia farming may reflect its low *opportunity costs* in engaging in this activity relative to carp farming. If resources that could have been used for farming carps were used to farm tilapia, then the advantage is comparative to country A's carp farming activities as carp farming competes with tilapia farming for resources. Second, it is important to clarify *what other countries* is country A's comparative advantage compared to. In this context, country A's strong comparative advantage in tilapia farming implies that the country tends to have a higher specialization in the activity as compared to other countries. These "other countries" could include all the countries in the world, countries in the region where country A is located, or a group of countries specifically chosen for comparison.

An additional point deserves clarification. Comparative advantage is often confused with absolute advantage. Absolute advantage refers to an entity's ability to produce a good or service at a lower cost per unit than the cost at which any other entity produces that good or service. Under absolute advantage, one entity can produce more output of a good or service per unit of productive input as compared to other entity, but lack comparative advantage (the determinant of specialization and trade) in the same good or service produced.

With comparative advantage, even if one producing entity has an absolute (dis) advantage in every type of output, it can benefit from specializing in and exporting those products in which it has a relative advantage (that is, a lower opportunity cost) and importing the goods in which it has a relative disadvantage (higher opportunity cost). What matters is not the absolute cost of production but the relative opportunity cost, which measures how much production of one good or service is reduced to produce one more unit of the other good or service.

In sum, the concept of comparative advantage has two useful applications. First, it serves as a descriptive (or "positive") concept that provides "a basic explanation of the international pattern of specialization in production and trade". Second, it "plays an important role in prescriptive (or "normative") economics" by "providing guidelines for government policies on resource allocation and trade" (UNIDO, 1986).

2.2 COMPARATIVE ADVANTAGE VERSUS COMPETITIVE ADVANTAGE

Similar to "comparative" advantage, another widely used term is "competitive" advantage. While these two terms are oftentimes used indistinguishably and interchangeably, they are sometimes used in parallel for denoting different concepts.

According to one distinction that is not well established in the literature, yet it is popular in empirical studies (Warr, 1994; Odhiambo, Kristjanson and Kashangaki, 1996; Hassan *et al.*, 1999; Jooste and van Zyl, 1999; Kannapiran and Fleming, 1999; Magagula and Faki, 1999; Nakhumwa *et al.*, 1999; Saasa *et al.*, 1999; USAID, 1999; Mucavele, 2000; Sukume *et al.*, 2000; Siggel and Ssemogerere, 2004), competitive advantage measures a country's (or other entities') profitability in one activity under "market" prices that could be distorted by policy or any other influence, while comparative advantage reflects the profitability under "shadow" prices that reflect the social value of costs and production subject to no such distortions.

This study does not follow this distinction because it does not reflect the spirit of "comparative" advantage. In our view, the distinction between competitive advantage and comparative advantage is similar to that between "absolute" and "comparative" advantage. For example, while Thailand's large cultured shrimp production offers a strong "competitive" advantage in all its cultured shrimp export markets, the degree of the advantage tends to be different for each market. The concept of "comparative advantage" is to capture such differences. Thus, if Thailand's *competitive* advantage in the United States market is greater than the advantage of its total exports to other world markets, then one can say that Thailand has a *comparative* advantage in the United States market relative to other markets.

In sum, comparative advantage is a concept intended to compare countries' industrial structures rather than comparing the competitiveness of their industries directly. In other words, comparative advantage reflects "efficient allocation of resources at the national level" as opposed to "the commercial performance of individual firms" reflected by competitive advantage (Kannapiran and Fleming, 1999).

2.3 COMPARATIVE ADVANTAGE: AN ASSESSMENT FRAMEWORK

The economics literature provides two complementary approaches for comparative advantage assessment. One is the domestic resource cost (DRC) or the equivalent "benefit-cost" (BC) approach (Odhiambo, Kristjanson and Kashangaki, 1996; Hassan *et al.*, 1999; Jooste and van Zyl, 1999; Magagula and Faki, 1999; Nakhumwa *et al.*, 1999; Saasa *et al.*, 1999; USAID, 1999; Mucavele, 2000; Sukume *et al.*, 2000); the other is the "revealed comparative advantage" (RCA) approach (Balassa, 1965; Vollrath, 1991; Memedovic, 1994).

The following first introduces how these two approaches in comparative advantage assessment have been employed in the literature and then are synthesized into a general framework.

2.3.1 The domestic resource cost/benefit-cost approach

The spirit of the DRC/BC approach is to measure a country's comparative advantage in an activity by its social profitability from engaging in the activity.

Benefit-cost analysis

The benefit-cost (BC) analysis directly measures the profitability of an economic activity by the following formula:

$$BC_{ij} = p_{ij} \Big/ c_{ij}, \tag{1}$$

where p_{ij} and c_{ij} represent the (average unit) price and cost of country i's production of good j, respectively.

Suppose $BC_{ij} > 1$, which according to equation (2.1) implies country *i's* production of good j is profitable (i.e. the revenue p_{ij} is greater than the cost c_{ij}); then this country is deemed as having "comparative advantage" in producing good j. The larger the BC ratio becomes, the greater the advantage is. In contrast, $BC_{ij} < 1$, which indicates that country *i's* production of good j is not profitable, would imply that this country has "comparative disadvantage" in producing good j. The smaller the BC ratio is, the greater the disadvantage would be.

DRC analysis

Domestic resource cost (DRC) analysis measures a country's efficiency in domestic resource utilization in the production of certain goods by means of the following formula:

$$DRC_{ij} = \frac{c_{ij}^{d}}{p_{ij} - c_{ij}^{f}} \quad , \tag{2}$$

where c_{ij}^{d} and c_{ij}^{f} represent respectively domestic and foreign input costs for country *i*'s production of good *j* – note that $c_{ij} = c_{ij}^{d} + c_{ij}^{f}$ (*i.e.* the total input cost is equal to the sum of domestic and foreign input costs).

A DRC ratio of less than one (i.e. $DRC_{ij} < 1$) implies that country *i* uses domestic resources efficiently in the sense that the domestic opportunity cost of country *i's* production of good *j* (measured by c_{ij}^{d}) is less than the domestic value-added generated by the production process (measured by $p_{ij} - c_{ij}^{f}$). In contrast, $DRC_{ij} > 1$ implies an inefficient use of domestic resources.

Therefore, $DRC_{ij} < 1$ is an indication that country *i* has a "comparative (economic) advantage" in producing good *j*. The smaller the DRC_{ij} is, the greater the advantage would be. Conversely, $DRC_{ij} > 1$ indicates the existence of country *i's* "comparative (economic) disadvantage" in producing good *j*. The larger the DRC_{ij} is, the greater the disadvantage would be.

Since $c_{ij} = c_{ij}^{d} + c_{ij}^{f}$, equations (1) and (2) imply that $DRC_{ij} < 1$ and $BC_{ij} > 1$ are equivalent. Therefore, the BC and DRC approaches are essentially the same.

Shadow prices

One key feature of the DRC/BC approach is to use "shadow prices" to value production revenues and costs. As opposed to observable market prices, shadow prices are "social" prices that take into account market distortions. For example, a country's low aquaculture production costs may not be a result of its high efficiency or productivity, but because of direct or indirect government subsidies in energy, feeds, water, or other production factors. Therefore, the use of distorted market prices to measure profitability tends to result in a "false" indication of comparative advantage or disadvantage.

To avoid such misrepresentation, shadow prices, which purge market prices from policy and other distortions and hence provide a measure of the true or social value of production costs and revenues, should be used to calculate the DRC/BC ratios for comparative advantage measurement.

Policy analysis matrix

Empirically, the policy analysis matrix (PAM) is a convenient tool for the DRC/BC analysis (Monke and Pearson, 1989). Table 1 shows a standard PAM, based on which at least four indicators of comparative advantage can be derived:[2]

(1) Net private profit: NPP = A – B – (C + D)
(2) Net social profit: NSP = (E – F) – (G + H)
(3) DRC^{market} = (C + D) / (A – B)
(4) DRC^{shadow} = (G + H) / (E – F)

Indicators (1) NPP and (2) NSP, which are based on the BC method, measure industries' profitability under market and shadow prices, respectively. A high NPP means a large profit margin and hence great competitiveness. However, as discussed above, a high NPP could be artificially created by subsidies, protection, tax breaks or other policy distortions and hence may not be sustainable in the long run. Therefore, the NSP (calculated at shadow prices) would reflect the "true" competitiveness of an industry.

Indicators (3) DRC^{market} and (4) DRC^{shadow}, which are based on the DRC approach, measure the relative efficiency of the use of domestic resources by an industry. The

[2] Table 1 is adopted from Nakhumwa *et al.* (1999), who discussed additional indicators that can be constructed based on PAM.

TABLE 1
Policy analysis matrix (PAM)

	Revenues	Tradable input costs	Capital/ labour cost	Land cost	Profits
Private prices	A	B	C	D	NPP
Social (shadow) prices	E	F	G	H	NSP
Policy effects (or transfers)	K	L	M	N	O

lower the DRC ratio is for an industry, the smaller amount of domestic resources the industry needs to use in order to generate a given amount of net foreign exchange revenue; hence, the more efficient the industry is in utilizing domestic resources.

The difference between DRC^{market} and DRC^{shadow} is similar to that between NPP and NSP in the use of market vs. shadow prices.

2.3.2 The RCA approach

The spirit of the "revealed" comparative advantage (RCA) approach is to use *ex post* specialization patterns to infer comparative advantage patterns: a country's actual high specialization in an activity can be viewed as an evidential indication that it has strong comparative advantage in that activity (Balassa, 1965). Comparative advantage is "revealed" (as opposed to actual) in that rather than reflecting a country's true comparative advantage, high specialization could be a result of policy interventions.

Based on this basic methodology, many different RCA indices have been suggested and disputed – see Appendix A for a review. While a consensus is yet to be reached, the standard Balassa's RCA measure (Balassa, 1965) is the most widely used by applied economists and will be adopted in this study.

RCA index defined in terms of relative competitiveness

Let X_{ij} denote individual country i's export of product j; then the standard Balassa's RCA index can be defined as

$$RCA_{ij} = \frac{s_{ij}}{s_i}, \tag{3}$$

where

$s_{ij} = \dfrac{X_{ij}}{\sum_i X_{ij}}$ denotes country i's share in export market j, and

$s_i = \dfrac{\sum_j X_{ij}}{\sum_i \sum_j X_{ij}}$ denotes the share of country i's total exports in the entire world export market.

Therefore, according to equation (3), RCA_{ij} essentially compares country i's share in export market j to its share in the entire world export market. In other words, RCA_{ij} measures country i's comparative advantage in product j by comparing its competitiveness in market j (measured by its share in the market) to the competitiveness of its total exports (measured by its share in the entire world market).[3]

Therefore, $RCA_{ij} > 1$, which indicates that country i's share in market j is greater than its share in the world market, implies that the country is relatively more competitive

[3] A "constant market share" (CMS) condition has often been used to evaluate countries' export competitiveness (e.g. Bowen and Pelzman, 1984; Chen, Xu and Duan, 2000; Richardson, 1971a; 1971b). A country that can keep its market share constant is deemed as being able to maintain its "competitiveness" in the market.

in market *j* than in other markets. This is often taken as evidence that country *i* has a "revealed comparative advantage" in exporting product *j*. Conversely, $RCA_{ij} < 1$ implies that country *i* is less competitive in market *j* than in other markets, which is often taken as evidence that country *i* has a "revealed comparative disadvantage" in exporting product *j*.

RCA index defined in terms of relative specialization

Equivalent to equation (3), the RCA index can also be defined in another form as

$$RCA_{ij} = \frac{c_{ij}}{c_j}, \tag{4}$$

where

$c_{ij} = \dfrac{X_{ij}}{\sum_j X_{ij}}$ represents the proportion of country *i*'s export of product *j* to its total exports; and

$c_j = \dfrac{\sum_i X_{ij}}{\sum_i \sum_j X_{ij}}$ represents the proportion of total world exports of product *j* relative to the total world exports of all products.

According to equation (4), $RCA_{ij} > 1$ implies that country *i*'s export specialization in product *j* (measured by c_{ij}) is higher than the world average export specialization in the product (measured by c_j), which provides another interpretation of country *i*'s comparative advantage in product *j*.

Conversely, $RCA_{ij} < 1$ implies that country *i* has below-average export specialization in product *j*, which indicates its comparative disadvantage in that product.

Flexibility in the application of the RCA approach

In essence, the RCA approach uses specialization patterns to infer comparative advantage patterns. Based on this premise, many RCA indices can be constructed to compare countries' specialization patterns in many activities (Richardson and Zhang, 1999). For example, an RCA index can be constructed to compare countries' comparative advantage patterns in exporting one aquaculture product (e.g. shrimp) to different markets; another RCA index can also be calculated to compare countries' comparative advantage patterns in producing different cultured species (e.g. tilapia, catfish and carp). Furthermore, at a more disaggregated level, an RCA index can be calculated to measure countries' comparative advantage in exporting different kinds of products for a single species (Ling, Leung and Shang, 1996).

Revealed comparative advantage variation (RCAV)

While RCA indices defined in equation (3) or (4) provide a snapshot of countries' comparative advantage patterns at a certain point of time, it is also informative to know how such patterns vary over time. Comparative advantage variation over time is often directly measured by the changes in RCA indices (e.g. Yeats, 1992; Hiley, 1999; Bojnec, 2001; Havrila and Gunawardana, 2003). That is, a higher RCA_{ij} index at time $t+1$ than at time *t* implies that country *i* has increased its comparative advantage in product *j*, while a lower RCA_{ij} index implies the opposite.

While the RCA literature seems to take this method for granted, we are aware of no attempt to theoretically justify it. However, the method is actually problematic. In Appendix B we show that a more appropriate indicator (with theoretical foundation) that measures revealed comparative advantage variation (RCAV) is

$$RCAV_{ij} = RCA_{ij,t+1} - \beta RCA_{ij,t}, \quad (5)$$

where $$\beta \equiv \frac{1+g}{1+\sum_j c_{ij,t} g_j},$$

g_j represents the growth rate of total world exports of product j, and
g represents the growth rate of total world exports of all products.

Since $\sum_j c_{j,t} g_j = g$,

β would be unity when $c_{ij,t}$ is identical to $c_{j,t}$ for every product j, which, according to equation (4), implies that $RCA_{ij,t} = 1$ for every product j. Therefore, for a country whose specialization pattern is similar to the world average, β would be close to unity; hence the direct use of the variation of the RCA index would not matter much. However, for a country whose specialization pattern is quite different from the world average, β can be substantially different from unity; hence the direct use of the RCA index in gauging its variation could lead to misleading conclusions.[4]

2.4 COMPARATIVE ADVANTAGE ASSESSMENT: A SYNTHESIS FRAMEWORK

Comparative advantage is a concept for explaining countries' (or other entities') specialization patterns. DRC/BC and RCA are two common approaches for comparative advantage assessment. They are complementary and have respective merits and problems. Their proper application can provide useful information for commercial and policy guidance.

2.4.1 The DRC/BC approach: merits and problems

The DRC/BC approach uses a country's shadow-price profitability in an economic activity to measure its comparative advantage in that activity. High profitability implies strong advantage. It should be noted that comparative advantage measured by this approach is in the dynamic sense. For example, suppose a country's DRC ratio for tilapia farming is lower than that for other freshwater species farming, which implies that the country can use resources more efficiently in tilapia farming and hence has strong comparative advantage in it. Then, the country should increase specialization in tilapia; in other words, tilapia should be a priority in its aquaculture development.

This direct policy implication is the main appeal of the DRC/BC approach. However, a methodological problem needs to be cautioned. In calculating DRC/BC ratios, shadow prices are used to value the social costs of production in order to avoid the influence of market distortions. The problem is that actual input structures adopted by producers react to such distortions. For example, suppose feed prices are artificially kept at a distorted low level; farmers would then tend to adopt more feed-intensive production systems. Thus, when feeds are valued under their shadow prices, those species that react to the artificial low feed prices more significantly would tend to appear more socially inefficient and hence be more likely to be deemed as having relatively weak comparative advantage, even though they could actually be socially efficient were farmers' behaviours not affected by the distorted feed prices in the first place.

Another problem of the DRC/BC approach is that short-term, dynamic comparative advantage indicated by a low DRC ratio is not necessarily consistent with comparative advantage in the long run. For example, suppose a country begins tilapia farming

[4] See Appendix B for an example of such misleading conclusions.

earlier than its potential competitors and DRC ratios indicate that it has a strong comparative advantage in it. While this advantage could reflect the country's inherent characteristics that allow it to culture tilapia relatively more efficiently, it could also be transitory and disappear when tilapia farming becomes more popular elsewhere. This could occur from a decline in tilapia price due to supply increases by other countries, a rise in tilapia production costs induced by production expansion, or both. Therefore, by neglecting the dynamic nature of comparative advantage, the country could over-commit to tilapia and result in an industrial structure that is actually at odds with its long-term comparative advantage pattern.

Empirically, one difficulty in applying the DRC/BC approach is the lack of quality data on production costs.

2.4.2 The RCA approach: problems and merits

The spirit of the RCA approach is to infer countries' comparative advantages in different activities by systematically comparing their specialization patterns in these activities. For example, the evidence that a country consistently has a relatively high specialization level in one species as compared to other countries indicates that the country may have some special characteristics in natural resource endowment structure, climate, local tastes, technology, human capital, etc., that give it a comparative advantage in that activity. However, a well-recognized problem is that strong "revealed" comparative advantage indicated by high RCA indices may not be a country's "true" comparative advantage, but could be artificially created by policy or other distortions.

From a policy-making perspective, another shortcoming of the RCA approach is that it does not provide direct policy recommendations. For example, suppose a country has a high RCA index for tilapia farming, which indicates that it has relatively high specialization (i.e. strong comparative advantage) in that activity. Although this indicates that tilapia farming is important for the country, it is not clear whether the relatively high specialization level is already optimal: should the government further promote the industry, maintain the status quo, or even reduce the specialization level?

In practice, a country that needs information on its comparative advantage patterns for designing development strategies may not have the luxury to wait for the patterns to be revealed.

One merit of the RCA approach is that it provides a systematic framework for comparing a variety of structural differences across countries. Such comparison could provide valuable information for policy guidance. In addition, data for RCA analysis are much more easily available than for the DRC/BC approach.

2.4.3 A terminology issue

While comparative advantage/disadvantage is a common categorization, applying the label "disadvantage" on industries with RCA indices less than unity or DRC ratios greater than unity seems to convey unnecessarily negative connotations. Besides, these categorizations also result inconvenient when comparative advantage variations are discussed. Therefore, we suggest replacing the "comparative advantage/disadvantage" categorization with "strong/weak comparative advantage". That is, RCA indices greater than one (or DRC ratios less than one) are indication of strong comparative advantage, while RCA indices less than one (or DRC ratios greater than one) indicate weak comparative advantage.

2.4.4 DRC/BC and RCA: policy applications

The DRC/BC and RCA approaches can provide useful and complementary information for commercial and policy decision-making regarding aquaculture

development. DRC ratios can provide information about the true economic viability and resource utilization efficiency of aquaculture activities, which is useful for determining aquaculture development priorities. Other factors remaining constant, priority should be given to those aquaculture activities with relatively low DRC ratios because such activities not only use domestic resources more efficiently, but also tend to be more economically viable due to their relatively large profit margins.

However, there are two caveats for using DRC ratios as policy guidance. First, it is important to bear in mind that DRC ratios may reflect short-term comparative advantage subject to changes over time. Second, when an aquaculture activity is identified as having a high DRC ratio (i.e. low resource utilization efficiency), a proper policy reaction is not to simply give it a low development priority, but to identify the underlying causes of the low efficiency and implement the appropriate correctives.

In sum, the relative and dynamic nature of comparative advantage should always be borne in mind when DRC ratios are used as a comparative advantage indicator.

Discretion is also needed when using the RCA approach. A country can use RCA analysis to examine the transition of its aquaculture industrial structure and compare it to other countries. Such examination and comparison can help the country detect whether its aquaculture development is consistent with its underlying comparative advantage patterns. For example, after RCA analysis helps identify a country's distinct specialization features (as compared to other countries), further research (e.g. DRC/BC analysis) can be conducted to examine whether these distinct features reflect the country's comparative advantage or represent a deviation from its optimal specialization pattern due to historical inertia, policy distortions, or other obstacles.

The RCA approach is especially useful for a country whose aquaculture is still at its "infancy" stage. This is so because, by providing a systematic comparison of aquaculture development experiences in other countries, RCA analysis gives the newcomer a "comparative advantage" to learn from these experiences. For example, when designing its aquaculture development strategy, a country would like to refer to the comparative advantage patterns of other countries that have similar resource endowment structure and other features. Understanding the driving forces behind these patterns and their transition can help the country avoid making similar mistakes and design a more sensible aquaculture development blueprint.

In the following two sections we apply the RCA approach to evaluate countries' comparative advantage in different aquaculture activities. We do not illustrate the application of the DRC/BC approach in this study, primarily because of a lack of data on aquaculture production costs. Table 2 provides a template for basic data needed to apply the DRC/BC approach. In addition, the DRC approach is well established in

TABLE 2
Data template for the DRC/BC approach

Basic information	Farming characteristics	Revenue	Costs
Country	Farm area (ha)	Production quantity (kg/year)[2]	Operating cost (USD or LCU/kg)3
Time period	Farming cycles[1] (No.)	Farm price (USD or LCU/kg)2	Total cost (USD or LCU/kg)3
Species name	Stocking density (fingerling/ha)1	Revenue (USD or LCU)	% of total cost to total revenue
Data sources	Yield (kg/ha/year)1		% of operating cost to total revenue
			% of operating cost to total cost
			% of wage cost to operating cost
			% of feed cost to operating cost
			% of seed cost to operating cost
			% of energy cost to operating cost

[1] Average or range.
[2] Quantity and price are for live weight, live-weight equivalent, or otherwise specified. LCU = local currency unit.
[3] Total cost = fixed cost (e.g. depreciation) + operating cost (including wage, feed, seed, energy, and other variable costs)

the literature and has several empirical references related to aquaculture (Ling, Leung and Shang, 1999; Lee *et al.*, 2003; Kaliba and Engle, 2003) and agriculture (Odhiambo, Kristjanson and Kashangaki, 1996; Hassan *et al.*, 1999; Jooste and van Zyl, 1999; Magagula and Faki, 1999; Nakhumwa *et al.*, 1999; Saasa *et al.*, 1999; USAID, 1999; Mucavele, 2000; Sukume *et al.*, 2000).

3. Cultured shrimp export comparative advantage: a global assessment

In this section we apply the assessment framework developed above to evaluate major shrimp farming countries' comparative advantage in exporting cultured shrimp to three major international markets (Japan, the United States of America, and the European Union). For readers' convenience, this section presents a self-contained report of the assessment exercise; its methodology is based on the framework developed above but modified to fit the issue at hand.

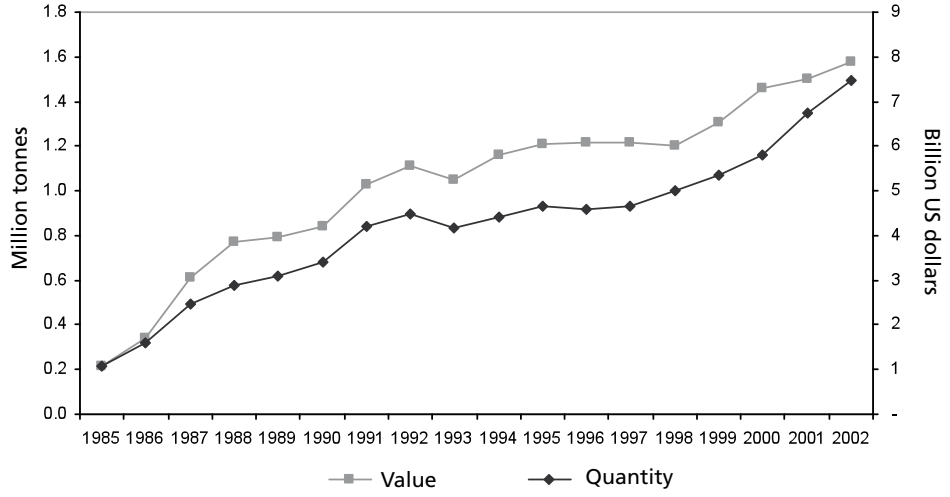
3.1 INTRODUCTION

Cultured shrimp production in the world has been growing dramatically over the last two decades, from 0.2 million metric tons (tonnes) in 1985 to 1.5 mmt in 2002; in terms of value it has grown from USD 1 billion to nearly USD 8 billion (Figure 1).

Shrimp farming has been export-oriented in most countries. The three major shrimp export markets are Japan, the United States of America and the European Union, which jointly consumed 90 percent of the world frozen cultured shrimp exports in the early 2000s (25, 48 and 17 percent for Japan, the United States of America and the European Union, respectively. See Figure 2).

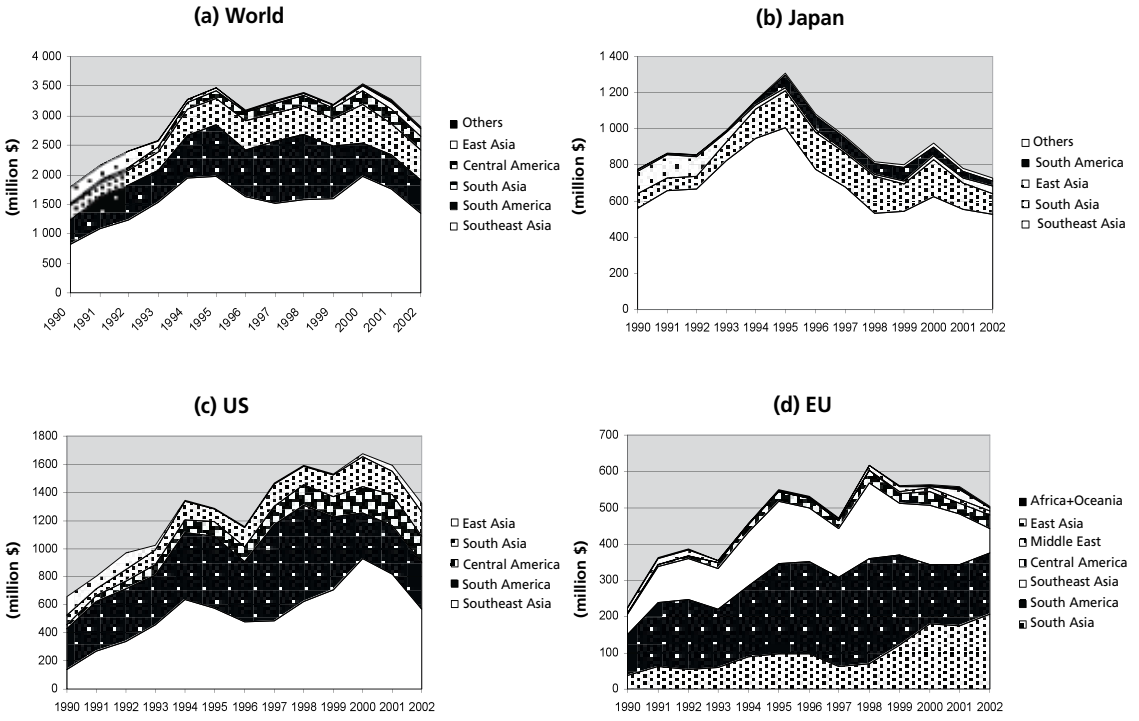
In the following sections we attempt to conduct a global, comparative assessment of 28 major shrimp farming countries' frozen cultured shrimp export performance in these three major international markets. These 28 countries accounted for 98 percent of the world cultured shrimp production in the early 2000s (Table 3). We first discuss the assessment methodology and data in section 3.2, then present the empirical results in section 3.3, and finally summarize the study in section 3.4.

FIGURE 1
World cultured shrimp production



Source: FAO (2008)

FIGURE 2
Cultured shrimp exports to various markets



3.2 METHODOLOGY AND DATA

Market share (MS) is a basic export performance indicator that reflects a country's "degree of dominance" in a market. Such dominance depends on two factors. One is the country's "size advantage" that reflects its total export capacity as compared to that of other countries. The other factor is its "comparative advantage" that reflects its export structure as compared to those of other countries. Dynamically, the change of degree of dominance can be directly measured by market share variation. We will develop an approach to decompose a country's total market share variation into "size" and "structural" variations that are driven by changes in size and comparative advantage respectively. We will also construct a "revealed comparative advantage variation" (*RCAV*) index to facilitate cross-country comparisons of comparative advantage variation.

3.2.1 Degree of dominance (market power)

When a country competes with other countries in an international market, the degree of its dominance in the market (i.e. market power) can be measured by its market share:

$$s_{ij,t} = E_{ij,t} / E_{j,t}, \tag{6}$$

where $E_{ij,t}$ denotes country *i*'s export to market *j*;
$E_{j,t} = \sum_i E_{ij,t}$ denotes the total export to market *j* by all countries (i.e. the size of market *j*);
t is the time subscript.

The larger the share a country controls, the more dominant this country is in the market. The degree of dominance depends on its "size advantage" and "comparative advantage".

TABLE 3
A profile of major shrimp farming countries

Country	Cultured shrimp production quantity (tonnes)			Share of world cultured shrimp production
	Early 1990s (1990–92 average)	Mid 1990s (1995–97 average)	Early 2000s (2000–02 average)	Early 2000s (2000–02 average)
Asia:				
China	203 751	90 063	302 106	24.4%
Thailand	155 482	242 871	250 754	20.2%
Indonesia	129 705	155 271	148 929	12.0%
India	40 600	69 089	104 872	8.5%
Viet Nam	35 327	51 454	68 144	5.5%
Bangladesh	19 726	40 737	57 408	4.6%
Philippines	61 273	69 997	40 560	3.3%
Malaysia	2 787	8 014	22 830	1.8%
Iran (Islamic Republic of)	31	274	5 872	0.5%
Myanmar	1	1 687	5 662	0.5%
Sri Lanka	1 500	3 508	5 573	0.4%
Saudi Arabia	122	411	3 587	0.3%
Republic of Korea	467	784	1 547	0.1%
Subtotal	**650 772**	**734 160**	**1 017 845**	**82.2%**
Latin America:				
Ecuador	98 265	115 409	56 703	4.6%
Mexico	5 936	15 535	42 449	3.4%
Brazil	1 933	2 995	41 796	3.4%
Colombia	7 383	6 740	11 797	1.0%
Honduras	4 267	8 621	10 532	0.9%
Venezuela (Bolivarian Republic of)	683	4 023	10 337	0.8%
Nicaragua	65	2 737	5 750	0.5%
Belize	185	961	4 163	0.3%
Guatemala	646	2 065	3 131	0.3%
Costa Rica	492	2 450	2 416	0.2%
Panama	3 457	5 711	1 986	0.2%
Peru	3 924	5 330	991	0.1%
Subtotal	**127 236**	**172 577**	**192 052**	**15.5%**
Others:				
Madagascar (Africa)	26	2 146	5 255	0.4%
Australia (Oceania)	769	1 556	3 142	0.3%
New Caledonia (Oceania)	622	974	1 783	0.1%
World	**805 066**	**928 700**	**1 238 902**	**100%**

3.2.2 Size advantage

Given other things, a country (e.g. Thailand) that has a large amount of cultured shrimp products for export tends to have a strong "size" advantage that gives it relatively high degree of dominance in every market.

A country's size advantage can be measured by its share in the world market:

$$s_{i,t} = E_{i,t} / E_t, \tag{7}$$

where $E_{i,t} = \sum_j E_{ij,t}$ denotes country *i*'s total cultured shrimp exports and

$E_t = \sum_{i,j} E_{ij,t}$ denotes total world cultured shrimp exports (i.e. the size of the world market).

Obviously, the larger a country's world market share is, the stronger its size advantage is.

3.2.3 Comparative advantage

Besides its size advantage, a country's market power in a specific market also depends on its "comparative advantage" which can be measured by its "revealed comparative advantage" (*RCA*) index:

$$RCA_{ij,t} = \frac{s_{ij,t}}{s_{i,t}}. \tag{8}$$

Dividing country *i*'s share in market *j* by its share in the world market, the $RCA_{ij,t}$ index defined in equation (8) essentially filters the impact of country *i*'s size advantage (measured by $s_{i,t}$) from its degree of dominance in market *j* (measured by $s_{ij,t}$). The residual can then be taken as a measure of its "structural" advantage in the market, which is commonly called "comparative advantage".[5,6]

According to equation (8), $RCA_{ij,t} > 1$ implies that $s_{ij,t} > s_{i,t}$, which indicates that country *i*'s degree of dominance in market *j* is greater than its dominance in the world market; namely, country *i* has a strong comparative advantage in market *j*. The greater the $RCA_{ij,t}$ index is, the stronger the advantage would be. Conversely, $RCA_{ij,t} < 1$ would indicate that country *i*'s degree of dominance in market *j* falls short of its dominance in the world market, which implies that it has a weak comparative advantage in market *j*. The smaller the $RCA_{ij,t}$ index is, the weaker the advantage would be.[7]

Note that the exact magnitude of the $RCA_{ij,t}$ index measures country *i*'s degree of dominance in market *j* relative to its dominance in the world market. For example, an $RCA_{ij,t}$ index of 1.5 implies that country *i*'s share in market *j* is 1.5 times larger than its share in the world market; conversely, an $RCA_{ij,t}$ index of 0.5 implies that country *i*'s share in market *j* is only half of its share in the world market.

3.2.4 Market share variation

While market share provides a static measure of market power at a certain point in time, market share variation defined as

$$\Delta s_{ij} = s_{ij,t+1} - s_{ij,t}, \tag{9}$$

can be used to measure the gain or loss of market power between time *t* and *t*+1.

A positive Δs_{ij} indicates that country *i* has increased its degree of dominance in market *j* between time *t* and *t*+1; the larger the Δs_{ij} is, the greater the market power gain would be. The interpretation of a negative Δs_{ij} would be the opposite.

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[5] Comparative advantage is a concept commonly used to explain specialization patterns: a country (or other entities) tends to have relatively high specialization in activities where it has strong comparative advantage. The idea of "revealed" comparative advantage is to use *ex post* specialization patterns to infer comparative advantage patterns: a country's actual high specialization in an activity can be viewed as an evidential indication that it has strong comparative advantage in that activity (Balassa, 1965). It is "revealed" (rather than actual) comparative advantage in that rather than reflecting true comparative advantage, high specialization could be a result of policy interventions.

[6] The way to reveal comparative advantage is a highly controversial issue. Many different RCA indices have been suggested and disputed (Bowen, 1983; Vollrath, 1991; Yeats, 1985). While a consensus is yet to be reached, the original Balassa's RCA indices (Balassa, 1965) are the most widely used by applied economists and will be adopted here.

[7] In the revealed comparative advantage literature, an RCA index greater than unity is often treated as an indication of the existence of comparative "advantage", while an RCA index less than unity indicates the existence of comparative "disadvantage". We do not follow this arbitrary categorization, which would be especially inconvenient when discussing comparative advantage variation. Instead, we treat RCA index greater (or less) than unity as an indication of "strong" (or "weak") comparative advantage.

According to equations (6)-(8), market share ($s_{ij,t}$) is the product of size advantage ($s_{i,t}$) and comparative advantage ($RCA_{ij,t}$). Similarly, market share variation defined in equation (9) can also be decomposed into "size variation" and "structural variation" to identify market share variation driven by changes in "size advantage" and "comparative advantage".

Size (market share) variation

To identify country *i*'s size variation in market *j*, we first derive what the country's share in market *j* would have been at time *t*+1 (denoted as $\tilde{s}_{ij,t+1}$) had there been no changes in its comparative advantage between time *t* and *t*+1. Then the difference between this hypothetical $\tilde{s}_{ij,t+1}$ and country *i*'s share in market *j* at the initial time *t* (*i.e.* $s_{ij,t}$) would provide a measure of the country's size variation in market *j*.

According to equation (8), a country's revealed comparative advantage in a market is measured by its share in the market divided by its share in the world market. More specifically, country *i*'s comparative advantage in market *j* relative to market *k* can be measured by the ratio between its shares in the two markets, i.e. $s_{ij,t}/s_{ik,t}$. Thus, a country would experience no comparative advantage variation between time *t* and *t*+1 only if its market share ratios for any two markets remain constant during the period, i.e.

$$\frac{\tilde{s}_{ij,t+1}}{\tilde{s}_{ik,t+1}} = \frac{s_{ij,t}}{s_{ik,t}}, \forall\, j,k,$$

or equivalently,

$$\frac{\tilde{s}_{ij,t+1}}{s_{ij,t}} = \frac{\tilde{s}_{ik,t+1}}{s_{ik,t}} \equiv g, \forall\, j,k, \tag{10}$$

Equation (10) indicates that only when a country's share in every market grows at the same rate would it experience no comparative advantage variation.[8]

According to equation (10), had country *i* maintained its export comparative advantage pattern between time *t* and *t*+1, its share in market *j* at time *t*+1 would be

$$\tilde{s}_{ij,t+1} = g s_{ij,t},$$

which, given the actual size of market *j* ($E_{j,t+1}$), allows the corresponding country *i*'s comparative-advantage-variation-free benchmark exports in market *j* to be calculated as

$$\tilde{E}_{ij,t+1} = \tilde{s}_{ij,t+1} E_{j,t+1} = g s_{ij,t} E_{j,t+1}. \tag{11}$$

The sum of country *i*'s benchmark exports ($\tilde{E}_{ij,t+1}$) in each market needs to be consistent with its actual total exports, i.e.

$$\sum_j \tilde{E}_{ij,t+1} = E_{i,t+1}. \tag{12}$$

Substituting equation (11) into (12) gives

[8] A similar "constant market share" (CMS) condition has often been used to evaluate countries' export competitiveness (e.g. Richardson, 1971a, 1971b; Bowen and Pelzman, 1984; Chen *et al.*, 2000). A country that can keep its market share constant is deemed as being able to maintain its "competitiveness" in the market. Therefore, what we call "degree of dominance" or "market power" here can also be called "competitiveness".

$$g = \frac{E_{i,t+1}}{\sum_j s_{ij,t} E_{j,t+1}}$$

which, substituted back to equation (10), gives

$$\tilde{s}_{ij,t+1} = \frac{s_{ij,t} E_{i,t+1}}{\sum_j s_{ij,t} E_{j,t+1}} = \alpha s_{ij,t}, \tag{13}$$

where $\alpha = \frac{1+g_i}{\sum_j c_{ij,t}(1+g_j)}$,

in which $g_i = (E_{i,t+1} - E_{i,t})/E_{i,t}$ represents the growth rate of country *i*'s total cultured shrimp exports between time *t* and *t*+1; $g_j = (E_{j,t+1} - E_{j,t})/E_{j,t}$ represents the growth rate of market *j*; and $c_{ij,t} = E_{ij,t})/E_{i,t}$ measures country's export specialization in market *j*.

Since $\tilde{s}_{ij,t+1}$ represents what country *i*'s share in market *j* would have been at time *t*+1 had its comparative advantage not changed between time *t* and *t*+1, the difference between this hypothetical $\tilde{s}_{ij,t+1}$ and country *i*'s actual market share at time *t* would provide a measure of its "size" market share variation (denoted as Δs_{ij}^{sc}), i.e.

$$\Delta s_{ij}^{sc} = \tilde{s}_{ij,t+1} - s_{ij,t} = (\alpha - 1) s_{ij,t}. \tag{14}$$

Structural (market share) variation

With size variation identified, structural variation (the other component of total market share variation) can be computed by subtracting size variation from total variation, i.e.

$$\Delta s_{ij}^{st} = \Delta s_{ij} - \Delta s_{ij}^{sc},$$

which, after substituted in equations (9) and (14), becomes

$$\Delta s_{ij}^{st} = s_{ij,t+1} - \tilde{s}_{ij,t+1} = s_{ij,t+1} - \alpha s_{ij,t}. \tag{15}$$

According to equation (15), structural variation is measured by the deviation of country *i*'s actual share in market *j* at time *t*+1 (i.e. $s_{ij,t+1}$) from what it would have been had country *i*'s comparative advantage not changed between time *t* and *t*+1 (i.e. $\tilde{s}_{ij,t+1}$).

3.2.5 Revealed comparative advantage variation

Although direct use of the variation of an *RCA* index to measure comparative advantage variation is often taken for granted in the *RCA* literature,[9] it is actually a questionable practice. In other words, it is usually not appropriate to directly use the variation of the $RCA_{ij,t}$ index to measure comparative advantage variation.

The reader is reminded that according to equation (8), country *i*'s revealed comparative advantage index for market *j* ($RCA_{ij,t}$) is the ratio between its share in market *j* and its world market share. When the size of each market is changed disproportionately between time *t* and *t*+1, it is generally not possible for a country to keep its $RCA_{ij,t}$ index constant in all the markets. In other words, the variation of a country's *RCA* indices may not necessarily reflect changes in its comparative advantage, but could also be caused by disproportionate changes in the sizes of markets. Therefore, we first need to derive what country *i*'s *RCA* index for market *j*

[9] For example Yeats (1992); Hiley (1999); Bojnec (2001); and Havrila and Gunawardana (2003).

would have been at time t+1 if it maintains its comparative advantage in the market at time t. Then we can use the deviation of its actual $RCA_{ij,t+1}$ from this benchmark RCA index to measure its comparative advantage variation between time t and t+1.

In the above discussion we have derived that country i's share in market j at time t+1 would have been $\tilde{s}_{ij,t+1}$ without comparative advantage variation between time t and t+1 – see equation (10). Therefore, without comparative advantage variation between time t and t+1, country i's RCA index for market j at time t+1 would be

$$\tilde{RCA}_{ij,t+1} = \frac{\tilde{s}_{ij,t+1}}{s_{i,t+1}},$$

which, according to equation (10), can be transformed into

$$\tilde{RCA}_{ij,t+1} = \beta RCA_{ij,t} \tag{16}$$

where $\beta = \dfrac{1+g}{1+\sum_j c_{ij,t} g_j}$,

in which $g = (E_{t+1} - E_t)/E_t$ represents the growth rate of the world market between time t and t+1; and g_j as well as $c_{ij,t}$ have been defined in equation (13).[10]

Since country i's RCA index for market j at time t+1 would be $\tilde{RCA}_{ij,t+1}$ when there is no comparative advantage variation between time t and t+1, the deviation of its actual RCA index at time t+1 from this $\tilde{RCA}_{ij,t+1}$ would provide a measure of its revealed comparative advantage variation ($RCAV$) in market j between time t and t+1, i.e.

$$RCAV_{ij} = RCA_{ij,t+1} - \tilde{RCA}_{ij,t+1} = RCA_{ij,t+1} - \beta RCA_{ij,t}. \tag{17}$$

A positive $RCAV_{ij}$ index implies that country i has increased its comparative advantage in market j; the higher the index is, the greater the advantage gain would be. A negative $RCAV_{ij}$ index would have the exact opposite implication.

According to equations (16) and (17),

$$RCAV_{ij} = \frac{s_{ij,t+1} - \tilde{s}_{ij,t+1}}{s_{i,t+1}}. \tag{17'}$$

Therefore, the $RCAV_{ij}$ index actually reflects country i's structure market share variation in market j (measured by $s_{ij,\,t+1} - \tilde{s}_{ij,t+1}$) normalized by its world market share $s_{j,\,t+1}$. The normalization is to facilitate cross-country comparison of export structural changes. That a country has a higher $RCAV$ index in a market than another country implies that the former has had an export structure change more biased to the market than the latter.

3.2.6 Data

Twenty-eight shrimp farming countries in eight regions are included in the global comparative assessment of frozen cultured shrimp export performance (Tables 3

[10] It is not difficult to verify that $\sum_j c_{j,t} g_j = g$,

where $c_{j,\,t} = E_{j,t}/E_t$ represents the proportion of world cultured shrimp exports sold to market j. Thus, β would be unity when $c_{ij,t}$ is identical to $c_{j,t}$ for every market j, i.e. when country i's RCA index for every market j is equal to unity. According to equation (8), it is not difficult to see that $RCA_{ij,t} = c_{ij,t}/c_{j,t}$. Otherwise, β would generally be different from unity unless every market grows at the same rate (i.e. $g_j = g, \forall j$). Therefore, when the sizes of markets are changed disproportionately, direct use of the variation of RCA indices to measure comparative advantage variation would not be appropriate in general.

and 4).[11] The assessment is focused on Japan, the United States of America and the European Union as the three major international frozen shrimp export markets; other (regional) export markets are aggregated into "other markets".

The UN Comtrade database is our main data source (United Nations, 2008). We used the data on commodity "shrimps and prawns, frozen", code S3-03611 under the Standard International Trade Classification, Revision 3 (SITC, Rev. 3).[12] We used the frozen shrimp imports of Japan, the United States of America and European Union from the 28 shrimp farming countries to represent the latter's exports to the respective markets.[13] The import value includes transportation and insurance costs (i.e. CIF).[14]

The data are aggregated, including both cultured and captured shrimp exports; thus we had to estimate frozen cultured shrimp exports from the aggregated data. We first calculated a country's cultured/total shrimp *production* ratio,[15] and then applied it as a proxy of the country's cultured/total shrimp *export* ratio to estimate the country's cultured shrimp exports. For example, 75 percent of Thailand's total shrimp production in 2001 came from aquaculture while its total frozen shrimp export to the EU in that year was USD70 million. Thus, the country's estimated cultured shrimp exports to the EU in 2001 would be equal to USD52.5 million (i.e. USD70 million multiplied by 75 percent).[16]

The time period under assessment is from the early 1990s (represented by the 1990–92 average) to the early 2000s (represented by the 2000–02 average), which includes two sub-periods from the early 1990s to the mid-1990s (represented by the 1995–97 average) and from the mid-1990s to the early 2000s.[17]

3.3 RESULTS

The size of the world frozen cultured shrimp export market (in terms of value) almost doubled during the first half of the 1990s, remained stable in the second half, and declined in the early 2000s (Figure 2a). Southeast Asia has always been the number one exporter in the market, responsible for most of its ups and downs. South America was in the second place in the 1990s, yet it tended to yield the place to South Asia in the

[11] Japan and the United States of America (with shares in world cultured shrimp production of 0.2 and 0.3 percent respectively in the early 2000s) are not considered since they are two of the three markets examined here. Taiwan, Province of China (with a 0.9 percent share of world cultured shrimp production in the early 2000s) is also excluded because data on its shrimp exports are not included in the United Nations Comtrade database.

[12] Here we only examine countries' performance in exporting "frozen" shrimp products, while some countries (e.g. Thailand, China and India) also have substantial exports of other types of shrimp products such as "prepared or preserved" or "fresh or chilled".

[13] The data for the EU are computed by summing the cultured shrimp imports of 15 EU countries including Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Netherlands, Portugal, Spain, Sweden and the United Kingdom.

[14] We use export value instead of quantity because different shrimp products are more comparable in terms of value than in terms of quantity. The choice between value and quantity can affect assessment results when the prices of shrimp products from different countries are significantly different. For example, in terms of quantity China was the second largest cultured shrimp exporter to the United States market in the early 2000s, while in terms of value China's United States market share during that period was smaller than that of Ecuador, Viet Nam and some other countries.

[15] Shrimp production data were obtained from FAO's FishStat database (FAO, 2008). Cultured shrimp production includes all species in the group of "shrimps and prawns" (code 45) under the FAO's International Standard Statistical Classification of Aquatic Animals and Plants (ISSCAAP).

[16] Since cultured shrimp is in general more likely to be exported than captured shrimp, using the cultured/captured shrimp production ratio as a proxy of their export ratio tends to underestimate the amount of cultured shrimp exports. Since the degree of such underestimation tends to be more severe for countries with relatively large captured shrimp production (e.g. China), these countries' comparative *static* performance tends to be underrated. However, the assessment results for their comparative *dynamic* performance would not be affected.

[17] We use average time periods to smooth the impacts of transitory shocks on countries' frozen shrimp exports.

early 2000s. In addition to South Asia, Central America is another region with steady growth in frozen cultured shrimp exports. East Asia (primarily China) was the third largest exporter in the early 1990s yet reduced its market share to nearly zero since 1993 until the recent recovery in the early 2000s.

3.3.1 The Japanese market

Japan was the largest frozen cultured shrimp export market in the early 1990s, accounting for 39 percent of world exports by quantity. However, the ratio declined to 34 percent by the mid-1990s and to 25 percent by the early 2000s primarily because of shrinking demand for shrimp by Japanese consumers in the context of a stagnated domestic economy. In terms of value, frozen cultured shrimp exports also experienced significant growth in the first half of the 1990s and an equally significant decline in the second half (Figure 2b).

Southeast Asia has always been the dominant exporter to the market, followed by South Asia. South America increased its presence in the market during the second half of the 1990s, but the market was already entering its declining phase. Despite the shrinking size of the market, East Asia (especially China) increased its exports in the early 2000s.

Thailand and Indonesia

In the early 1990s, Thailand and Indonesia were the two largest exporters to the Japan market, meaning that they had a strong revealed comparative advantage (Figure 3a). Their Japan RCA indices were 1.3 and 1.9 respectively (Table 5), which implies that their Japan market shares were respectively 1.3 and 1.9 times greater than their world market shares.

FIGURE 3
Cultured shrimp exports to the Japan market

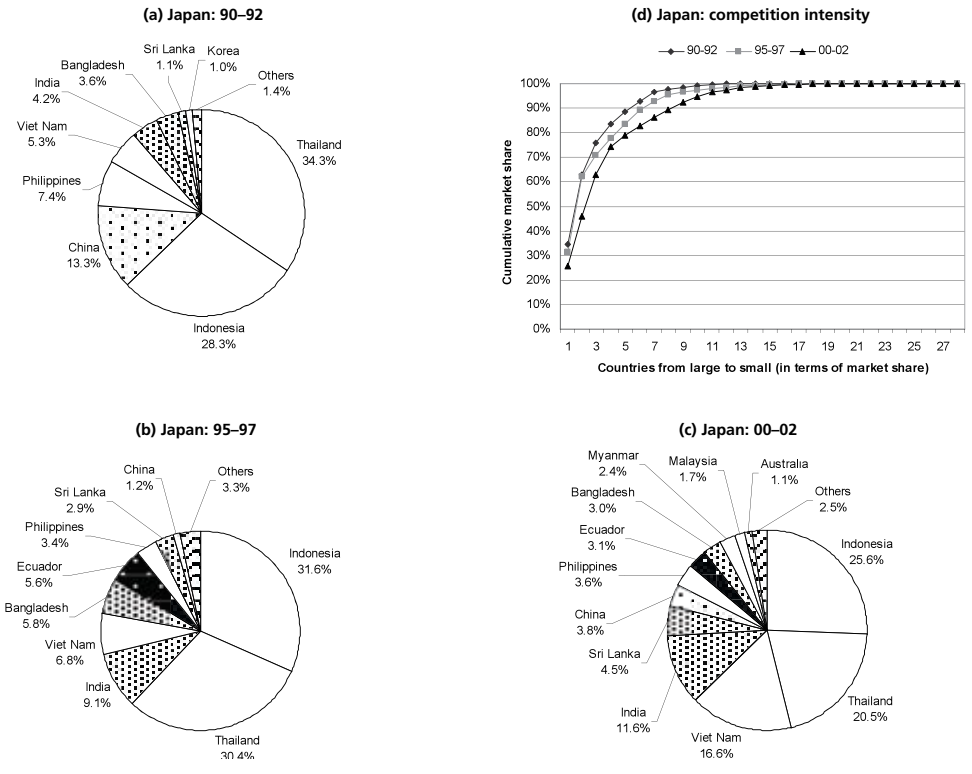


TABLE 4
Cultured shrimp exports to the world market (million USD)

Region	Country	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	World market share (1990)	World market share (2002)
Africa	Madagascar	0.2	0.5	0.5	0.2	0.7	0.8	0.8	3.3	1.8	2.4	3.8	7.8	6.1	0.0%	0.2%
Central America	Belize	0.3	1.1	3.9	4.5	4.6	6.1	4.8	7.9	10.4	22.3	25.3	20.9	17.4	0.0%	0.6%
	Costa Rica	0.3	1.7	1.7	1.7	3.2	10.0	9.6	9.4	8.1	10.1	7.3	8.8	11.6	0.0%	0.4%
	Guatemala	4.3	4.6	6.2	18.6	25.1	15.0	16.5	17.9	8.8	10.1	13.6	22.4	28.4	0.2%	1.0%
	Honduras	20.9	30.0	40.4	54.3	46.4	39.6	46.1	46.3	41.8	40.1	64.5	61.2	58.6	1.2%	2.1%
	Mexico	4.3	5.7	3.6	8.5	15.0	25.4	26.2	37.1	70.1	48.9	61.9	102.1	69.4	0.2%	2.5%
	Nicaragua	5.1	5.3	3.5	8.9	21.9	40.4	37.7	41.6	54.6	49.1	57.7	46.3	38.8	0.3%	1.4%
	Central America	**35**	**49**	**59**	**96**	**116**	**136**	**141**	**160**	**194**	**181**	**230**	**262**	**224**	**2.0%**	**8.0%**
South America	Brazil	2.1	3.1	3.7	4.0	4.2	2.3	3.5	2.3	4.9	14.7	45.6	90.7	136.1	0.1%	4.8%
	Colombia	33.7	29.7	39.0	37.9	52.6	55.9	38.5	41.8	47.6	50.5	59.0	55.7	47.3	1.9%	1.7%
	Ecuador	376.2	511.8	540.8	480.6	628.4	739.9	693.5	911.2	923.0	714.8	338.8	333.7	288.3	21.0%	10.2%
	Panama	3.0	1.9	2.0	7.6	17.9	38.8	30.2	48.1	59.4	33.2	33.1	34.5	30.4	0.2%	1.1%
	Peru	7.8	7.0	10.5	9.4	11.1	13.2	11.1	22.4	27.8	4.4	0.6	1.6	5.7	0.4%	0.2%
	Venezuela (Bolivarian Republic of)	1.2	2.6	5.1	3.7	7.4	11.6	19.9	31.3	29.7	68.6	82.0	51.1	49.5	0.1%	1.8%
	South America	**424**	**556**	**601**	**543**	**722**	**862**	**797**	**1 057**	**1 092**	**886**	**559**	**567**	**557**	**23.6%**	**19.8%**
East Asia	China	269.4	236.3	267.0	91.7	39.2	32.3	22.1	28.8	31.4	33.4	80.5	109.9	130.0	15.0%	4.6%
	Republic of Korea	10.7	8.2	8.1	6.5	3.8	5.7	3.0	1.3	1.2	1.3	0.7	3.9	2.5	0.6%	0.1%
	East Asia	**280**	**245**	**275**	**98**	**43**	**38**	**25**	**30**	**33**	**35**	**81**	**114**	**132**	**15.6%**	**4.7%**
Middle East	Iran (Islamic Republic of)	0.0	0.0	0.0	0.0	0.1	0.2	0.3	1.0	2.2	6.2	12.6	14.2	16.3	0.0%	0.6%
	Saudi Arabia	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.3	0.7	2.3	1.4	3.6	3.4	0.0%	0.1%
	Middle East	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**1**	**3**	**8**	**14**	**18**	**20**	**0.0%**	**0.7%**

TABLE 4 (Continued)
Cultured shrimp exports to the world market (million USD)

Region	Country	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	World market share (1990)	World market share (2002)
South Asia	Bangladesh	170.1	145.9	164.8	205.7	266.0	269.4	307.9	284.6	241.8	293.8	363.5	272.8	279.0	9.5%	9.9%
	India	54.6	59.6	64.5	88.2	145.3	144.1	144.4	156.3	158.3	145.0	217.7	202.8	206.1	3.0%	7.3%
	Sri Lanka	12.3	10.1	11.7	15.2	30.3	38.0	41.1	33.7	74.0	33.1	73.8	49.5	30.2	0.7%	1.1%
	South Asia	**237**	**216**	**241**	**309**	**442**	**452**	**493**	**475**	**474**	**472**	**655**	**525**	**515**	**13.2%**	**18.3%**
Southeast Asia	Indonesia	269.7	344.1	333.3	383.8	414.7	444.5	426.9	436.7	339.3	321.6	355.9	327.5	281.9	15.0%	10.0%
	Malaysia	0.1	0.4	0.3	8.5	3.7	17.0	20.9	22.3	21.4	29.1	45.5	49.2	38.2	0.0%	1.4%
	Myanmar	2.2	2.5	6.3	10.8	17.6	22.3	25.5	29.1	33.5	30.5	50.8	55.4	55.7	0.1%	2.0%
	Philippines	72.5	98.9	67.5	55.6	71.8	60.4	51.8	33.0	24.3	40.3	28.9	29.4	56.0	4.0%	2.0%
	Thailand	403.1	586.5	736.7	972.5	1 322.7	1 321.9	997.8	871.0	1 012.9	1 008.7	1 217.2	994.6	579.1	22.5%	20.6%
	Viet Nam	67.4	55.8	85.5	96.0	117.4	114.8	106.9	124.9	154.6	165.9	283.4	308.4	336.1	3.8%	11.9%
	Southeast Asia	**815**	**1 088**	**1 230**	**1 527**	**1 948**	**1 981**	**1 630**	**1 517**	**1 586**	**1 596**	**1 982**	**1 765**	**1 347**	**45.4%**	**47.8%**
Oceania	Australia	3.5	4.3	4.1	5.8	8.9	9.4	8.0	7.2	5.8	11.1	15.2	14.2	12.5	0.2%	0.4%
	New Caledonia	0.0	0.0	0.0	0.0	0.0	0.2	0.4	0.5	0.9	2.4	2.0	2.3	2.8	0.0%	0.1%
	Oceania	**3**	**4**	**4**	**6**	**9**	**10**	**8**	**8**	**7**	**14**	**17**	**17**	**15**	**0.2%**	**0.5%**
World		1 795	2 158	2 411	2 580	3 280	3 480	3 096	3 251	3 390	3 194	3 543	3 275	2 817	100%	100%

Source: United Nations (2008)

TABLE 5
Cultured shrimp export performance in the Japanese market

Region	Country	First period (early-1990s to mid-1990s)						Second period (mid-1990s to early-2000s)					
		Market share (%)				RCA indices		Market share (%)				RCA indices	
		Initial	Total variation	Size variation	Structural variation	Initial	RCAV	Initial	Total variation	Size variation	Structural variation	Initial	RCAV
Africa	Madagascar	0.0	0.0	0.0	0.0	0.8	0.06	0.0	0.1	0.1	-0.1	0.9	-0.32
	Africa	**0.0**	**0.0**	**0.0**	**0.0**	**0.8**	**0.06**	**0.0**	**0.1**	**0.1**	**-0.1**	**0.9**	**-0.32**
Central America	Belize	0.0	0.0	0.0	0.0	0.0	0.00	0.0	0.0	0.0	0.0	0.0	0.00
	Costa Rica	0.0	0.0	0.0	0.0	0.0	-0.03	0.0	0.0	0.0	0.0	0.0	0.00
	Guatemala	0.0	0.0	0.0	0.0	0.0	0.00	0.0	0.0	0.0	0.0	0.0	0.03
	Honduras	0.0	0.0	0.0	0.0	0.0	0.02	0.0	0.0	0.0	0.0	0.0	-0.02
	Mexico	0.0	0.1	0.1	0.0	0.2	-0.05	0.1	0.1	0.1	0.0	0.1	-0.02
	Nicaragua	0.0	0.2	0.0	0.2	0.0	0.19	0.2	0.2	0.0	0.2	0.2	0.11
	Central America	**0.0**	**0.3**	**0.0**	**0.3**	**0.0**	**0.07**	**0.4**	**0.3**	**0.2**	**0.1**	**0.1**	**0.01**
South America	Brazil	0.1	0.0	-0.1	0.1	1.0	1.09	0.2	0.7	7.0	-6.2	2.2	-2.21
	Colombia	0.8	-0.2	-0.1	-0.1	0.5	-0.06	0.6	0.0	0.1	-0.1	0.4	-0.03
	Ecuador	0.1	5.5	0.0	5.5	0.0	0.23	5.6	-2.5	-3.5	1.0	0.2	0.10
	Panama	0.0	0.0	0.0	0.0	0.0	0.00	0.0	0.0	0.0	0.0	0.0	0.00
	Peru	0.0	0.0	0.0	0.0	0.0	0.01	0.0	0.0	0.0	0.0	0.0	-0.01
	Venezuela (Bolivarian Republic of)	0.0	0.0	0.0	0.0	0.0	0.01	0.0	0.0	0.0	0.0	0.0	-0.02
	South America	**1.0**	**5.4**	**0.1**	**5.3**	**0.0**	**0.19**	**6.3**	**-1.8**	**-2.8**	**1.0**	**0.2**	**0.06**
East Asia	China	13.3	-12.1	-12.4	0.3	1.1	0.35	1.2	2.6	4.0	-1.4	1.5	-0.42
	Republic of Korea	1.0	-0.8	-0.7	0.0	2.4	-0.44	0.2	-0.2	0.0	-0.2	2.3	-2.28
	East Asia	**14.4**	**-12.9**	**-13.3**	**0.4**	**1.1**	**0.39**	**1.5**	**2.4**	**4.3**	**-1.9**	**1.5**	**-0.56**
Middle East	Iran (Islamic Republic of)	0.0	0.0	0.0	0.0	0.2	0.76	0.0	0.1	0.4	-0.3	1.0	-0.67
	Saudi Arabia	0.0	0.0	0.0	0.0	0.0	1.23	0.0	0.0	0.1	-0.1	1.2	-1.18
	Middle East	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.99**	**0.0**	**0.1**	**0.6**	**-0.4**	**1.0**	**-0.75**
South Asia	Bangladesh	3.6	2.2	0.2	2.0	0.5	0.23	5.8	-2.8	0.3	-3.1	0.7	-0.33
	India	4.2	4.9	2.9	2.0	1.5	0.43	9.1	2.5	6.2	-3.7	2.0	-0.57
	Sri Lanka	1.1	1.8	1.4	0.4	2.0	0.35	2.9	1.6	2.2	-0.6	2.5	-0.35
	South Asia	**8.9**	**8.9**	**2.3**	**6.6**	**0.8**	**0.46**	**17.8**	**1.3**	**4.9**	**-3.6**	**1.2**	**-0.21**
Southeast Asia	Indonesia	28.3	3.3	-1.1	4.4	1.9	0.33	31.6	-6.0	-2.3	-3.7	2.4	-0.37
	Malaysia	0.0	0.6	0.5	0.1	0.9	0.18	0.6	1.1	0.8	0.2	1.0	0.17
	Myanmar	0.0	0.6	0.1	0.5	0.2	0.68	0.7	1.8	0.9	0.9	0.8	0.52
	Philippines	7.4	-4.0	-4.2	0.2	2.0	0.15	3.4	0.2	0.0	0.3	2.3	0.21
	Thailand	34.3	-4.0	7.7	-11.6	1.3	-0.36	30.4	-9.9	-3.5	-6.4	0.9	-0.22
	Viet Nam	5.3	1.5	0.2	1.3	1.6	0.37	6.8	9.9	15.1	-5.2	1.9	-0.54
	Southeast Asia	**75.4**	**-2.0**	**7.5**	**-9.5**	**1.5**	**-0.18**	**73.4**	**-3.0**	**5.8**	**-8.8**	**1.4**	**-0.17**
Oceania	Australia	0.3	0.2	0.1	0.1	1.8	0.29	0.6	0.5	0.6	-0.1	2.2	-0.27
	New Caledonia	0.0	0.0	0.0	0.0	0.1	0.22	0.0	0.1	0.0	0.1	0.3	1.16
	Oceania	**0.3**	**0.2**	**0.2**	**0.1**	**1.8**	**0.20**	**0.6**	**0.6**	**0.8**	**-0.1**	**2.1**	**-0.29**

During the first period, from the early to mid-1990s, Indonesia's world market share declined from 15 to 13 percent. Yet its Japan market share has nevertheless increased from 28 to 32 percent. In other words, despite the size advantage decline, Indonesia was still able to increase its degree of dominance in the Japan market through comparative advantage gains.

As shown in Table 5, Indonesia's total market share variation in the Japanese market during the first period was 3.3 percent, which can be decomposed into -1.1 percent of size variation and 4.4 percent of structural variation. The negative size variation implies that had Indonesia maintained its comparative advantage pattern during the first period, it would have yielded 1.1 percent of the Japanese market. Yet, the country has actually gained 3.3 percent because of the 4.4 percent of structural variation that reflects its comparative advantage gains in the Japan market.

During the first period, contrary to Indonesia (which had lost world market share yet had gained market share in Japan), Thailand increased its world market share from 27 to 32 percent yet reduced its Japan market share from 34 to 30 percent. The 4 percent of its Japan market share decline is the result of an 8 percent size gain in tandem with a 12 percent of structural decline.

During the second period (from the mid-1990s to the early-2000s), Indonesia further reduced its world market share from 13 to 10 percent while its Japan market share went from 32 to 26 percent. This 6 percent decline in Japanese market share was caused by a 2.3 percent of size decline as well as a 3.7 percent of structural decline. Thailand had a similar experience and reduced its world market share from 32 to 29 percent and its Japan market share from 30 to 20 percent. This 10 percent decline in Japanese market share was caused by a 3.5 percent of size decline in addition to a 6.4 percent of structural decline (Table 5).

China and the Philippines

In the early 1990s, China and the Philippines were the third and fourth largest exporters to the Japanese market, respectively controlling 13 and 7.4 percent of the market (Figure 3a). They also had large revealed comparative advantages in the market with *RCA* indices of 1.1 and 2.0 respectively. However, both countries reduced their Japan market power significantly during the first period (Table 5). China lost nearly the entire 13 percent of its Japan market share because of the collapse of its cultured shrimp production caused by disease outbreaks in 1993 (Table 3). The Philippines expanded its annual cultured shrimp production from 61 000 to 70 000 tonnes during this period; yet this expansion was not sufficient to prevent the decline of its Japan market share from 7.4 to 3.4 percent. The RCAV indices reveal that their declining dominance in the Japan market was caused completely by a size advantage decline (Table 5).

With its annual cultured shrimp production rising from 90 000 to 300 000 tonnes, China increased its Japan market share by 2.6 percent during the second period, which was the result of a 4 percent size gain together with a 1.4 percent of structural decline. The Philippines also increased its Japanese market share slightly from 3.4 to 3.6 percent, which was mainly due to a comparative advantage gain (Table 5).

Viet Nam

Viet Nam, a rising star in the shrinking Japanese market, increased its market share from 5.3 percent in the early 1990s to 6.8 percent in the mid-1990s, and then to 17 percent in the early 2000s (Figure 3). While the expansion during the first period was mainly a structural effect due to its comparative advantage gain in the Japan market, the expansion during the second period was completely a size effect corresponding to an increase in its world market share from 3.5 percent in the mid-1990s to 10 percent in the early 2000s (Table 5).

Bangladesh, India and Sri Lanka

In the early 1990s, Bangladesh, India and Sri Lanka held 3.6, 4.2 and 1.1 percent of the Japanese market, respectively. While India and Sri Lanka had strong revealed comparative advantage in the market with *RCA* indices of 1.5 and 2.0 respectively, Bangladesh's *RCA* index was only 0.5.

During the first period all these three South Asian countries increased their Japan market shares through gains in both size and comparative advantage (Figure 3 and Table 5). During the second period all three countries reduced their comparative advantage in the Japanese market (Table 5). While India and Sri Lanka can still manage to increase their shares in the market through size advantage gain, Bangladesh (whose size advantage gain was not sufficient to overcome its comparative advantage decline), had to yield some of its Japan market share.

Other countries

Information on other countries' frozen cultured shrimp export performance in the Japanese market can be found in Table 5.

Asian-Pacific dominance

The Japanese market has been dominated by Asian-Pacific countries. Ecuador is the only non-Asian-Pacific country that has ever obtained non-trivial market power in the Japanese market. Its Japan market share was 5.6 percent in the mid-1990s but it nevertheless declined to 3.1 percent in the early 2000s (Figure 3).

The Asian-Pacific dominance in the Japan market is evident not only in terms of market power but also in terms of comparative advantage – Brazil is the only non-Asian-Pacific country that has ever had strong comparative advantage in the Japanese market (Table 5). However, not all Asian countries have strong comparative advantage in the Japanese market. Bangladesh is the only Asian country that never enjoyed strong comparative advantage. Iran (Islamic Republic of) and Saudi Arabia in the Middle East had only a transitory strong comparative advantage in the mid-1990s. Thailand had a strong comparative advantage in the early 1990s but it has weakened since the mid-1990s. Interestingly, Korea (the closest neighbour to Japan) had only a weak comparative advantage by the early 2000s.

Competition intensity

The Japanese market has become increasingly competitive in the sense that market shares have been distributed more and more evenly across countries. While over 60 percent of the market was controlled by only two countries (Indonesia and Thailand) in the early and mid-1990s, Viet Nam also emerged as a top supplier by the early 2000s (Figure 3). In general, the cumulative market share curves in Figure 3d indicate that the Japan market share has become less concentrated in the early 2000s than in the early 1990s.

Comparative advantage variation

According to the *RCAV* indices in Table 5, the following countries have gained comparative advantage in the Japanese market during both study periods: Myanmar, Malaysia and the Philippines in Southeast Asia; Nicaragua in Central America; and Ecuador in South America. On the contrary, Thailand, Republic of Korea, Mexico and Colombia have reduced their comparative advantage.

3.3.2 The United States of America market

Rapid economic growth in the United States during the 1990s increased the country's consumption of the world frozen cultured shrimp exports from 38 percent in the early 1990s to 40 percent in the mid-1990s, and then to 48 percent in the early 2000s, when it became the largest international frozen cultured shrimp market (Figure 2c).

South America and Southeast Asia are the two major exporters to this market; yet both have reduced their exports recently. Central America and South Asia have relatively smaller cultured shrimp exports to the United States market; however, their respective shares have been increasing in the most recent years. East Asian (mainly China) exports to the United States were at the same level as Southeast Asia in the early 1990s; this market share collapsed to nearly zero since 1993 as a consequence of declining shrimp farming. The recovery of the Chinese industry in the early 2000s led to a reactivation of shrimp exports. China became the second largest frozen shrimp exporter (in terms of quantity) to the United States in 2003.

Ecuador and Thailand

Ecuador and Thailand are the two most dominant exporters to the United States. market (Figure 4). In the early 1990s Ecuador accounted for 22 percent of the world market while Thailand represented 27 percent. In contrast, Ecuador's share in the United States (39 percent) exceeded that of Thailand (23 percent). This reflects Ecuador's much stronger comparative advantage in the United States market (with an *RCA* index of 1.7) than Thailand (with an *RCA* index of 0.8).

During the first period, Thailand raised its United States market share significantly by 11 percent (from 23 to 34 percent) through 5 percent of size gain and 6 percent of structural gain. In contrast, Ecuador reduced its United States market share from 39 to 36 percent because of its declining comparative advantage (Table 6). During the second period, Ecuador's United States market share declined further to only 13 percent

FIGURE 4
Cultured shrimp exports to the United States of America market

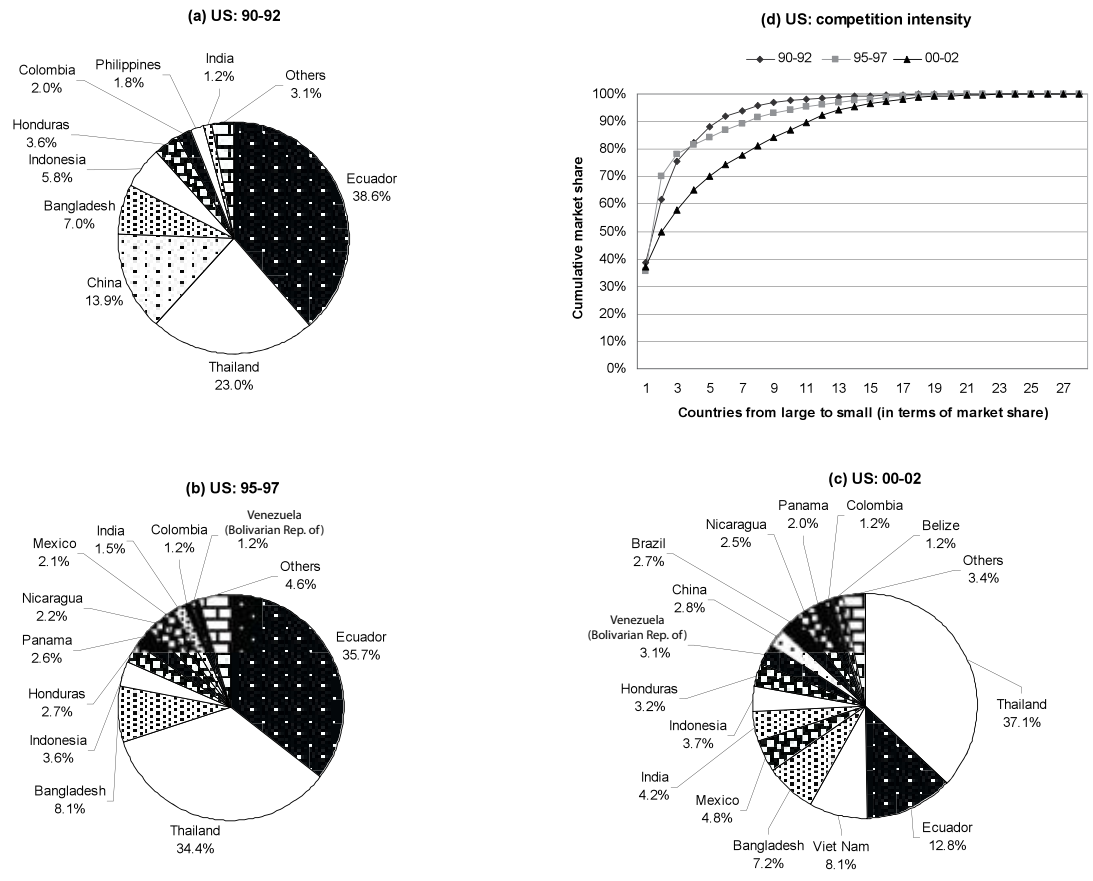


TABLE 6
Cultured shrimp export performance in the United States of America market

Region	Country	First period (early 1990s to mid-1990s)						Second period (mid-1990s to early 2000s)					
		Market share (%)				RCA indices		Market share (%)				RCA indices	
		Initial	Total variation	Size variation	Structural variation	Initial	RCAV	Initial	Total variation	Size variation	Structural variation	Initial	RCAV
Africa	Madagascar	0.0	0.0	0.0	0.0	0.0	0.00	0.0	0.0	0.0	0.0	0.0	0.00
	Africa	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.00**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.00**
Central America	Belize	0.1	0.3	0.2	0.1	1.7	0.75	0.4	0.7	0.8	-0.1	2.3	-0.17
	Costa Rica	0.1	0.4	0.4	0.0	1.6	-0.02	0.4	-0.1	-0.1	0.0	1.5	-0.06
	Guatemala	0.4	0.4	0.4	-0.1	1.8	-0.14	0.8	0.0	0.1	-0.1	1.6	-0.22
	Honduras	3.6	-0.8	-0.4	-0.5	2.5	-0.34	2.7	0.5	0.6	-0.1	2.0	-0.04
	Mexico	0.5	1.6	1.6	0.0	2.4	-0.02	2.1	2.7	2.7	0.0	2.3	0.02
	Nicaragua	0.3	1.9	1.2	0.7	1.3	0.56	2.2	0.3	0.1	0.1	1.8	0.08
	Central America	**5.0**	**3.7**	**4.5**	**-0.8**	**2.2**	**-0.18**	**8.7**	**4.1**	**3.8**	**0.3**	**2.0**	**0.04**
South America	Brazil	0.2	-0.1	-0.1	-0.1	1.1	-0.61	0.0	2.7	1.8	0.9	0.6	0.30
	Colombia	2.0	-0.8	-0.3	-0.5	1.3	-0.37	1.2	0.0	0.2	-0.2	0.9	-0.11
	Ecuador	38.6	-2.9	0.3	-3.2	1.7	-0.13	35.7	-22.9	-22.3	-0.6	1.5	-0.06
	Panama	0.3	2.4	2.4	0.0	2.3	-0.01	2.6	-0.6	-0.7	0.1	2.2	0.11
	Peru	0.8	0.0	0.1	-0.1	1.9	-0.19	0.8	-0.7	-0.7	0.0	1.6	0.02
	Venezuela (Bolivarian Republic of)	0.2	1.0	0.6	0.4	1.4	0.56	1.2	1.9	1.9	0.0	1.9	0.01
	South America	**42.0**	**-0.4**	**2.4**	**-2.8**	**1.7**	**-0.10**	**41.6**	**-19.7**	**-18.1**	**-1.6**	**1.5**	**-0.09**
East Asia	China	13.9	-13.3	-12.9	-0.4	1.1	-0.50	0.5	2.3	1.8	0.5	0.6	0.15
	Republic of Korea	0.0	0.0	0.0	0.0	0.0	0.18	0.0	0.0	0.0	0.0	0.2	-0.23
	East Asia	**13.9**	**-13.3**	**-12.8**	**-0.5**	**1.1**	**-0.52**	**0.6**	**2.2**	**1.6**	**0.6**	**0.6**	**0.18**
Middle East	Iran (Islamic Republic of)	0.0	0.0	0.0	0.0	0.0	0.00	0.0	0.1	0.0	0.1	0.0	0.12
	Saudi Arabia	0.0	0.0	0.0	0.0	0.0	0.17	0.0	0.2	0.0	0.1	0.2	1.65
	Middle East	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.03**	**0.0**	**0.2**	**0.0**	**0.2**	**0.0**	**0.37**
South Asia	Bangladesh	7.0	1.1	0.4	0.7	0.9	0.08	8.1	-0.8	0.4	-1.3	0.9	-0.13
	India	1.2	0.4	0.8	-0.4	0.4	-0.09	1.5	2.7	1.1	1.6	0.3	0.25
	Sri Lanka	0.2	0.1	0.3	-0.2	0.4	-0.19	0.3	0.3	0.2	0.1	0.3	0.07
	South Asia	**8.4**	**1.6**	**2.2**	**-0.7**	**0.8**	**-0.05**	**9.9**	**2.2**	**2.7**	**-0.6**	**0.7**	**-0.03**
South-east Asia	Indonesia	5.8	-2.3	-0.2	-2.0	0.4	-0.15	3.6	0.1	-0.3	0.3	0.3	0.03
	Malaysia	0.0	0.1	0.2	-0.2	0.4	-0.29	0.1	0.2	0.1	0.1	0.1	0.09
	Myanmar	0.1	0.0	0.1	-0.1	0.3	-0.16	0.1	0.6	0.1	0.5	0.1	0.33
	Philippines	1.8	-1.5	-1.0	-0.4	0.5	-0.29	0.4	0.0	0.0	0.0	0.3	-0.04
	Thailand	23.0	11.4	5.1	6.2	0.8	0.19	34.4	2.7	-3.9	6.6	1.1	0.23
	Viet Nam	0.0	0.8	0.0	0.8	0.0	0.21	0.8	7.3	1.7	5.7	0.2	0.59
	Southeast Asia	**30.7**	**8.5**	**3.1**	**5.4**	**0.6**	**0.10**	**39.2**	**10.9**	**3.1**	**7.8**	**0.8**	**0.15**
Oceania	Australia	0.0	0.0	0.0	0.0	0.1	-0.06	0.0	0.0	0.0	0.0	0.0	0.03
	New Caledonia	0.0	0.0	0.0	0.0	0.0	0.00	0.0	0.0	0.0	0.0	0.0	0.15
	Oceania	**0.0**	**0.0**	**0.0**	**0.0**	**0.1**	**-0.06**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.05**

because of a size-advantage decline caused by shrimp diseases that reduced the country's shrimp production by half (Tables 3 and 6). Thailand has also reduced its size advantage in the United States market during the second period; however, its United States market share nevertheless increased from 34 to 37 percent through comparative advantage gains (Table 6).

China

In the early 1990s, China controlled 14 percent of the United States market where it had a strong comparative advantage (*RCA* index = 1.1). However, as its world market share fell from 12 percent in the early 1990s to 0.8 percent in the mid-1990s (due to the disease-induced shrimp farming collapse in 1993), its United States market share declined even more severely (from 14 to 0.5 percent). According to the *RCAV* indices for the first period, China's comparative advantage in the United States declined but it then increased in both the Japanese and EU markets (Tables 5–7).

During the second period, China increased its world and United States market shares to 3.3 and 2.8 percent, respectively.[18] *RCAV* indices during this period indicate that China has gained comparative advantage in the United States market in detriment of the Japan and EU markets (Tables 5-7).

Viet Nam, India, Mexico and Brazil

Viet Nam, India, Mexico and Brazil have been performing as four rising stars in the United States market, jointly supplying 20 percent of exports in the early 2000s (Table 6). Viet Nam increased its United States market share from less than 1 percent in the mid-1990s to 8 percent in the early 2000s through 2 percent of size and 6 percent of structural gain. India held 1.2 percent of the United States market in the early 1990s and then 1.5 percent in the mid-1990s through size gains; its share increased significantly to 4.2 percent in the early 2000s through 1.1 percent of size and 1.6 percent of structural gain (Table 6).

Mexico has maintained a very strong comparative advantage in the United States market with an *RCA* index consistently above 2. Its size advantage gains driven by rapid shrimp farming growth increased its United States market share from 0.5 percent in the early 1990s to 2.1 percent in the mid-1990s and 4.8 percent in the early 2000s. On the other hand, Brazil increased its annual cultured shrimp production significantly from 3 000 tonnes in the mid-1990s to 42 000 tonnes in the early 2000s. Accordingly, its United States market share increased from nearly zero to 3 percent through 1.8 percent of size and 0.9 percent of structural gain (Table 6).

Other countries

Information on other countries' frozen cultured shrimp export performance in the United States market can be found in Table 6.

Regional dominance in the United States market

As far as market share is concerned, South America was the most dominant exporter to the United States market in the early and mid-1990s, controlling 42 percent of the market. Yet this share had declined to 22 percent by the early 2000s; by then, Southeast Asia was the most important supplier. The region increased its United States market share from 31 percent in the early 1990s to 39 percent in the mid-1990s and 50 percent in the early-2000s. Central America and South Asia also gained market power in the United States during both periods (Table 6).

[18] China's frozen cultured shrimp export performance might be underrated by the way we estimate cultured shrimp exports based on total shrimp exports; see footnote 17.

With regard to revealed comparative advantage, the Latin American dominance in the United States market is as evident as the Asian-Pacific dominance is in the Japan market (Table 6). China in the early 1990s, Thailand in the mid-1990s and early 2000s, and Saudi Arabia in the early 2000s have been the only non-Latin American countries to enjoy strong comparative advantage in the United States market. On the other hand, Brazil in the mid-1990s and Colombia in the mid-1990s and early 2000s were the only Latin American countries to exhibit weak comparative advantage in the United States market.

Competitive intensity

As previously observed in Japan, the United States market has become increasingly competitive, especially in the early 2000s (Figure 4d). While only two countries (Ecuador and Thailand) controlled 70 percent of the United States market in the mid-1990s, five countries accounted for that share in the early 2000s. Similarly, while six countries controlled 90 percent of the market in the early 1990s, 12 countries accounted for the same market share in the early 2000s.

Comparative advantage variation

Thailand, Viet Nam, Nicaragua and Venezuela (Bolivarian Republic of) exhibited comparative advantage gains in the United States. market during both periods. Belize, Bangladesh and the Republic of Korea enjoyed comparative advantage gains during the first period but declines during the second one. Brazil, Mexico, Panama, Peru, Myanmar, Malaysia, Indonesia, Australia, India, Sri Lanka and China experienced a decline in comparative advantage during the first period yet recorded gains during the second.

Most of the countries with falling comparative advantage during both periods (i.e. Honduras, Costa Rica, Guatemala, Ecuador and Colombia) are in Latin America; the only exception is the Philippines (Table 6).

3.3.3 The European Union market

Relative to Japan and the United States, the EU market has been relatively small, absorbing 15, 16 and 17 percent of the world frozen cultured shrimp exports in the early 1990s, mid-1990s and early 2000s, respectively. However, its absolute size grew significantly through the late 1990s (Figure 2d). As compared to Japan and the United States, the EU market has been more competitive in the sense that market shares have been distributed more evenly across exporters (Figure 5).

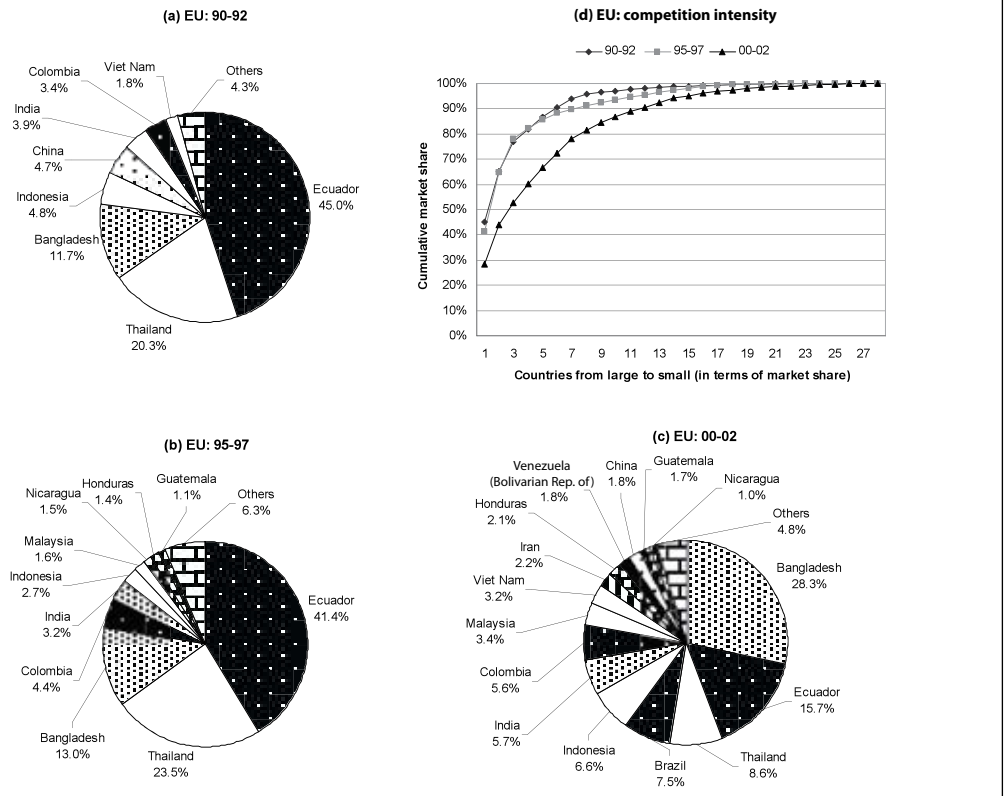
South America was the largest exporter to the market in the 1990s, followed by Southeast Asia (Figure 2d). Both regions reduced their EU exports in the early 2000s while South Asia became the largest exporter by the same time period. The market shares of Central America, Middle East and East Asia have been relatively small.

Ecuador, Thailand and Bangladesh

Ecuador, Thailand and Bangladesh were the three most dominant countries in the EU market in the early 1990s. Ecuador held 45 percent of the market in the early 1990s and was the number one exporter (Figure 5). Its share fell slightly to 41 percent in the mid-1990s because of a declining comparative advantage, and then it dropped further to only 16 percent in the early 2000s because of a declining size advantage (Table 7).

Thailand was the second largest exporter to the EU market in the early and mid-1990s and the third largest in the early 2000s (Figure 5). Yet its comparative advantage in the market has been weak and declining (Table 7). Bangladesh increased its EU market share from 13 percent in the mid-1990s to 28 percent in the early 2000s when it replaced Ecuador as the number one exporter. A gain in comparative advantage was the main driving force behind this 15 percent surge (Table 7); in contrast, the country's

FIGURE 5
Cultured shrimp exports to the European Union market



world market share increased only slightly from 8.7 to 9.5 percent during the same period.

Brazil

In addition to Bangladesh, Brazil recorded large comparative advantage gains during the second period (Table 7). Seven points of its 7.5 percent market share gain during the second period was due to gains in comparative advantage.

Colombia, India and Indonesia

The shares of Colombia, India and Indonesia in the EU market have been relatively large and stable. Colombia had a strong and increasing comparative advantage during the entire study period, which helped increase its market share from 3.4 percent in the early 1990s to 4.4 percent in the mid-1990s and 5.6 percent in the early 2000s (Table 7).

Indonesia reduced its market share from 4.8 percent in the early 1990s to 2.7 percent in the mid-1990s because of further declines in its already weak comparative advantage position. Yet a subsequent comparative advantage gain during the second period helped raise the country's market share to 6.6 percent in the early 2000s (Table 7). India reduced its EU market share from 3.9 to 3.2 percent during the first period because of a decline in comparative advantage (from strong to weak) and then raised it to 5.7 percent in the early 2000s because of a size advantage gain (Table 7).

Other countries

Information on other countries' frozen cultured shrimp export performance in the EU market can be found in Table 7.

TABLE 7
Cultured shrimp export performance in the European Union market

Region	Country	First period (early 1990s to mid-1990s)						Second period (mid-1990s to early 2000s)					
		Market share (%)				RCA indices		Market share (%)				RCA indices	
		Initial	Total variation	Size variation	Structural variation	Initial	RCAV	Initial	Total variation	Size variation	Structural variation	Initial	RCAV
Africa	Madagascar	0.1	0.1	0.1	0.0	4.0	0.19	0.2	0.7	0.6	0.1	4.1	0.62
	Africa	**0.1**	**0.1**	**0.1**	**0.0**	**4.0**	**0.19**	**0.2**	**0.7**	**0.6**	**0.1**	**4.1**	**0.62**
Central America	Belize	0.1	-0.1	0.2	-0.3	1.6	-1.33	0.0	0.5	0.1	0.4	0.2	0.60
	Costa Rica	0.1	0.6	0.6	0.0	2.5	0.10	0.7	-0.1	-0.1	0.1	2.5	0.18
	Guatemala	0.5	0.7	0.5	0.1	2.1	0.29	1.1	0.6	0.2	0.4	2.3	0.64
	Honduras	0.5	0.9	0.0	1.0	0.3	0.73	1.4	0.7	0.3	0.4	1.1	0.20
	Mexico	0.0	0.1	0.0	0.1	0.0	0.14	0.1	0.1	0.2	0.0	0.1	-0.02
	Nicaragua	0.7	0.8	2.8	-1.9	3.0	-1.59	1.5	-0.5	0.1	-0.6	1.2	-0.37
	Central America	**1.9**	**3.0**	**1.7**	**1.3**	**0.8**	**0.30**	**4.9**	**1.4**	**2.2**	**-0.8**	**1.1**	**-0.11**
South America	Brazil	0.1	-0.1	-0.1	-0.1	0.9	-0.81	0.0	7.5	0.5	7.0	0.1	2.49
	Colombia	3.4	1.0	-0.5	1.5	2.1	1.07	4.4	1.2	0.6	0.6	3.2	0.35
	Ecuador	45.0	-3.5	0.3	-3.8	2.0	-0.16	41.4	-25.7	-25.9	0.2	1.7	0.02
	Panama	0.1	0.7	0.7	0.0	0.7	0.02	0.8	-0.5	-0.2	-0.3	0.7	-0.32
	Peru	0.7	0.2	0.1	0.1	1.8	0.27	0.9	-0.8	-0.8	0.0	2.0	-0.30
	Venezuela (Bolivarian Republic of)	0.4	0.5	1.5	-1.0	3.1	-1.52	0.9	0.9	1.5	-0.6	1.5	-0.30
	South America	**49.7**	**-1.2**	**2.9**	**-4.1**	**2.0**	**-0.15**	**48.5**	**-17.5**	**-21.1**	**3.6**	**1.8**	**0.20**
East Asia	China	4.7	-4.0	-4.4	0.4	0.4	0.49	0.8	1.0	2.4	-1.4	0.9	-0.41
	Republic of Korea	0.1	-0.1	-0.1	0.0	0.2	-0.16	0.0	0.3	0.0	0.3	0.0	4.29
	East Asia	**4.8**	**-4.1**	**-4.5**	**0.4**	**0.4**	**0.41**	**0.8**	**1.4**	**2.2**	**-0.8**	**0.8**	**-0.25**
Middle East	Iran (Islamic Republic of)	0.0	0.1	0.1	0.0	5.6	-1.47	0.1	2.1	1.7	0.4	3.9	0.85
	Saudi Arabia	0.0	0.0	0.0	0.0	5.3	-4.07	0.0	0.0	0.1	-0.1	0.7	-0.75
	Middle East	**0.0**	**0.1**	**0.1**	**0.0**	**5.3**	**-1.45**	**0.1**	**2.1**	**1.8**	**0.3**	**3.3**	**0.56**
South Asia	Bangladesh	11.7	1.2	0.7	0.5	1.6	0.06	13.0	15.3	0.7	14.6	1.5	1.54
	India	3.9	-0.7	2.7	-3.4	1.4	-0.76	3.2	2.5	2.2	0.3	0.7	0.05
	Sri Lanka	0.2	-0.1	0.2	-0.4	0.3	-0.31	0.1	0.3	0.0	0.3	0.1	0.19
	South Asia	**15.8**	**0.4**	**4.2**	**-3.8**	**1.5**	**-0.27**	**16.2**	**18.2**	**4.5**	**13.7**	**1.1**	**0.78**
Southeast Asia	Indonesia	4.8	-2.1	-0.2	-1.9	0.3	-0.14	2.7	3.9	-0.2	4.1	0.2	0.41
	Malaysia	0.0	1.5	0.9	0.7	1.6	1.07	1.6	1.9	2.1	-0.3	2.5	-0.21
	Myanmar	0.1	0.4	0.4	0.0	0.9	0.04	0.6	0.2	0.7	-0.6	0.7	-0.34
	Philippines	0.3	-0.3	-0.2	-0.1	0.1	-0.06	0.0	0.2	0.0	0.2	0.0	0.19
	Thailand	20.3	3.1	4.5	-1.4	0.7	-0.04	23.5	-14.9	-2.7	-12.3	0.7	-0.42
	Viet Nam	1.8	-0.9	0.1	-1.0	0.6	-0.29	0.9	2.3	2.0	0.3	0.3	0.03
	Southeast Asia	**27.4**	**1.8**	**2.7**	**-0.9**	**0.6**	**-0.02**	**29.2**	**-6.5**	**2.3**	**-8.8**	**0.6**	**-0.17**
Oceania	Australia	0.2	-0.1	0.1	-0.3	1.3	-1.00	0.1	0.1	0.1	0.0	0.3	0.11
	New Caledonia	0.0	0.0	0.0	0.0	3.0	1.48	0.0	0.1	0.2	-0.1	4.0	-1.46
	Oceania	**0.2**	**-0.1**	**0.1**	**-0.2**	**1.3**	**-0.83**	**0.1**	**0.3**	**0.2**	**0.1**	**0.5**	**0.18**

Regional dominance in the European Union market

With regard to market power, three regions reduced their market shares during the entire study period (South America from 50 to 31 percent, Southeast Asia from 27 to 23 percent, and East Asia from 4.8 to 2.1 percent); the other 5 regions increased their shares (South Asia from 16 to 34 percent, Central America from 1.9 to 6.3 percent, the Middle East from virtually zero to 2.2 percent, Africa from 0.1 to 0.9 percent, and Oceania from 0.2 to 0.4 percent).

With regard to revealed comparative advantage, the EU market is more diversified than the Japanese and United States markets. While countries with strong comparative advantage in the Japanese and United States markets are concentrated in the Asian-Pacific and Latin American regions respectively, there has been at least one country from every region (except East Asia) with strong comparative advantage in the EU market during the entire period from the early 1990s to the early 2000s (Costa Rica and Guatemala in Central America; Colombia, Ecuador, Peru and Venezuela (Bolivarian Republic of) in South America; Iran (Islamic Republic of) in the Middle East; Bangladesh in South Asia; Malaysia in Southeast Asia; New Caledonia in Oceania; and Madagascar in Africa). Even South Korea from East Asia enjoyed very strong comparative advantage gains by the early 2000s (Table 7).

Five out of nine countries with weak comparative advantage in the EU market during the entire study period are from Southeast Asia (Indonesia, Myanmar, Philippines, Thailand and Viet Nam); the other six countries are Mexico, Panama, China and Sri Lanka.

Competitive intensity

Similar to the Japanese and United States markets, the EU market has also become increasingly competitive, especially in the early 2000s (Figure 5d). While the four top countries controlled over 80 percent of the market in the mid-1990s, eight countries accounted for the same market share in the early 2000s.

Comparative advantage variation

According to the *RCAV* indices, New Caledonia, Malaysia, Colombia, Honduras, China, Guatemala, Peru, Madagascar, Mexico and Costa Rica were the 10 countries with the largest comparative advantage gains in the EU market during the first period. For the same period, Saudi Arabia, Nicaragua, Venezuela (Bolivarian Republic of), Iran (Islamic Republic of), Belize, Australia, Brazil, India, Sri Lanka and Viet Nam were the 10 countries with the largest comparative advantage declines (Table 7).

During the second period (from the mid-1990s to the early 2000s), Republic of Korea, Brazil, Bangladesh, Iran (Islamic Republic of), Guatemala, Madagascar, Belize, Indonesia, Colombia and Honduras were the 10 countries with the largest comparative advantage gains in the market, while Thailand, New Caledonia, Saudi Arabia, China, Nicaragua, Myanmar, Panama, Venezuela (Bolivarian Republic of), Peru, Malaysia and Mexico saw declines in their comparative advantage (Table 7).

3.4 Summary

We have presented a systematic and comparative assessment of 28 major shrimp farming countries' performance in three major international frozen cultured shrimp export markets (Japan, the United States and EU). We used market share as a basic export performance indicator to measure countries' degree of dominance in a market. We identified "size advantage" and "comparative advantage" as two factors behind the degree of dominance. Dynamically, we used the temporal variation in market shares to gauge changes in market power; we also decomposed total market share variation into "size variation" and "structural variation" in order to identify the "size" and

"structural" sources of the variation. We also defined the RCAV index to compare countries' comparative advantage variation over time.

We found that all the three markets have become more competitive between the early 1990s and the early 2000s in the sense that market power has become less concentrated. We also found that the Asian-Pacific countries overwhelmingly dominate the Japanese market in terms of not only market power but also comparative advantage. We also found that most of the countries with strong comparative advantage in the United States market are from Latin America while most Latin American countries enjoy a strong advantage in the United States market. However, we did not find any obvious regional dominance pattern of comparative advantage in the EU market.

Limited by space considerations, we have only discussed the performance of some relatively large cultured shrimp exporting countries in each of the three markets; the analysis results for the entire set of 28 countries under investigation are reported in Tables 5–7.

The systematic and comparative account of countries' frozen cultured shrimp export performance as undertaken here represents an initial research effort; further research examining exporters and markets in greater detail is necessary to explain performance and identify the driving forces behind market dynamics.

4. Comparative advantage in freshwater fish farming

In this section we apply the RCA approach to a regional assessment of countries' comparative advantage in culturing three freshwater fish species.[19]

4.1 BACKGROUND

As a traditional and major aquaculture species group, freshwater finfish accounted for 38 percent of world aquaculture production by quantity and 34 percent by value in 2003. According to FAO, more than 120 freshwater finfish species have been cultured since 1950 (FAO, 2008). While many countries tend to focus on indigenous species, some species such as carp, catfish, and tilapia have generated truly global aquaculture industries.

Given limited resources, there are tradeoffs associated with the culture of these many different species: more resources allocated to farming one species means less resources for others. In the long run, a country's optimal aquaculture specialization pattern reflecting an efficient resource allocation can be shaped by market forces. In the short run, however, information about these patterns is important so that resources are not wasted on the "wrong" species. Governments and funding agencies also wish to have such information in order to avoid picking "losers". For society as a whole, such information can make aquaculture development more efficient and less painful.

While the future is unknown, history might help. In the spirit of the RCA approach, it would be informative to systematically compare countries' historical specialization patterns so as to "reveal" their comparative advantages and associated changes.

4.2 METHODOLOGY

This examination covers three regions: Asia, Latin America and the Caribbean (LAC), and sub-Saharan Africa (SSA). Three major freshwater finfish species are considered (carp, catfish, and tilapia).[20] Three separate RCA assessments are conducted, one for each region. In each assessment we used the "revealed comparative advantage" (RCA) index to compare countries' specialization patterns in the three species, and the "revealed comparative advantage variation" (RCAV) index to examine changes in these patterns.

While traditional RCA assessments are based on export data, in this analysis we used production data instead. That is, the RCA assessments in this study examine countries' *production* instead of *export* specialization patterns. Export data were not used primarily because they are not available – our attempts to obtain disaggregated export data on the three species were not fruitful.[21]

Export data are generally a better choice in RCA analysis because they are more comparable. While countries' exports compete in the same markets, their production may be significantly affected by domestic demand that tend to be quite different across

[19] "Fish" in this section includes only finfish.

[20] According to the International Standard Statistical Classification of Aquatic Animals and Plants (ISSCAAP), freshwater fishes are categorized into carp, tilapia, and miscellaneous freshwater fishes (in which catfish is a main species).

[21] Such data are not available in FAO's FishStat, UN Comtrade, or EUROSTAT. The "United States Foreign Trade" database maintained by the United States National Marine Fisheries Service provides data on tilapia and catfish exports to the United States market but no data are provided on carp.

countries. However, when the focus is on aquaculture's contribution to food supply and economic growth, production data may be able to provide useful information. For example, suppose a country has a relatively high specialization in tilapia production yet relatively low specialization in tilapia exports because most of the production is consumed by local consumers who favour the species. Under this situation, RCA indices calculated from trade data will be low for tilapia, which reflects that the country has a weak comparative advantage in exporting tilapia because of its high domestic preference for this species. However, the country's high specialization in tilapia production indicates that as far as farming is concerned, the country actually exhibits a strong comparative advantage. Therefore, even though tilapia may not be an export "shining star", it can still be considered a development priority because of its domestic contribution.[22]

4.2.1 Production RCA index

Similar to the trade RCA index defined in equation (4), we define the following production RCA index:

$$RCA_{ij} = \frac{c_{ij}}{c_j}, \tag{18}$$

where

$$c_{ij} = \frac{Q_{ij}}{\sum_j Q_{ij}}$$

is the ratio of country *i*'s production of species *j* (denoted as Q_{ij}) to its total production of all three species (i.e. $\sum_j Q_{ij}$).

Thus c_{ij}, as country *i*'s "specialization ratio" in culturing species *j*, measures the degree of concentration of country *i*'s freshwater fish farming on species *j*.

Similarly,

$$c_j = \frac{\sum_i Q_{ij}}{\sum_i \sum_j Q_{ij}}$$

represents the ratio between the production of species *j* by the entire region (i.e. $\sum_i Q_{ij}$) and the region's total production of all three species (i.e. $\sum_i \sum_j Q_{ij}$).

Thus, c_j represents the region's average specialization ratio in culturing species *j*.

An $RCA_{ij} > 1$, which according to equation (18) implies that $c_{ij} > c_j$, indicates that country *i*'s freshwater fish farming is more specialized in species *j* than the region's average; therefore, this above-average specialization can be an evidential indication that the country has a "strong comparative advantage" in culturing species *j*. In other words, the observation that country *i*'s freshwater fish farming is more concentrated on species *j* than its neighbouring countries implies that the country may have special characteristics making it relatively more suitable to engage in the farming of species *j*. Conversely, $RCA_{ij} < 1$ indicates that country *i* has a lower-than-average specialization in culturing species *j*, which may reveal that it has a "weak comparative advantage" in culturing the species.

[22] As the progress of globalization and free trade reduces producers' advantages in domestic markets, the differences between domestic and export markets tend to diminish. Eventually all producers may need to compete in a global market where their performances are measured by their production.

The greater the RCA index, the stronger the comparative advantage is. For example, a production RCA_{ij} index of 2 implies that country *i*'s specialization ratio in farming species *j* is two times as high as the region's average.

4.2.2 Production RCAV index

According to equation (A.6.2) in Appendix B, a production "revealed comparative advantage variation" (RCAV) index can be defined as

$$RCAV_{ij} = \frac{c_{ij,t+1}}{c_{j,t+1}} - \frac{\tilde{c}_{ij,t+1}}{c_{j,t+1}}, \tag{19}$$

where the first term on the right hand side represents country *i*'s actual production RCA index for species *j* at time *t*+1 while the second term represents the same RCA index under the hypothetical situation that country *i* has experienced no comparative advantage variation between time *t* and *t*+1.

We simplify the RCAV index in equation (19) into

$$RCAV_{ij} = c_{ij,t+1} - \tilde{c}_{ij,t+1}. \tag{19'}$$

Since the denominator $c_{j,t+1}$ (i.e. the region's average specialization ratio in culturing species *j*) is constant for all the countries in the region, the two RCAV indices defined in equations (19) and (19') are equivalent for cross-country comparisons of comparative advantage variation. However, the RCAV index defined in equation (19') can be more revealing for comparative advantage shifts among species because when defined as such, the sum of a country's RCAV indices for all species is equal to zero, i.e.

$$\sum_j RCAV_{ij} = \sum_j c_{ij,t+1} - \sum_j \tilde{c}_{ij,t+1} = 1 - 1 = 0.$$

Therefore, the RCAV index defined in equation (19') is not only able to indicate whether country *i* has gained (or lost) comparative advantage in species *j* but also provide information about the sources (or destinations) and magnitude of the gain (or loss).

According to equation (19'), $RCAV_{ij} > 0$ implies that country *i*'s *actual* specialization ratio in culturing species *j* (i.e. $c_{ij,t+1}$) is greater than the corresponding constant-comparative-advantage benchmark ratio (i.e. $\tilde{c}_{ij,t+1}$) that represents country *i*'s specialization ratio in culturing species *j* under the hypothetical situation that it has experienced no comparative advantage variation between time *t* and *t*+1. Therefore, $RCAV_{ij} > 0$ can be taken as an indication that country *i* has increased its comparative advantage in culturing species *j*. The greater the RCAV index, the larger the comparative advantage gain is.

Stated plainly, given country *i*'s production specialization pattern at time *t*, its specialization ratio in culturing species *j* at time *t*+1 would have been $\tilde{c}_{ij,t+1}$ had it experienced no comparative advantage variation in freshwater fish farming between time *t* and *t*+1. Then, if its actual production specialization ratio $c_{ij,t+1}$ turns out to be greater than this constant-comparative-advantage benchmark $\tilde{c}_{ij,t+1}$, which according to equation (19') implies that $RCAV_{ij} > 0$, we can say that country *i* has increased its comparative advantage in culturing species *j* during the period; the magnitude of the gain can be measured by the difference between $c_{ij,t+1}$ and $\tilde{c}_{ij,t+1}$.

Conversely, $RCAV_{ij} < 0$ is an indication that country *i* has reduced its comparative advantage in culturing species *j*. The smaller the negative RCAV index, the greater the comparative advantage decline is.

4.2.3 Two interpretations of RCA

As indicated by equations (3) and (4), there are two equivalent ways to interpret revealed comparative advantage. According to equation (3), revealed comparative advantage reflects a country's degree of dominance in a specific market as compared to its general dominance in the world market. On the other hand, according to equation (4), revealed comparative advantage reflects a country's degree of specialization in one product as compared to the world (or region) average specialization in the product.

A decision on which of these two equivalent interpretations should be adopted is contingent on the research perspective. In the shrimp export performance assessment presented in the previous section, we followed the "dominance" interpretation because we wanted to compare countries' shrimp export performance in different markets and identify the size and structural factors behind their performance changes. Yet in the freshwater fish farming comparative advantage assessment presented in this section, we will follow the "specialization" interpretation to compare countries' specialization patterns in culturing different species and how these patterns change over time. As discussed in section 4.1, the motivation of this study is to provide information useful for private and public decision makers regarding the structure of freshwater fish farming industries.

4.3 DATA

Freshwater fish farming production data from 1985 to 2003 were obtained from the FishStat database (FAO, 2008). The study period was divided into four sub-periods (1985–89, 1990–94, 1995–99, and 2000–03); data during each period were averaged to smooth away the impacts of transitory shocks on production.[23]

A total of 111 countries in the three regions reported freshwater finfish farming production during 1985 to 2003: 41 in Asia, 32 in LAC and 38 in SSA (Table 8). We divided the freshwater finfish category into four groups: carp, catfish, tilapia, and (miscellaneous) others. *Carp* includes all species in the ISSAAP group of "carps, barbells and other cyprinids"; *catfish* includes all species in the order of "siluriformes"; *tilapia* is the aggregate of all species in the ISSAAP group of "tilapias and other cichlids"; *miscellaneous others* include the remaining species.

4.4 RESULTS

According to FAO, world freshwater fish farming yielded 23 million tonnes of production in 2003. Carp, tilapia and catfish accounted for 74, 7 and 2 percent of this production, respectively.[24] Carp has always been the most dominant freshwater fish farming species (Figure 6), yet the carp farming specialization ratio (i.e. carp as a percentage of total freshwater fish farming production) in the world has declined from 80 percent in 1985–89 to 77 percent in 2000–03. As compared to carp, the specialization ratios for tilapia and catfish farming have been relatively small. While the ratio for tilapia increased from 4.8 percent in 1985–89 to 6.9 percent in 2000–03, the catfish ratio declined from 4.0 to 2.3 percent.

In sum, freshwater fish farming in the world has become more diversified during the study period (Figure 6). Rapid growth in the farming of tilapia and other miscellaneous species is the primary cause of this increasing diversification.

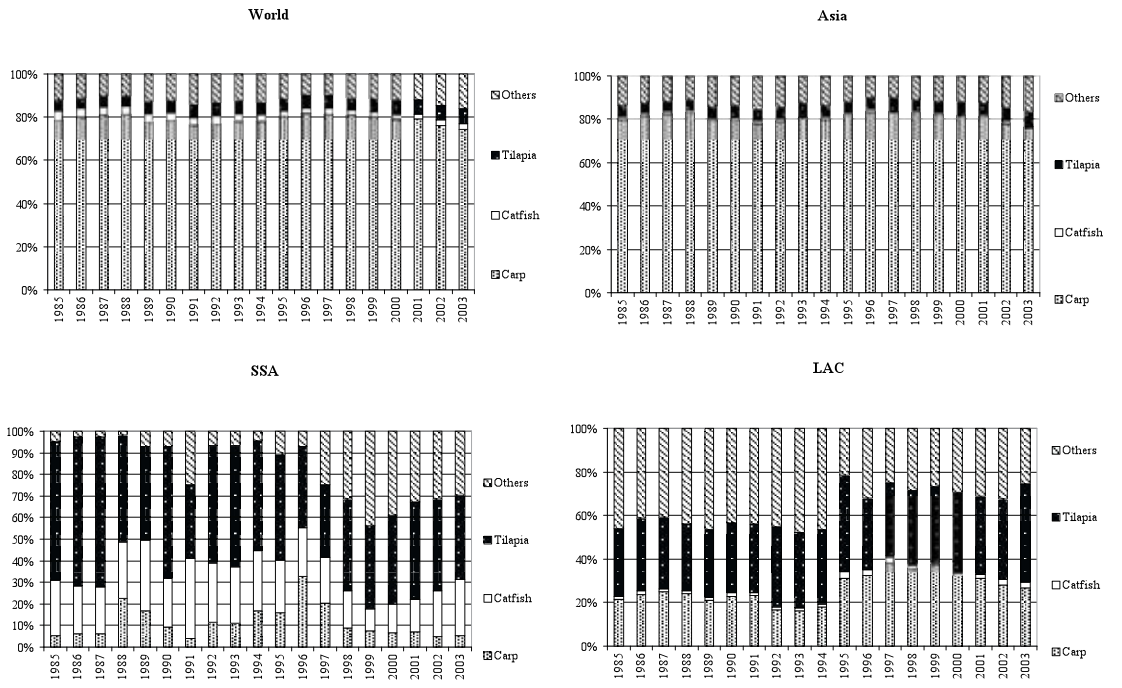
4.4.1 Freshwater fish farming comparative advantage in Asia

Asia is the largest freshwater fish farming region in the world, accounting for 95 percent of world production in 2003 (Table 8). Carp is Asia's most dominant freshwater fish

[23] Note that the time periods in this study are different from those used in the shrimp export performance analysis.

[24] Because some of these species might be included in the miscellaneous fishes category, the ratios tend to be understated.

FIGURE 6
Freshwater fish farming specialization patterns in the world



farming species, being cultured in more than 40 countries and accounting for 79 percent of the region's total freshwater fish farming production in 2003 (Figure 6).

Asia is also the largest catfish farming region in the world, accounting for 41 percent of world production in 2003. However, the region's specialization ratio in catfish farming has traditionally been the lowest among the three regions studied here (Figure 6): the ratio declined from 1.3 percent during 1985–89 to 0.9 percent during 2000–03. In addition, Asia is also the largest tilapia farming region in the world, accounting for 78 percent of world production in 2003. The region's average specialization ratio in tilapia farming was 6 percent in 2003, lower as compared to the other two regions (Figure 6).

In the following we discuss Asian countries' comparative advantage in the three species. We considered five Asian subregions including East Asia, Central Asia, the former Union of the Soviet Socialist Republics (the former USSR), Middle East, South Asia and Southeast Asia. We used two null hypotheses to guide the analysis of RCA and RCAV indices. First, we hypothesize that countries in the same subregion should have similar comparative advantage patterns. When this hypothesis is rejected, we identify the corresponding "outlier" patterns. We also hypothesize that countries in the same subregion tend to have similar comparative advantage variation in freshwater fish farming and identify outlier patterns accordingly.

East Asia

Table 9 lists 4 East Asian countries that have engaged in freshwater fish farming during the study period. China has been the largest freshwater fish farming country in the world, while the scale of fish farming in the other three countries (Japan, the Democratic People's Republic of Korea and the Republic of Korea) has been relatively small.

During 1985–89, all four East Asian countries had above-unity carp RCA indices (Table 9), implying a strong revealed comparative advantage in carp farming. For

TABLE 8
Annual freshwater finfish farming production (tonnes)

Region	Country	1985–89	2000–03	Region	Country	1985–89	2000–03	Region	Country	1985–89	2000-03
East Asia	China	3 517 070	15 660 142	South America	Brazil	12 400	152 867	Western SSA	Nigeria	10 864	27 864
South Asia	India	782 800	1 981 740	South America	Colombia	968	39 586	Western SSA	Ghana	372	4 836
South Asia	Bangladesh	143 708	687 855	Caribbean	Cuba	4 136	24 898	Eastern SSA	Zambia	895	4 473
Southeast Asia	Indonesia	196 116	477 501	Central America	Mexico	11 616	20 458	Eastern SSA	Uganda	36	3 399
Southeast Asia	Viet Nam	109 910	447 463	Central America	Costa Rica	109	11 220	Central SSA	Dem. Rep. of the Congo	622	2 688
Southeast Asia	Thailand	82 759	270 357	South America	Ecuador	59	7 791	Eastern SSA	The Madagascar	224	2 433
Southeast Asia	Myanmar	5 787	163 415	Caribbean	Jamaica	2 055	4 379	Eastern SSA	Zimbabwe	45	2 255
Southeast Asia	Philippines	73 251	130 517	South America	Venezuela (Bolivarian Republic of)	176	4 336	Northern SSA	Sudan	52	1 300
Southeast Asia	Taiwan, Province of China	86 488	93 628	Central America	Guatemala	109	2 497	Western SSA	Togo	17	991
Southeast Asia	Lao People's Democratic Republic	6 000	54 171	Caribbean	Dominican Republic	9	2 207	Western SSA	Côte d'Ivoire	168	974
Middle East	Iran, Islamic Republic of	22 307	46 534	Central America	Honduras	244	1 920	Eastern SSA	Kenya	244	709
Southeast Asia	Malaysia	5 898	45 454	Central America	Panama	430	677	Western SSA	Mali	13	637
South Asia	Nepal	4 965	16 593	South America	Argentina	0	449	Eastern SSA	Malawi	194	594
Middle East	Israel	12 746	15 450	South America	Guyana	17	446	Eastern SSA	Rwanda	52	586
Southeast Asia	Cambodia	3 568	14 871	South America	Peru	327	353	Southern SSA	South Africa	89	297
South Asia	Pakistan	8 401	13 291	Central America	El Salvador	14	290	Eastern SSA	Tanzania	100	286
East Asia	Japan	24 850	10 304	Caribbean	Puerto Rico	9	132	Central SSA	Cameroon	139	216
Middle East	Syrian Arab Republic	2 613	6 471	South America	Paraguay	41	107	Central SSA	Gabon	2	210
East Asia	Republic of Korea	5 182	5 996	South America	Bolivia (Plurinational State of)	21	83	Eastern SSA	Burundi	19	138
Former USSR	Uzbekistan	20 723	4 862	South America	Suriname	0	79	Central SSA	Central African	146	123
South Asia	Sri Lanka	4 400	3 848	Central America	Nicaragua	3	44	Northern SSA	Libyan Arab Jamajiriya	37	100
East Asia	North Korea	5 000	3 700	South America	French Guiana	0	21	Eastern SSA	Réunion	0	73

TABLE 8 (Continued)
Annual freshwater finfish farming production (tonnes)

Region	Country	1985–89	2000–03	Region	Country	1985–89	2000–03	Region	Country	1985–89	2000-03
Middle East	Saudi Arabia	431	3 168	Caribbean	Trinidad and Tobago	2	11	Southern SSA	Swaziland	22	65
Southeast Asia	China, Hong Kong SAR	5 541	1 927	Caribbean	Martinique	5	8	Eastern SSA	Mozambique	12	50
Middle East	Iraq	4 451	1 811	South America	Uruguay	3	7	Western SSA	Sierra Leone	16	30
Former USSR	Kazakhstan	7 878	676	Caribbean	Dominica	0	3	Western SSA	Niger	14	29
Former USSR	Armenia	4 280	670	Caribbean	Guadeloupe	0	2	Eastern SSA	Mauritius	4	28
Middle East	Turkey	1 837	658	Caribbean	Saint Lucia	0	2	Central SSA	Congo	139	26
Southeast Asia	Singapore	0	647	Caribbean	Grenada	0	1	Western SSA	Liberia	4	16
Middle East	Jordan	61	569	Caribbean	Bahamas	35	0	Western SSA	Senegal	5	14
Former USSR	Azerbaijan	1 633	158	Central America	Belize	0	0	Southern SSA	Namibia	0	13
Former USSR	Tajikistan	3 246	124	Caribbean	Virgin Islands	4	0	Southern SSA	Lesotho	24	8
Middle East	Lebanon	0	90					Western SSA	Benin	74	7
Former USSR	Kyrgyzstan	1 062	77					Western SSA	Burkina Faso	23	5
Southeast Asia	Brunei	2	71					Southern SSA	Mayotte	0	3
Former USSR	Georgia	780	63					Eastern SSA	Ethiopia	20	0
Former USSR	Turkmenistan	2 422	43					Western SSA	Gambia	0	0
South Asia	Bhutan	14	30					Western SSA	Guinea	2	0
Middle East	Kuwait	0	20								
Middle East	Cyprus	1	0								
Middle East	United Arab Emirates	0	0								
Asia		**5 158 179**	**20 164 960**	**Latin America and Caribbean**		**32 793**	**274 869**	**Sub-Saharan Africa**		**14 688**	**55 469**

Sorted by 2000–03 average production

TABLE 9
Freshwater fish farming comparative advantage (East Asia)

Country	Species	Production quantity (tonnes)				RCA		RCAV		
		1985–89	1990–94	1995–99	2000–03	1985–89	2000–03	Sub-period I[1]	Sub-period II	Sub-period III
China	Carp	3 282 199	5 158 350	10 307 442	13 037 102	1.18	1.05	-2.4%	-4.6%	-1.9%
	Catfish	0	0	0	0	0.00	0.00	0.0%	0.0%	0.0%
	Tilapia	43 315	162 071	456 477	703 323	0.27	0.79	1.4%	1.2%	0.1%
	Others	191 556	332 808	933 438	1 919 717	0.36	0.88	0.9%	3.4%	1.8%
Japan	Carp	19 885	15 972	13 213	9 674	1.01	1.18	-0.8%	11.4%	5.9%
	Catfish	0	0	0	0	0.00	0.00	0.0%	0.0%	0.0%
	Tilapia	4 592	4 420	1 165	434	4.12	0.74	0.4%	-12.3%	-4.9%
	Others	374	355	324	196	0.10	0.14	0.4%	0.9%	-1.0%
Democratic People's Republic of Korea	Carp	4 140	4 760	2 203	2 200	1.04	0.75	4.0%	-32.7%	8.9%
	Catfish	0	0	0	0	0.00	0.00	0.0%	0.0%	0.0%
	Tilapia	0	0	0	0	0.00	0.00	0.0%	0.0%	0.0%
	Others	860	640	1 594	1 500	1.14	2.90	-4.0%	32.7%	-8.9%
Republic of Korea	Carp	4 683	11 779	9 946	2 552	1.14	0.54	-10.8%	-11.8%	-26.9%
	Catfish	0	1 615	2 502	2 324	0.00	41.42	10.9%	8.3%	22.4%
	Tilapia	144	506	821	717	0.62	2.10	0.2%	2.5%	5.3%
	Others	354	882	799	404	0.45	0.48	-0.2%	1.0%	-0.8%

[1] Sub-period I goes from the second half of the 1980s (1985–89) to the first half of the 1990s (1990–1994); sub-period II goes from the first half of the 1990s (1990–94) to the second half of the 1990s; and sub-period III goes from the second half of the 1990s (1995–99) to the early 2000s (2000–03).

example, China's carp RCA index of 1.18 implied that China's specialization ratio in carp farming was 1.18 times as high as the Asia's average. This relatively structural bias towards carp farming serves as an evidential indication of China's strong comparative advantage in the activity. During 2000–03, while China and Japan still maintained their strong comparative advantage in carp farming, the two Koreas reduced theirs to a condition of weak advantage.

During 1985–89, Japan was the only East Asian country that had a strong revealed comparative advantage in tilapia farming with an RCA index of 4.12. Yet the index had declined to 0.74 by 2000–03. In contrast, the Republic of Korea raised its tilapia RCA index from 0.62 in 1985–89 to 2.1 in 2000–03. Another special feature of the Republic of Korea's fish farming as compared to its East Asian peers is catfish farming. While the other three countries have not reported any substantial catfish farming production during the study period, the Republic of Korea had developed catfish farming as much as tilapia farming by 2000–03 (Table 9). In fact, the country's catfish RCA index at the time was above 40, which implies that its specialization ratio in catfish farming was 40 times higher than the Asia's average.

Dynamically, China and the Republic of Korea are two countries that have been shifting their comparative advantage in freshwater fish farming from carp to other species. For example, China's carp RCAV index for sub-period I (between 1985–89 and 1990–94) is a negative 2.4 percent, which implies that compared to Asian countries in general, China's comparative advantage shifted 2.4 percent from carp farming to other species (specifically 1.4 percent to tilapia and 0.9 percent to miscellaneous others. See Table 9). Similar declines in China's comparative advantage in carp farming also occurred during sub-period II (between 1990–94 and 1995–99) and sub-period III (between 1995–99 and 2000–03).

The Republic of Korea's experience of declining comparative advantage in carp farming is similar to that of China; the difference is that it has occurred to a greater

TABLE 10
Freshwater fish farming comparative advantage (Central Asia)

Country	Species	Production quantity (tonnes)				RCA		RCAV		
		1985–89	1990–94	1995–99	2000–03	1985–89	2000–03	Sub-period I[1]	Sub-period II	Sub-period III
Armenia	Carp	4 280	2 445	392	670	1.26	1.26	-1.6%	-3.7%	6.6%
	Catfish	0	0	0	0	0.00	0.00	0.0%	0.0%	0.0%
	Tilapia	0	0	0	0	0.00	0.00	0.0%	0.0%	0.0%
	Others	0	41	21	0	0.00	0.00	1.6%	3.7%	-6.6%
Azerbaijan	Carp	1 633	1 447	327	158	1.26	1.26	-1.3%	-0.4%	1.9%
	Catfish	0	0	0	0	0.00	0.00	0.0%	0.0%	0.0%
	Tilapia	0	0	0	0	0.00	0.00	0.0%	0.0%	0.0%
	Others	0	19	5	0	0.00	0.00	1.3%	0.4%	-1.9%
Georgia	Carp	780	998	87	59	1.26	1.19	-2.7%	-6.4%	5.5%
	Catfish	0	0	0	0	0.00	0.00	0.0%	0.0%	0.0%
	Tilapia	0	0	0	0	0.00	0.00	0.0%	0.0%	0.0%
	Others	0	27	8	4	0.00	0.40	2.7%	6.4%	-5.5%
Kazakhstan	Carp	7 878	5 928	1 478	676	1.26	1.26	-1.5%	-4.8%	7.7%
	Catfish	0	5	2	0	0.00	0.00	0.1%	0.1%	-0.1%
	Tilapia	0	0	0	0	0.00	0.00	0.0%	0.0%	0.0%
	Others	0	82	90	0	0.00	0.00	1.4%	4.7%	-7.6%
Kyrgyzstan	Carp	1 062	561	151	77	1.26	1.26	0.0%	0.0%	0.0%
	Catfish	0	0	0	0	0.00	0.00	0.0%	0.0%	0.0%
	Tilapia	0	0	0	0	0.00	0.00	0.0%	0.0%	0.0%
	Others	0	0	0	0	0.00	0.00	0.0%	0.0%	0.0%
Tajikistan	Carp	3 246	2 522	121	124	1.26	1.26	0.0%	0.0%	0.0%
	Catfish	0	0	0	0	0.00	0.00	0.0%	0.0%	0.0%
	Tilapia	0	0	0	0	0.00	0.00	0.0%	0.0%	0.0%
	Others	0	0	0	0	0.00	0.00	0.0%	0.0%	0.0%
Turkmenistan	Carp	2 422	2 179	643	43	1.26	1.26	0.0%	0.0%	0.0%
	Catfish	0	0	0	0	0.00	0.00	0.0%	0.0%	0.0%
	Tilapia	0	0	0	0	0.00	0.00	0.0%	0.0%	0.0%
	Others	0	0	0	0	0.00	0.00	0.0%	0.0%	0.0%
Uzbekistan	Carp	20 723	19 709	7 065	4 862	1.26	1.26	0.0%	0.0%	0.0%
	Catfish	0	0	0	0	0.00	0.00	0.0%	0.0%	0.0%
	Tilapia	0	0	0	0	0.00	0.00	0.0%	0.0%	0.0%
	Others	0	0	0	0	0.00	0.00	0.0%	0.0%	0.0%

[1] Sub-period I goes from the second half of the 1980s (1985–89) to the first half of the 1990s (1990–1994); sub-period II goes from the first half of the 1990s (1990–94) to the second half of the 1990s; and sub-period III goes from the second half of the 1990s (1995–99) to the early 2000s (2000–03).

extent (Table 9). Japan's experience is, however, just the opposite. Its RCAV indices show that it has gained comparative advantage in carp farming against tilapia for both sub-periods II and III (Table 9).

Central Asia

Table 10 lists eight former USSR members in Central Asia that have undertaken freshwater fish farming during the study period. Most of these eight countries (except Georgia) had completely specialized in carp farming during the early 2000s; even Georgia was highly specialized. In fact, carp has always been virtually the only freshwater fish species cultured in the region. Although five countries (Armenia,

TABLE 11

Freshwater fish farming comparative advantage (Middle East)

Country	Species	Production quantity (tonnes)				RCA		RCAV		
		1985–89	1990–94	1995–99	2000–03	1985–89	2000–03	Sub-period I[1]	Sub-period II	Sub-period III
Cyprus	Carp	0	0	0	0	0.00	--	--	--	--
	Catfish	0	0	0	0	0.00	--	--	--	--
	Tilapia	1	0	0	0	22.27	--	--	--	--
	Others	0	0	0	0	0.00	--	--	--	--
Iran, (Islamic Republic of)	Carp	22 307	22 509	26 494	46 534	1.26	1.26	0.0%	0.0%	0.0%
	Catfish	0	0	0	0	0.00	0.00	0.0%	0.0%	0.0%
	Tilapia	0	0	0	0	0.00	0.00	0.0%	0.0%	0.0%
	Others	0	0	0	0	0.00	0.00	0.0%	0.0%	0.0%
Iraq	Carp	4 451	3 240	3 637	1 811	1.26	1.26	0.0%	0.0%	0.0%
	Catfish	0	0	0	0	0.00	0.00	0.0%	0.0%	0.0%
	Tilapia	0	0	0	0	0.00	0.00	0.0%	0.0%	0.0%
	Others	0	0	0	0	0.00	0.00	0.0%	0.0%	0.0%
Israel	Carp	8 674	7 955	7 810	7 592	0.86	0.62	-2.0%	-8.9%	-2.3%
	Catfish	0	0	0	0	0.00	0.00	0.0%	0.0%	0.0%
	Tilapia	4 072	4 742	6 293	7 480	7.11	8.48	2.0%	8.8%	0.0%
	Others	0	0	25	378	0.00	0.17	0.0%	0.2%	2.2%
Jordan	Carp	18	13	42	2	0.37	0.00	-0.3%	-12.6%	-12.8%
	Catfish	0	0	0	0	0.00	0.00	0.0%	0.0%	0.0%
	Tilapia	43	37	238	567	15.70	17.45	0.3%	12.6%	12.8%
	Others	0	0	0	0	0.00	0.00	0.0%	0.0%	0.0%
Kuwait	Carp	0	0	0	0	--	0.00	--	--	0.0%
	Catfish	0	0	0	0	--	0.00	--	--	0.0%
	Tilapia	0	0	42	20	--	17.52	--	--	0.0%
	Others	0	0	0	0	--	0.00	--	--	0.0%
Lebanon	Carp	0	0	0	15	--	0.21	--	--	--
	Catfish	0	0	0	50	--	59.39	--	--	--
	Tilapia	0	0	0	25	--	4.87	--	--	--
	Others	0	0	0	0	--	0.00	--	--	--
Saudi Arabia	Carp	0	8	0	0	0.00	0.00	0.4%	-0.4%	0.0%
	Catfish	0	0	20	31	0.00	1.04	0.0%	0.6%	0.5%
	Tilapia	431	2 130	3 390	3 137	22.27	17.35	-0.4%	-0.2%	-0.5%
	Others	0	0	0	0	0.00	0.00	0.0%	0.0%	0.0%
Syrian Arab Republic	Carp	2 040	3 149	4 923	2 942	0.98	0.57	2.7%	-0.1%	-31.1%
	Catfish	0	0	54	571	0.00	9.43	0.0%	0.9%	8.0%
	Tilapia	573	885	1 247	2 958	4.89	8.01	-2.7%	-0.8%	23.0%
	Others	0	0	0	0	0.00	0.00	0.0%	0.0%	0.0%
Turkey	Carp	1 837	530	771	658	1.26	1.26	0.0%	0.0%	0.0%
	Catfish	0	0	0	0	0.00	0.00	0.0%	0.0%	0.0%
	Tilapia	0	0	0	0	0.00	0.00	0.0%	0.0%	0.0%
	Others	0	0	0	0	0.00	0.00	0.0%	0.0%	0.0%
United Arab Emirates	Carp	0	0	0	0	0.00	--	--	--	--
	Catfish	0	0	0	0	0.00	--	--	--	--
	Tilapia	0	0	0	0	22.27	--	--	--	--
	Others	0	0	0	0	0.00	--	--	--	--

[1] Sub-period I goes from the second half of the 1980s (1985–89) to the first half of the 1990s (1990–1994); sub-period II goes from the first half of the 1990s (1990–94) to the second half of the 1990s; and sub-period III goes from the second half of the 1990s (1995–99) to the early 2000s (2000–03).

Azerbaijan, Kyrgyzstan, Kazakhstan and Georgia) attempted culture of other species during the 1990s, Georgia was the only one that had less than 100 percent specialization in carp by 2000–03.

Despite the high specialization, the region's annual cultured carp production declined from 42 000 mt in 1985–89 to only 6 700 mt in 2000–03.

Middle East

Table 11 lists 11 Middle East countries that have engaged in freshwater fish farming during the study period. Iran (Islamic Republic of), Iraq, and Turkey have completely specialized in carp farming (Table 11). While carp production has been increasing in Iran (Islamic Republic of) during the study period, Iraq and Turkey have reduced output levels.

Although carp is the most important species in the Middle East (Figure 7), Israel, Jordan, Saudi Arabia, and the Syrian Arab Republic had a strong comparative advantage in tilapia farming during the period of analysis (Table 11). The RCAV indices suggest that Israel and Jordan have been shifting their freshwater fish farming comparative advantage away from carp to tilapia farming. Israel's cultured carp production in 1985–89 doubled its tilapia production; however, tilapia farming had reached the same scale as carp farming by the early 2000s.

Catfish farming is a novelty in the Middle East. The Syrian Arab Republic, Saudi Arabia, and Lebanon were the only three countries with catfish farming production by the early 2000s. The RCAV indices suggest that the Syrian Arab Republic and Saudi Arabia have shifted their freshwater fish farming comparative advantage from carp and/or tilapia to catfish farming during the sub-periods II and III (Table 11).

Lebanon started freshwater fish farming in the early 2000s, culturing all three species (Table 11). Production has been focused mostly on catfish. Lebanon's specialization in catfish farming is nearly 60 times higher than the Asia's average (RCA index = 59.4).

South Asia

Table 12 lists six South Asian countries that have undertaken freshwater fish farming during the study period. Carp has traditionally been the most important species in South Asia (Figure 7). Nepal and Pakistan have completely specialized in carp farming (Table 12). India, the largest freshwater fish farming country in the region and second largest in the world, also shows a high specialization in carp farming. The RCAV indices suggest that India has been shifting comparative advantage from other species to carp farming (Table 12).

India has also substantial catfish farming; the RCA indices suggest that it had a strong revealed comparative advantage in catfish farming during the study period. However, its annual catfish production declined from 60 000 tonnes in 1995–99 to 20 000 tonnes in 2000–03; the corresponding negative RCAV index reflects a decline in India's comparative advantage in catfish farming.

Bangladesh is the third largest freshwater fish farming country in the world. The country also focuses on carp farming and has increased its comparative advantage during the early 2000s (Table 12). Sri Lanka, an outlier in South Asia, had completely specialized in tilapia farming during the study period.

Southeast Asia

Table 13 lists 11 Southeast Asian countries that engaged in freshwater fish farming during the study period.[25] As compared to other Asian sub-regions, Southeast Asia has

[25] Viet Nam in Southeast Asia was the fifth largest freshwater fish farming country in the world in the early 2000s (Table 8). Unfortunately, we had to exclude it from the comparative advantage analysis because disaggregated data on its freshwater fish farming industry are not available.

TABLE 12
Freshwater fish farming comparative advantage (South Asia)

Country	Species	Production quantity (tonnes)				RCA		RCAV		
		1985–89	1990–94	1995–99	2000–03	1985–89	2000–03	Sub-period I[1]	Sub-period II	Sub-period III
Bangladesh	Carp	0	0	319 279	538 619	0.00	0.99	0.0%	76.2%	7.9%
	Catfish	0	0	0	0	0.00	0.00	0.0%	0.0%	0.0%
	Tilapia	0	0	0	0	0.00	0.00	0.0%	0.0%	0.0%
	Others	143 708	203 183	99 157	149 237	6.66	1.55	0.0%	-76.2%	-7.9%
Bhutan	Carp	0	0	0	0	0.00	0.00	0.0%	0.0%	0.0%
	Catfish	0	0	0	0	0.00	0.00	0.0%	0.0%	0.0%
	Tilapia	0	0	0	0	0.00	0.00	0.0%	0.0%	0.0%
	Others	14	32	30	30	6.66	7.15	0.0%	0.0%	0.0%
India	Carp	494 200	878 761	1 498 838	1 835 532	0.80	1.17	4.4%	8.8%	12.2%
	Catfish	36 400	44 899	61 262	22 259	3.65	1.20	-0.9%	0.2%	-1.9%
	Tilapia	0	0	0	0	0.00	0.00	0.0%	0.0%	0.0%
	Others	252 200	337 091	227 786	123 949	2.14	0.45	-3.5%	-9.1%	-10.3%
Nepal	Carp	4 965	9 882	11 688	16 593	1.26	1.26	0.0%	0.0%	0.0%
	Catfish	0	0	0	0	0.00	0.00	0.0%	0.0%	0.0%
	Tilapia	0	0	0	0	0.00	0.00	0.0%	0.0%	0.0%
	Others	0	0	0	0	0.00	0.00	0.0%	0.0%	0.0%
Pakistan	Carp	8 401	12 659	16 800	13 291	1.26	1.26	0.0%	0.0%	0.0%
	Catfish	0	0	0	0	0.00	0.00	0.0%	0.0%	0.0%
	Tilapia	0	0	0	0	0.00	0.00	0.0%	0.0%	0.0%
	Others	0	0	0	0	0.00	0.00	0.0%	0.0%	0.0%
Sri Lanka	Carp	0	0	9	0	0.00	0.00	0.0%	0.3%	-0.2%
	Catfish	0	0	0	0	0.00	0.00	0.0%	0.0%	0.0%
	Tilapia	4 400	3 500	3 257	3 848	22.27	17.52	0.0%	-0.3%	0.2%
	Others	0	0	0	0	0.00	0.00	0.0%	0.0%	0.0%

[1] Sub-period I goes from the second half of the 1980s (1985–89) to the first half of the 1990s (1990–1994); sub-period II goes from the first half of the 1990s (1990–94) to the second half of the 1990s; and sub-period III goes from the second half of the 1990s (1995–99) to the early 2000s (2000–03).

the most diversified freshwater fish farming industry (Figure 7). Unlike the other four Asian sub-regions, carp is not the dominant species. Among the 11 Southeast Asian freshwater fish farming countries (or districts) listed in Table 13, only Cambodia, Lao People's Democratic Republic and Myanmar have a strong comparative advantage in carp farming. The RCAV indices imply that this advantage has been declining in the three countries during the study period. In fact, none of the 11 Southeast Asian countries has a positive carp RCAV index during the sub-period II; the Philippines is the one outlier that gained comparative advantage in carp farming during the sub-period III (Table 13).

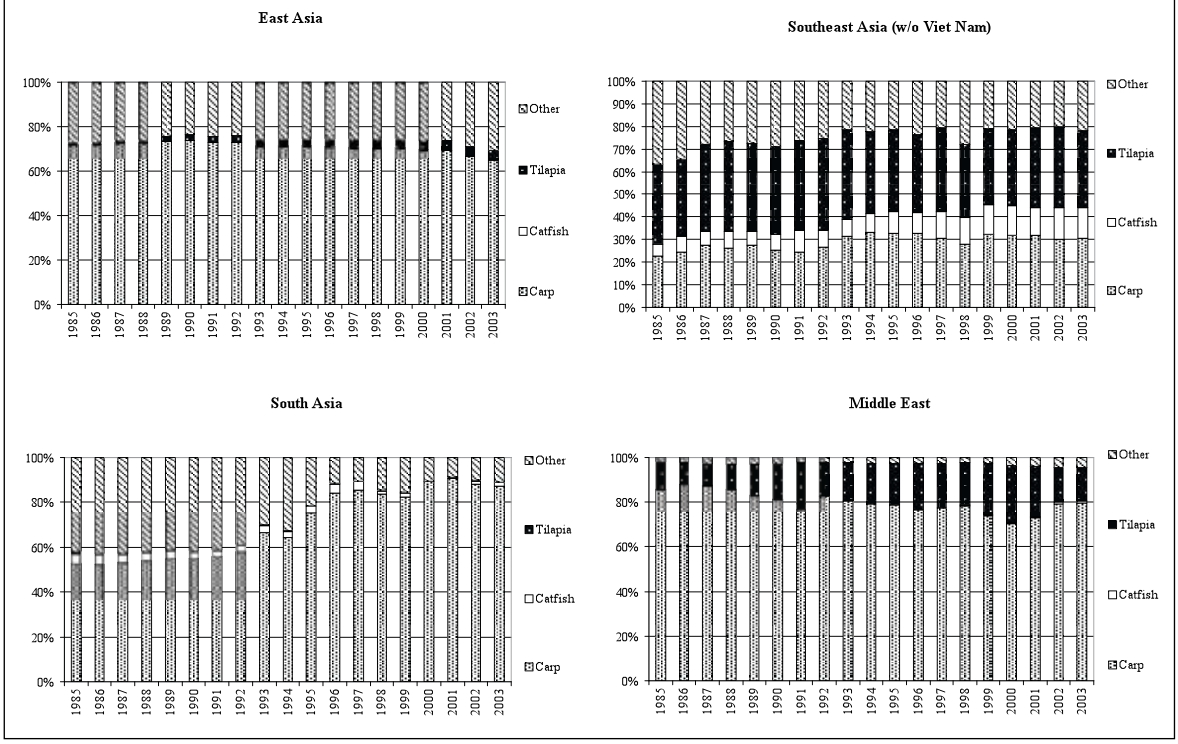
Tilapia is the most important species in Southeast Asia's freshwater fish farming (Figure 7) and it was cultured by all 11 countries listed in Table 13 in the early 2000s. The Philippines and Taiwan, Province of China have the strongest comparative advantage in tilapia farming with RCA indices of 15 and 14 in the early 2000s, respectively. The RCAV indices suggest that Taiwan, Province of China increased its comparative advantage in tilapia during the study period while the Philippines lost some of its tilapia advantage during sub-periods II and III (Table 13). Among the 11 Southeast Asian countries listed in Table 13, Cambodia and Myanmar were the only two with weak comparative advantage in tilapia farming in the early 2000s.

TABLE 13
Freshwater fish farming comparative advantage (Southeast Asia)

Country	Species	Production quantity (tonnes)				RCA		RCAV		
		1985–89	1990–94	1995–99	2000–03	1985–89	2000–03	Sub-period I[1]	Sub-period II	Sub-period III
Brunei Darussalam	Carp	1	3	10	17	0.54	0.31	6.5%	-27.0%	0.2%
	Catfish	0	1	0	5	0.00	6.79	17.2%	-15.3%	6.3%
	Tilapia	0	1	17	39	0.00	9.73	24.1%	26.3%	4.9%
	Others	1	0	7	10	3.80	0.98	-47.8%	16.1%	-11.4%
Cambodia	Carp	3 188	6 555	10 052	13 307	1.13	1.13	-0.1%	-1.2%	0.0%
	Catfish	285	587	894	1 169	6.27	8.40	0.5%	1.2%	0.4%
	Tilapia	95	196	292	395	0.59	0.47	-0.4%	0.1%	-0.4%
	Others	0	0	0	0	0.00	0.00	0.0%	0.0%	0.0%
China, Hong Kong Special Administrative Region	Carp	3 650	3 239	1 975	1 263	0.83	0.82	-0.2%	-8.7%	12.4%
	Catfish	124	191	5	0	1.76	0.00	1.7%	-3.2%	-0.1%
	Tilapia	1 547	731	763	597	6.22	5.42	-17.0%	8.4%	7.0%
	Others	220	972	629	68	0.26	0.25	15.5%	3.4%	-19.3%
Indonesia	Carp	114 617	142 007	191 347	238 483	0.74	0.63	-3.6%	-3.4%	-0.2%
	Catfish	2 005	6 561	19 985	47 223	0.80	10.57	1.6%	3.5%	5.0%
	Tilapia	34 775	58 865	72 544	105 950	3.95	3.89	2.1%	-1.8%	0.0%
	Others	44 718	53 525	64 084	85 845	1.52	1.28	0.0%	1.7%	-4.7%
Lao People's Democratic Republic	Carp	5 250	9 356	12 326	27 086	1.10	0.63	1.8%	-29.0%	-4.9%
	Catfish	0	0	0	0	0.00	0.00	0.0%	0.0%	0.0%
	Tilapia	750	1 336	7 267	24 376	2.78	7.88	-1.8%	23.1%	7.2%
	Others	0	0	1 212	2 709	0.00	0.36	0.0%	5.8%	-2.3%
Malaysia	Carp	4 133	5 243	4 856	5 088	0.88	0.14	-25.7%	-25.9%	-6.1%
	Catfish	70	817	5 692	15 302	0.93	35.99	5.5%	16.5%	14.6%
	Tilapia	1 398	4 859	12 195	19 510	5.28	7.52	12.3%	9.0%	-7.9%
	Others	298	1 538	2 647	5 554	0.34	0.87	7.9%	0.4%	-0.6%
Myanmar	Carp	5 787	31 623	77 328	117 734	1.26	0.91	0.0%	0.0%	-27.9%
	Catfish	0	0	0	650	0.00	0.43	0.0%	0.0%	0.4%
	Tilapia	0	0	0	1 250	0.00	0.13	0.0%	0.0%	0.8%
	Others	0	0	0	43 781	0.00	1.91	0.0%	0.0%	26.8%
Philippines	Carp	6 640	4 296	4 408	14 324	0.11	0.14	-3.3%	0.0%	6.7%
	Catfish	126	1 144	1 056	1 814	0.13	1.49	1.1%	0.1%	0.4%
	Tilapia	66 190	86 113	81 805	112 920	20.12	15.15	0.8%	-1.3%	-5.2%
	Others	295	1 651	2 393	1 459	0.03	0.08	1.5%	1.2%	-2.0%
Singapore	Carp	0	0	7	14	--	0.03	--	--	-0.1%
	Catfish	0	0	8	7	--	1.10	--	--	-1.3%
	Tilapia	0	0	60	74	--	2.00	--	--	-11.1%
	Others	0	0	167	552	--	6.10	--	--	12.5%
Taiwan, Province of China	Carp	28 599	25 324	18 070	13 167	0.42	0.18	1.5%	-7.7%	-8.7%
	Catfish	76	377	297	1 532	0.07	1.75	0.4%	0.0%	1.3%
	Tilapia	50 281	50 866	45 303	75 607	12.95	14.14	1.9%	1.9%	14.0%
	Others	7 532	2 704	5 924	3 323	0.58	0.25	-3.9%	5.8%	-6.5%
Thailand	Carp	15 130	26 379	44 639	54 098	0.23	0.25	1.7%	-2.6%	1.5%
	Catfish	26 619	40 653	66 809	95 554	25.23	37.78	0.5%	0.9%	9.5%
	Tilapia	18 776	41 574	81 886	87 052	5.05	5.64	5.0%	3.5%	-7.4%
	Others	22 233	22 801	28 715	33 653	1.79	0.89	-7.2%	-1.9%	-3.6%

[1] Sub-period I goes from the second half of the 1980s (1985–89) to the first half of the 1990s (1990–1994); sub-period II goes from the first half of the 1990s (1990–94) to the second half of the 1990s; and sub-period III goes from the second half of the 1990s (1995–99) to the early 2000s (2000–03).

FIGURE 7
Freshwater fish farming specialization patterns in Asia



Catfish has been gaining position in Southeast Asia (Figure 7). Indonesia, Malaysia, and Thailand are important producers of catfish and have been increasing their comparative advantage in the species (Table 13). Only China, Hong Kong SAR, Lao People's Democratic Republic and Myanmar had weak comparative advantage in catfish farming during the early 2000s.

Malaysia has the most dynamic specialization pattern (Figure 8). In 1985–89, production was mostly focused on carp, although the respective RCA index (0.88) reveals that its specialization ratio in carp farming was below Asia's average. Malaysia's tilapia RCA index of 5.28 reveals its strong comparative advantage in tilapia farming. During 1990–94, Malaysia's tilapia production caught up with carp production (Table 13 and Figure 8). Catfish farming reached significant production levels at around the same time. During 1995–99, tilapia took over carp to become the number one species in Malaysia; the country's specialization ratio in catfish farming also increased (Figure 8). By 2000–03, Malaysia had further increased its specialization ratio in catfish farming; the RCAV indices revealed that comparative advantages had shifted from tilapia, carp and miscellaneous other species towards catfish farming.

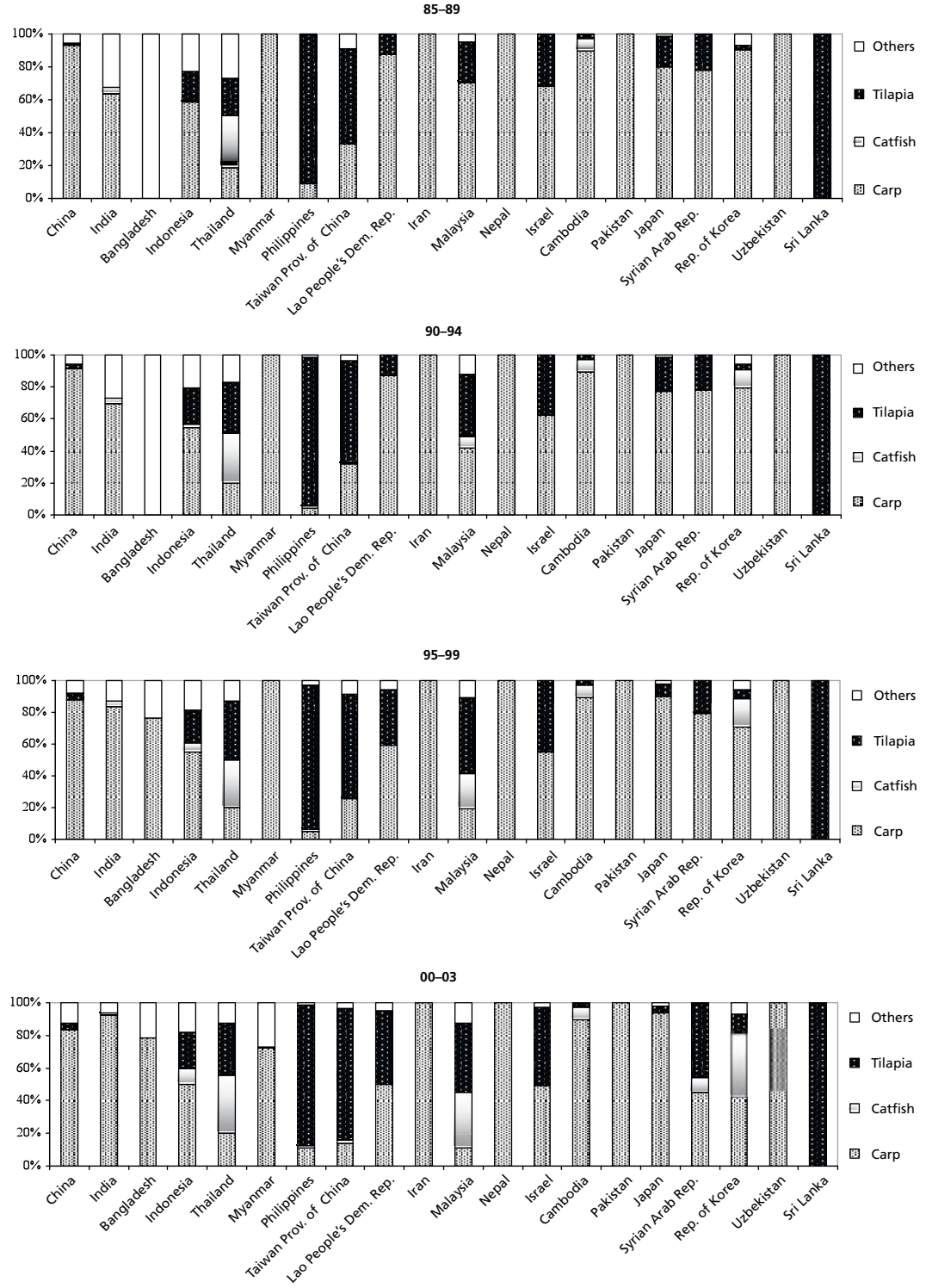
4.4.2 Freshwater fish farming comparative advantage in Latin America and the Caribbean

The LAC countries cultured nearly 300 000 tonnes of freshwater finfish in 2003, which was nevertheless only 1.3 percent of the world total. Tilapia is the dominant species in the region (Figure 6), accounting for 45 percent of its total freshwater fish farming production in 2003. Carp and catfish accounted for 27 and 3 percent of production, respectively.

Caribbean

Table 14 lists 12 Caribbean countries that engaged in freshwater fish farming during the study period. Cuba is the largest freshwater farming country in the region. It

FIGURE 8
Freshwater fish farming specialization patterns of Asian countries



Countries are placed in descending order from left to right according to their levels of freshwater fish farming production during 2000–2003.

exhibited strong comparative advantage in tilapia farming during 1985–89. The RCA index of 2.27 implies that the country's specialization ratio in tilapia farming at the time was 2.27 times higher than the LAC's average. However, advantage shifted to carp and miscellaneous other species during the study period. In the early 2000s, Cuba's tilapia RCA index was merely 0.06 while its RCA index for carp had reached 1.97.

TABLE 14

Freshwater fish farming comparative advantage (Caribbean)

Country	Species	Production quantity (tonnes)				RCA		RCAV		
		1985–89	1990–94	1995–99	2000–03	1985–89	2000–03	Sub-period I[1]	Sub-period II	Sub-period III
Bahamas	Carp	0	0	0	0	0.00	--	0%	--	--
	Catfish	0	0	0	0	0.00	--	0%	--	--
	Tilapia	35	10	0	0	3.15	--	0%	--	--
	Others	0	0	0	0	0.00	--	0%	--	--
Cuba	Carp	958	4 464	20 240	14 474	1.00	1.97	25%	-2%	3%
	Catfish	102	80	92	451	1.48	0.83	-1%	-1%	2%
	Tilapia	2 982	3 034	1 600	590	2.27	0.06	-47%	-19%	-3%
	Others	94	2 609	10 656	9 383	0.05	1.27	23%	21%	-1%
Dominica	Carp	0	0	0	0	--	0.00	--	0%	0%
	Catfish	0	0	0	0	--	0.00	--	0%	0%
	Tilapia	0	1	2	3	--	2.59	--	0%	0%
	Others	0	0	0	0	--	0.00	--	0%	0%
Dominican Republic	Carp	1	169	238	500	0.38	0.77	4%	3%	1%
	Catfish	0	0	0	0	0.00	0.00	0%	0%	0%
	Tilapia	8	481	479	1 707	2.88	2.00	-63%	17%	20%
	Others	0	932	177	0	0.00	0.00	59%	-20%	-21%
Grenada	Carp	0	0	0	0	--	0.00	--	--	--
	Catfish	0	0	0	0	--	0.00	--	--	--
	Tilapia	0	0	0	1	--	2.59	--	--	--
	Others	0	0	0	0	--	0.00	--	--	--
Guadeloupe	Carp	0	0	0	0	--	0.00	--	--	--
	Catfish	0	0	0	0	--	0.00	--	--	--
	Tilapia	0	0	0	2	--	2.59	--	--	--
	Others	0	0	0	0	--	0.00	--	--	--
Jamaica	Carp	2	2	2	1	0.00	0.00	0%	0%	0%
	Catfish	0	0	0	0	0.00	0.00	0%	0%	0%
	Tilapia	2 050	3 273	3 562	4 378	3.14	2.59	0%	0%	0%
	Others	3	3	3	0	0.00	0.00	0%	0%	0%
Martinique	Carp	0	0	0	0	0.00	0.00	0%	0%	0%
	Catfish	0	0	0	0	0.00	0.00	0%	0%	0%
	Tilapia	5	50	15	8	3.15	2.59	0%	0%	0%
	Others	0	0	0	0	0.00	0.00	0%	0%	0%
Puerto Rico	Carp	0	0	0	2	0.00	0.04	0%	0%	1%
	Catfish	0	0	0	7	0.00	2.30	0%	0%	5%
	Tilapia	9	69	17	122	3.15	2.39	0%	0%	-8%
	Others	0	0	0	2	0.00	0.05	0%	0%	2%
Saint Lucia	Carp	0	0	0	0	--	0.00	--	--	0%
	Catfish	0	0	0	0	--	0.00	--	--	0%
	Tilapia	0	0	1	2	--	2.59	--	--	0%
	Others	0	0	0	0	--	0.00	--	--	0%
Trinidad and Tobago	Carp	0	0	0	0	0.00	0.00	0%	0%	0%
	Catfish	0	0	0	1	0.00	4.25	0%	1%	8%
	Tilapia	2	3	14	10	3.15	2.35	0%	-1%	-8%
	Others	0	0	0	0	0.00	0.00	0%	0%	0%
US Virgin Islands	Carp	0	0	0	0	0.00	--	--	--	--
	Catfish	0	0	0	0	0.00	--	--	--	--
	Tilapia	4	0	0	0	3.15	--	--	--	--
	Others	0	0	0	0	0.00	--	--	--	--

[1] Sub-period I goes from the second half of the 1980s (1985–89) to the first half of the 1990s (1990–1994); sub-period II goes from the first half of the 1990s (1990–94) to the second half of the 1990s; and sub-period III goes from the second half of the 1990s (1995–99) to the early 2000s (2000–03).

Dominican Republic also increased its comparative advantage in carp farming during the study period. However, its carp RCA index of 0.77 in the early 2000s was still below the LAC's average. Jamaica and other smaller fish farming countries in the region maintained its strong comparative advantage in tilapia farming for the entire study period.

Central America

Table 15 lists eight Central American countries that engaged in freshwater fish farming during the study period. Carp was the most important species in Central America's freshwater fish farming during the 1980s but it was gradually displaced by tilapia

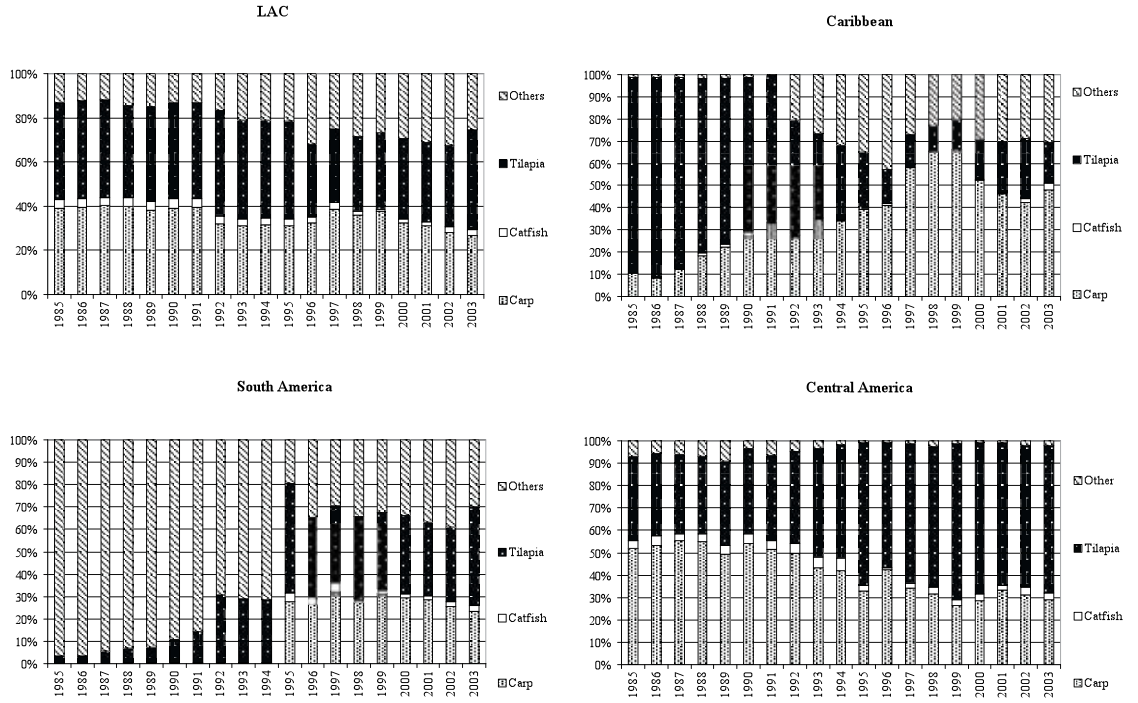
TABLE 15

Freshwater fish farming comparative advantage (Central America)

Country	Species	Production quantity (tonnes)				RCA		RCAV		
		1985–89	1990–94	1995–99	2000–03	1985–89	2000–03	Sub-period I[1]	Sub-period II	Sub-period III
Belize	Carp	0	0	0	0	--	--	--	0%	--
	Catfish	0	0	0	0	--	--	--	0%	--
	Tilapia	0	0	146	0	--	--	--	100%	--
	Others	0	1	0	0	--	--	--	-100%	--
Costa Rica	Carp	7	1	0	0	0.29	0.00	-5%	0%	0%
	Catfish	0	0	0	50	0.00	0.20	0%	0%	0%
	Tilapia	102	1 586	4 797	11 170	2.94	2.58	5%	0%	0%
	Others	0	7	15	0	0.00	0.00	0%	0%	0%
El Salvador	Carp	0	4	1	0	0.00	0.00	6%	-10%	-1%
	Catfish	0	0	0	0	0.00	0.00	0%	0%	0%
	Tilapia	14	63	169	286	3.15	2.56	-6%	9%	1%
	Others	0	0	3	4	0.00	0.04	0%	1%	0%
Guatemala	Carp	4	24	91	15	0.15	0.02	3%	-6%	-3%
	Catfish	0	1	6	9	0.00	0.16	0%	0%	0%
	Tilapia	105	405	1 920	2 466	3.04	2.56	-3%	5%	3%
	Others	0	0	2	7	0.00	0.01	0%	0%	0%
Honduras	Carp	53	10	11	0	0.94	0.00	-11%	-9%	-2%
	Catfish	0	0	0	0	0.00	0.00	0%	0%	0%
	Tilapia	97	140	378	1 920	1.26	2.59	41%	8%	9%
	Others	94	18	30	0	0.88	0.00	-30%	1%	-7%
Mexico	Carp	6 300	7 628	6 654	11 315	2.35	1.87	7%	-17%	10%
	Catfish	440	760	452	1 020	2.28	2.28	2%	-3%	1%
	Tilapia	4 100	4 868	5 404	7 528	1.11	0.95	-6%	19%	-12%
	Others	776	627	298	596	0.15	0.10	-3%	1%	0%
Nicaragua	Carp	1	0	0	0	1.10	0.00	-15%	-9%	0%
	Catfish	0	0	0	0	0.00	0.00	0%	0%	0%
	Tilapia	2	4	27	44	2.35	2.59	15%	9%	0%
	Others	0	0	0	0	0.00	0.00	0%	0%	0%
Panama	Carp	188	120	53	6	1.89	0.03	16%	-51%	-14%
	Catfish	0	0	0	0	0.00	0.00	0%	0%	0%
	Tilapia	121	77	218	669	0.89	2.56	2%	54%	17%
	Others	121	30	7	3	0.65	0.01	-18%	-3%	-2%

[1] Sub-period I goes from the second half of the 1980s (1985–89) to the first half of the 1990s (1990–1994); sub-period II goes from the first half of the 1990s (1990–94) to the second half of the 1990s; and sub-period III goes from the second half of the 1990s (1995–99) to the early 2000s (2000–03).

FIGURE 9
Freshwater fish farming specialization patterns in Latin America and the Caribbean



since the mid-1990s (Figure 9). Central America's carp farming has been concentrated primarily in Mexico. In fact, Mexico was the only Central American country with a strong comparative advantage in carp farming by the early 2000s. On the other hand, Mexico reduced its tilapia RCA index below unity in the early 2000s and hence it became the only Central American country with weak comparative advantage in tilapia farming.

Costa Rica, Guatemala and other relatively small countries in the region had strong comparative advantage in tilapia farming exclusively (Table 15 and Figure 10). Catfish is not a popular species in Central America. Mexico is the only Central American country with non-trivial production. Its catfish RCA index of 2.28 indicates that its specialization ratio in catfish farming is more than two times higher than the LAC's average.

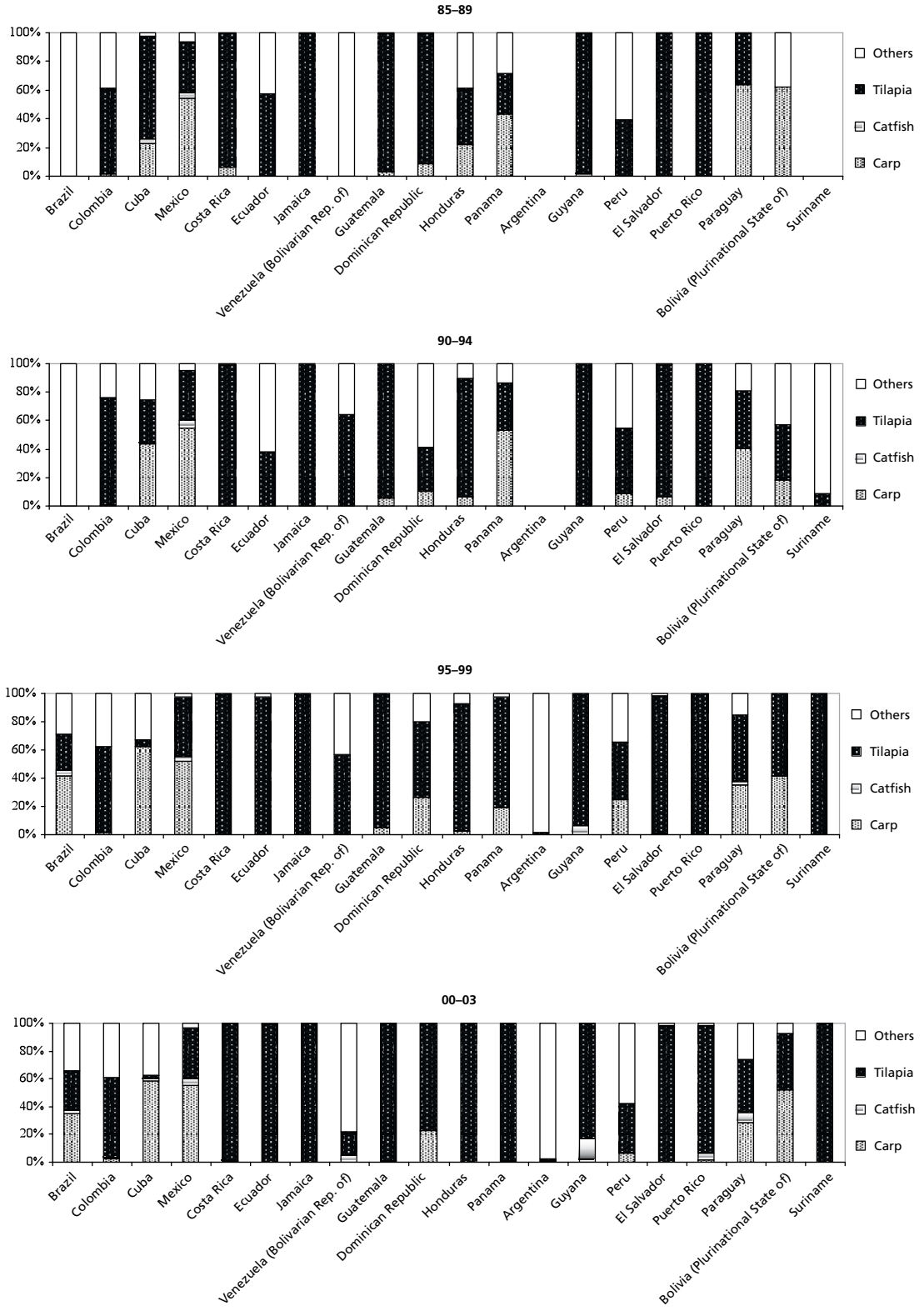
South America

Table 16 lists 12 South American countries that engaged in freshwater fish farming during the study period. Brazil is the largest freshwater fish farming country in the region. By the early 2000s it had strong comparative advantage in carp and catfish farming yet weak advantage in tilapia farming.[26] Colombia, the second largest freshwater fish farming country in the region, maintained its strong comparative advantage in tilapia aquaculture during the study period. However, this advantage declined during sub-periods II and III while comparative advantage gains were recorded for carp and miscellaneous other species (Table 16 and Figure 10).

Tilapia is also the main freshwater farming species in Bolivia (Plurinational State of), Ecuador, Guyana, Paraguay, Peru and Venezuela (Bolivarian Republic of).

[26] Brazil's freshwater fish farming production data in FishStat were reported in aggregate in the category of "miscellaneous others" until 1995.

FIGURE 10
Freshwater fish farming specialization patterns of Latin America and the Caribbean countries



Countries are placed in descending order from left to right according to their levels of freshwater fish farming production during 2000–2003.

TABLE 16
Freshwater fish farming comparative advantage (South America)

Country	Species	Production quantity (tonnes)				RCA		RCAV		
		1985–89	1990–94	1995–99	2000–03	1985–89	2000–03	Sub-period I[1]	Sub-period II	Sub-period III
Argentina	Carp	0	0	0	5	--	0.04	--	--	1%
	Catfish	0	0	0	0	--	0.00	--	--	0%
	Tilapia	0	0	7	6	--	0.03	--	--	0%
	Others	0	0	390	438	--	3.28	--	--	-1%
Bolivia (Plurinational State of)	Carp	13	31	32	43	2.71	1.77	-38%	7%	17%
	Catfish	0	0	0	0	0.00	0.00	0%	0%	0%
	Tilapia	0	66	45	34	0.00	1.05	39%	18%	-25%
	Others	8	72	0	6	0.86	0.24	-1%	-25%	7%
Brazil	Carp	0	0	31 810	53 549	0.00	1.19	0%	42%	0%
	Catfish	0	0	2 997	4 140	0.00	1.24	0%	4%	-1%
	Tilapia	0	0	19 145	43 213	0.00	0.73	0%	25%	0%
	Others	12 400	23 500	22 241	51 965	2.30	1.15	0%	-71%	2%
Colombia	Carp	14	68	393	1 118	0.06	0.10	0%	0%	2%
	Catfish	0	0	26	35	0.00	0.04	0%	0%	0%
	Tilapia	581	7 652	16 740	22 943	1.89	1.50	15%	-22%	-4%
	Others	373	2 385	10 173	15 490	0.89	1.32	-15%	22%	2%
Ecuador	Carp	0	0	0	0	0.00	0.00	0%	0%	0%
	Catfish	0	0	0	0	0.00	0.00	0%	0%	0%
	Tilapia	34	382	1 572	7 748	1.81	2.57	-20%	46%	1%
	Others	25	625	33	43	0.97	0.02	20%	-46%	-1%
French Guiana	Carp	0	0	0	9	--	1.44	--	--	42%
	Catfish	0	0	0	2	--	3.22	--	--	7%
	Tilapia	0	0	0	0	--	0.00	--	--	0%
	Others	0	0	6	11	--	1.70	--	--	-49%
Guyana	Carp	0	0	0	0	0.00	0.00	0%	0%	0%
	Catfish	0	0	15	76	0.87	7.77	-1%	6%	11%
	Tilapia	17	83	208	370	3.10	2.15	1%	-6%	-11%
	Others	0	0	0	0	0.00	0.00	0%	0%	0%
Paraguay	Carp	26	30	77	30	2.75	0.95	-16%	-24%	-1%
	Catfish	0	0	6	9	0.00	3.65	0%	3%	5%
	Tilapia	15	30	103	40	1.15	0.97	-3%	15%	-14%
	Others	0	14	34	28	0.00	0.89	19%	7%	10%
Peru	Carp	0	38	30	22	0.00	0.21	8%	7%	-14%
	Catfish	0	0	0	0	0.00	0.00	0%	0%	0%
	Tilapia	128	204	48	126	1.24	0.93	7%	-12%	-7%
	Others	199	201	42	205	1.40	1.96	-15%	5%	21%
Suriname	Carp	0	0	0	0	--	0.00	--	0%	0%
	Catfish	0	0	0	0	--	0.00	--	0%	0%
	Tilapia	0	0	11	79	--	2.59	--	85%	0%
	Others	0	2	0	0	--	0.00	--	-85%	0%
Uruguay	Carp	0	1	1	2	0.00	0.73	31%	-10%	2%
	Catfish	3	3	4	4	60.16	22.84	-31%	10%	-30%
	Tilapia	0	0	0	0	0.00	0.00	0%	0%	0%
	Others	0	0	0	2	0.00	0.96	0%	0%	29%
Venezuela (Bolivarian Republic of)	Carp	0	0	0	0	0.00	0.00	0%	0%	0%
	Catfish	0	0	0	215	0.00	2.27	0%	0%	5%
	Tilapia	0	467	1 923	722	0.00	0.43	65%	-19%	-40%
	Others	176	255	1 463	3 399	2.30	2.64	-65%	19%	36%

[1] Sub-period I goes from the second half of the 1980s (1985–89) to the first half of the 1990s (1990–1994); sub-period II goes from the first half of the 1990s (1990–94) to the second half of the 1990s; and sub-period III goes from the second half of the 1990s (1995–99) to the early 2000s (2000–03).

However, RCAV indices reveal that all these countries (except Ecuador) have reduced their comparative advantage in tilapia aquaculture in favour of either carp farming (e.g. Bolivia [Plurinational State of] and Colombia) or catfish farming (e.g. Guyana, Paraguay and Venezuela [Bolivarian Republic of]).

4.4.3 Freshwater fish farming comparative advantage in sub-Saharan Africa

As compared to Asia and LAC, sub-Saharan Africa has a much smaller freshwater fish farming industry. The region cultured only 60 000 mt of freshwater fish in 2003. Tilapia is the primary species in SSA accounting for more than 60 percent of production during 1985–89, yet the specialization ratio had declined to 39 percent by the early 2000s (Figure 6). Catfish is also an important species, accounting for more than 20 percent of the region's total freshwater fish farming production in the early 2000s (Figure 6). The specialization ratio for carp farming in the region was only 5 percent in the early 2000s, lower than the ratios in Asia and LAC.

Eastern SSA

Table 17 lists 13 countries in eastern SSA that engaged in freshwater fish farming during the study period. Tilapia is the main freshwater fish farming species. The region increased its specialization in carp farming during the mid 1990s but this trend was reversed since 1997. The importance of catfish in the region has become more significant during the early 2000s (Figure 11).

Madagascar and Ethiopia were the only eastern SSA countries that had no ongoing tilapia farming by the early 2000s (Table 17 and Figure 12). In fact, Madagascar completely specialized in carp farming since the 1990s. Kenya and Uganda also exhibited strong comparative advantage in carp farming by the early 2000s, yet this advantage had declined in both countries over the period of study. Kenya and Uganda also had a strong comparative advantage in catfish farming in the early 2000s, which increased consistently over the study period.

FIGURE 11
Freshwater fish farming specialization patterns in sub-Saharan Africa

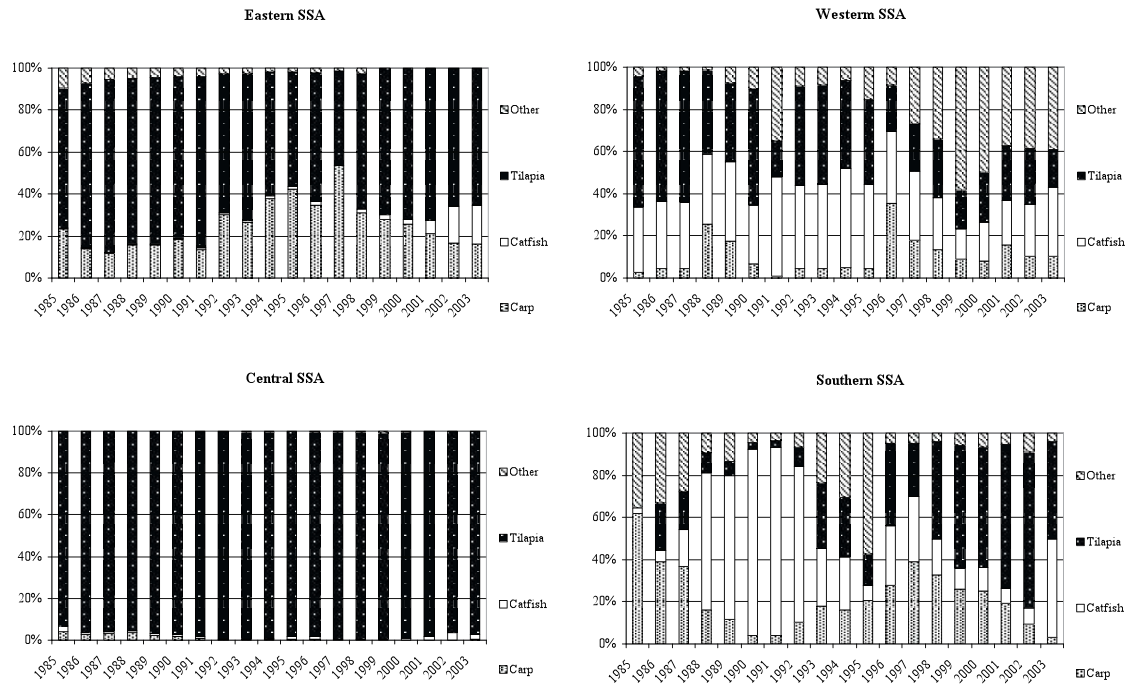
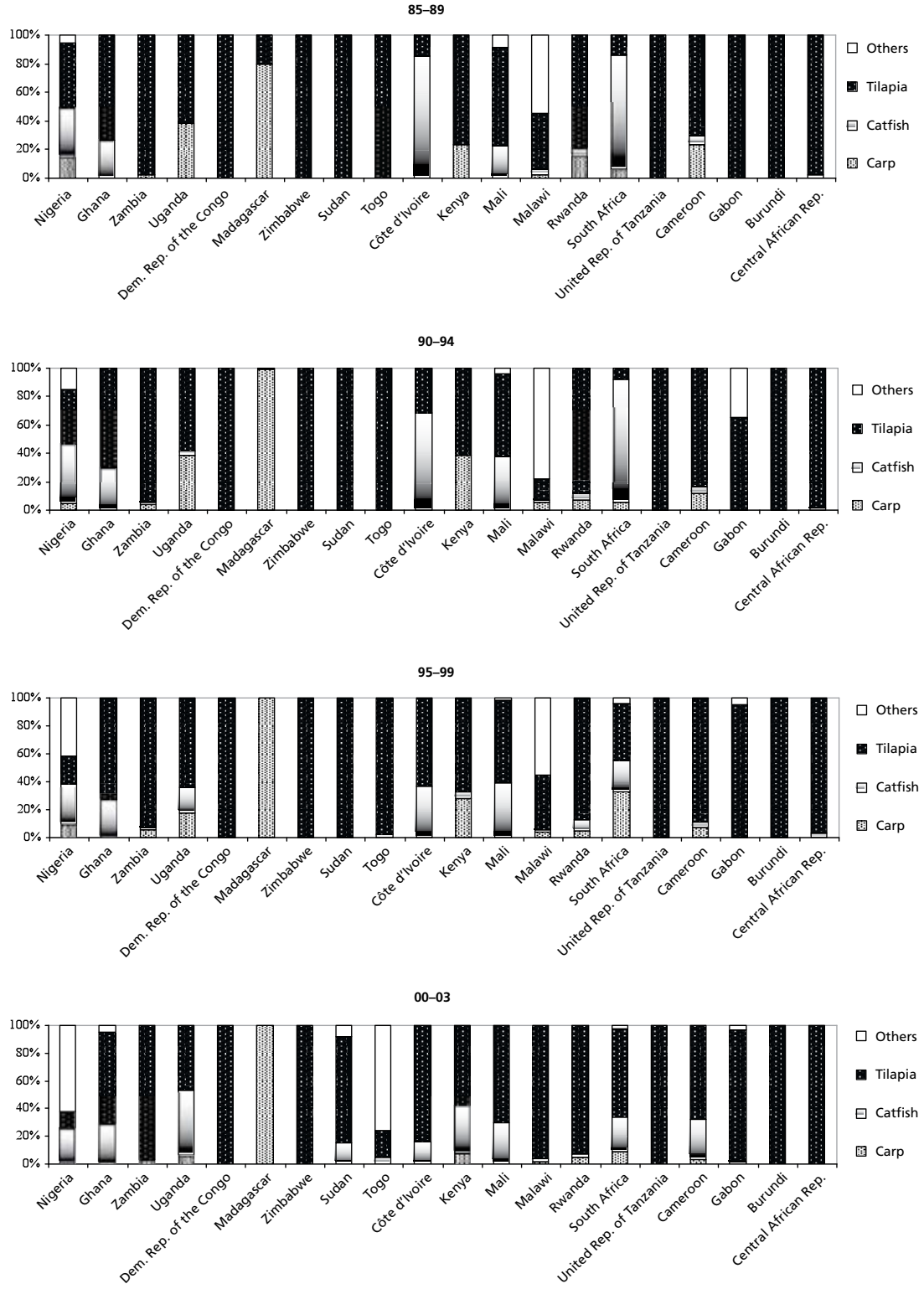


TABLE 17
Freshwater fish farming comparative advantage (eastern SSA)

Country	Species	Production quantity (tonnes)				RCA		RCAV		
		1985–89	1990–94	1995–99	2000–03	1985–89	2000–03	Sub-period I[1]	Sub-period II	Sub-period III
Burundi	Carp	0	0	0	0	0.00	0.00	0%	0%	0%
	Catfish	0	0	0	0	0.00	0.00	0%	0%	0%
	Tilapia	19	48	52	138	1.87	2.43	0%	0%	0%
	Others	0	0	0	0	0.00	0.00	0%	0%	0%
Ethiopia	Carp	6	4	3	0	2.18	--	-13%	-10%	--
	Catfish	0	0	0	0	0.00	--	0%	0%	--
	Tilapia	14	27	23	0	1.31	--	13%	10%	--
	Others	0	0	0	0	0.00	--	0%	0%	--
Kenya	Carp	57	289	112	58	1.70	1.40	18%	-28%	-3%
	Catfish	0	0	20	237	0.00	1.69	0%	5%	27%
	Tilapia	187	460	273	414	1.43	1.42	-18%	23%	-24%
	Others	0	0	0	0	0.00	0.00	0%	0%	0%
Madagascar	Carp	178	1 272	3 254	2 433	5.76	17.01	23%	0%	0%
	Catfish	0	0	0	0	0.00	0.00	0%	0%	0%
	Tilapia	46	8	0	0	0.38	0.00	-23%	0%	0%
	Others	0	0	0	0	0.00	0.00	0%	0%	0%
Malawi	Carp	5	13	13	8	0.18	0.23	5%	0%	0%
	Catfish	8	2	7	15	0.14	0.13	-2%	2%	1%
	Tilapia	76	34	131	571	0.73	2.33	-8%	33%	62%
	Others	106	171	187	0	11.70	0.00	5%	-35%	-62%
Mauritius	Carp		2	0	0	0.00	0.00	10%	-17%	0%
	Catfish	0	0	0	0	0.00	0.00	0%	0%	0%
	Tilapia	4	14	53	28	1.87	2.43	-10%	17%	0%
	Others	0	0	0	0	0.00	0.00	0%	0%	0%
Mozambique	Carp	0	0	0	10	0.00	3.42	0%	0%	20%
	Catfish	0	0	0	0	0.00	0.00	0%	0%	0%
	Tilapia	12	34	8	35	1.87	1.70	0%	0%	-30%
	Others	0	0	0	5	0.00	0.30	0%	0%	10%
Reunion	Carp			9	3	--	0.59	--	--	-3%
	Catfish	0	0	0	0	--	0.00	--	--	0%
	Tilapia	0	0	48	70	--	2.34	--	--	3%
	Others	0	0	0	0	--	0.00	--	--	0%
Rwanda	Carp	8	5	7	30	1.12	0.86	-6%	-8%	3%
	Catfish	3	4	12	13	0.21	0.11	-1%	4%	-6%
	Tilapia	41	68	126	544	1.47	2.25	8%	4%	3%
	Others	0	0	0	0	0.00	0.00	0%	0%	0%
Tanzania	Carp	0	0	0	0	0.00	0.00	0%	0%	0%
	Catfish	0	0	0	0	0.00	0.00	0%	0%	0%
	Tilapia	100	295	200	286	1.87	2.43	0%	0%	0%
	Others	0	0	0	0	0.00	0.00	0%	0%	0%
Uganda	Carp	14	35	56	225	2.79	1.13	4%	-37%	0%
	Catfish	0	3	57	1 597	0.00	2.37	3%	16%	26%
	Tilapia	22	53	199	1 577	1.15	1.13	-8%	21%	-26%
	Others	0	0	0	0	0.00	0.00	0%	0%	0%
Zambia	Carp	24	133	249	129	0.20	0.49	2%	-2%	1%
	Catfish	0	53	78	0	0.00	0.00	2%	0%	-2%
	Tilapia	871	3 188	4 101	4 344	1.82	2.36	-3%	1%	1%
	Others	0	0	0	0	0.00	0.00	0%	0%	0%
Zimbabwe	Carp	0	0	0	0	0.00	0.00	0%	0%	0%
	Catfish	0	0	0	0	0.00	0.00	0%	0%	0%
	Tilapia	45	38	271	2 255	1.87	2.43	0%	0%	0%
	Others	0	0	0	0	0.00	0.00	0%	0%	0%

[1] Sub-period I goes from the second half of the 1980s (1985–89) to the first half of the 1990s (1990–1994); sub-period II goes from the first half of the 1990s (1990–94) to the second half of the 1990s; and sub-period III goes from the second half of the 1990s (1995–99) to the early 2000s (2000–03).

FIGURE 12
Freshwater fish farming specialization patterns of sub-Saharan Africa countries



Countries are placed in descending order from left to right according to their levels of freshwater fish farming production during 2000–2003.

TABLE 18
Freshwater fish farming comparative advantage (western sub-Saharan Africa)

Country	Species	Production quantity (tonnes)				RCA		RCAV		
		1985–89	1990–94	1995–99	2000–03	1985–89	2000–03	Sub-period I[1]	Sub-period II	Sub-period III
Benin	Carp	0	0	0	0	0.00	0.00	--	--	--
	Catfish	58	0	0	0	2.81	0.00	--	--	--
	Tilapia	16	0	0	0	0.39	0.00	--	--	--
	Others	0	0	0	7	0.00	3.02	--	--	--
Burkina Faso	Carp	0	0	0	0	0.00	0.00	0%	0%	0%
	Catfish	3	2	0	0	0.47	0.00	42%	-52%	0%
	Tilapia	20	1	28	5	1.63	2.43	-42%	52%	0%
	Others	0	0	0	0	0.00	0.00	0%	0%	0%
Côte d'Ivoire	Carp	0	0	0	0	0.00	0.00	0%	0%	0%
	Catfish	143	154	281	157	3.03	0.81	-18%	-28%	-21%
	Tilapia	25	71	485	817	0.28	2.04	18%	28%	21%
	Others	0	0	0	0	0.00	0.00	0%	0%	0%
Gambia	Carp	0	0	0	0	--	--	--	--	--
	Catfish	0	0	2	0	--	--	--	--	--
	Tilapia	0	0	0	0	--	--	--	--	--
	Others	0	0	2	0	--	--	--	--	--
Ghana	Carp	0	0	0	0	0.00	0.00	0%	0%	0%
	Catfish	99	131	335	1 407	0.95	1.47	2%	0%	2%
	Tilapia	273	302	905	3 199	1.37	1.61	-2%	0%	-6%
	Others	0	0	0	230	0.00	0.14	0%	0%	5%
Guinea	Carp	0	0	0	0	0.00	--	0%	0%	--
	Catfish	1	3	2	0	1.98	--	43%	0%	--
	Tilapia	1	0	0	0	0.83	--	-43%	0%	--
	Others	0	0	0	0	0.00	--	0%	0%	--
Liberia	Carp	0	0	0	0	0.00	0.00	--	--	--
	Catfish	0	0	0	2	0.00	0.71	--	--	--
	Tilapia	4	0	0	14	1.87	2.09	--	--	--
	Others	0	0	0	0	0.00	0.00	--	--	--
Mali	Carp	0	0	0	0	0.00	0.00	0%	0%	0%
	Catfish	3	18	28	190	0.80	1.51	16%	9%	-10%
	Tilapia	9	28	43	446	1.28	1.70	-3%	2%	12%
	Others	1	2	1	0	1.92	0.00	-14%	-11%	-2%
Niger	Carp	0	0	0	0	0.00	0.00	0%	0%	0%
	Catfish	0	0	0	0	0.00	0.00	0%	0%	0%
	Tilapia	14	18	17	29	1.87	2.43	0%	0%	0%
	Others	0	0	0	0	0.00	0.00	0%	0%	0%
Nigeria	Carp	1 637	584	2 010	205	1.09	0.13	-7%	3%	-2%
	Catfish	3 727	5 583	5 716	6 985	1.22	1.26	7%	2%	-2%
	Tilapia	4 944	5 256	4 063	3 444	0.85	0.30	-4%	-10%	-7%
	Others	556	1 950	8 504	17 231	1.10	1.87	4%	5%	11%
Senegal	Carp	0	0	0	0	0.00	0.00	0%	0%	0%
	Catfish	0	0	0	0	0.00	0.00	0%	0%	0%
	Tilapia	5	13	51	14	1.87	2.43	0%	0%	0%
	Others	0	0	0	0	0.00	0.00	0%	0%	0%
Sierra Leone	Carp	0	0	0	0	0.00	0.00	0%	0%	0%
	Catfish	0	0	0	0	0.00	0.00	0%	0%	0%
	Tilapia	16	20	29	30	1.87	2.43	0%	0%	0%
	Others	0	0	0	0	0.00	0.00	0%	0%	0%
Togo	Carp	0	0	0	0	0.00	0.00	0%	0%	0%
	Catfish	0	0	1	52	0.00	0.26	0%	2%	3%
	Tilapia	17	99	47	192	1.87	0.47	0%	-2%	-79%
	Others	0	0	0	748	0.00	2.28	0%	0%	75%

[1] Sub-period I goes from the second half of the 1980s (1985–89) to the first half of the 1990s (1990–1994); sub-period II goes from the first half of the 1990s (1990–94) to the second half of the 1990s; and sub-period III goes from the second half of the 1990s (1995–99) to the early 2000s (2000–03).

Zambia and Zimbabwe have relatively large freshwater fish farming production volumes, mostly concentrated on tilapia (Table 17). Other countries with relatively small aquaculture production (e.g. Burundi, Malawi, Mauritius, Mozambique, Réunion, Rwanda and Tanzania) also had strong comparative advantage in tilapia farming exclusively by the early 2000s.

Western SSA

Table 18 lists 13 western SSA countries that engaged in freshwater fish farming during the study period. In 1985 tilapia was the most important species in western SSA, accounting for 60 percent of the region's freshwater fish farming. Catfish was in second place, accounting for another 30 percent. By 1996, carp had become the most important species with a specialization ratio of 35 percent; catfish held on to the second position with a specialization ratio of 34 percent; in contrast, tilapia declined to only 22 percent. By 2003, catfish had become the number-one species with a specialization ratio of 33 percent; tilapia came in second place (18 percent) while the ratio for carp was only 10 percent. The remaining 40 percent was accounted for by miscellaneous other species (Figure 11).

Tilapia is a traditional and popular species in western SSA. Nigeria and Togo were the only two countries that had weak comparative advantage in tilapia farming in the early 2000s; both countries reduced their comparative advantage during the study period (Table 18). Côte d'Ivoire and Mali were the only two western SSA countries with comparative advantage gains in tilapia farming during the sub-period III.

Catfish farming in western SSA has been concentrated in Ghana, Mali, and Nigeria; the RCA indices revealed that these three countries had strong comparative advantage in catfish farming in the early 2000s (Table 18). However, only Ghana among these three countries had gained comparative advantage in catfish during the sub-period III. It must be noted that Togo also gained comparative advantage during the study period.

Despite a temporary farming boom in Nigeria in 1996, none of the 13 Western SSA countries had a strong comparative advantage in carp farming in the early 2000s.

Southern, Northern and Central SSA

Results of the analyses for southern, northern and central SSA are reported in Tables 19, 20 and 21, respectively. The RCA indices suggested that South Africa in southern SSA had strong comparative advantage in all three species in the early 2000s, yet the RCAV analysis indicated that comparative advantage was shifting towards tilapia farming from the other species (Table 19). Sudan (a northern SSA country) had completely specialized in tilapia farming until the early 2000s when it began conducting some catfish farming (Table 20).

All of the five Central SSA countries (i.e. Cameroon, Central African Republic, Congo, Democratic Republic of the Congo and Gabon) had strong comparative advantage in tilapia farming during the study period (Table 21). Cameroon has shifted its advantage in tilapia towards both carp and catfish farming during the sub-period III.

4.5 DISCUSSION

Countries tend to have different freshwater fish farming specialization patterns. The RCA approach provides a convenient tool for systematically examining these patterns. We have used this approach to examine the farming of three freshwater species (carp, catfish and tilapia) in 111 countries in Asia, LAC and SSA (see Tables 9–21). In this section we summarize some insights provided by the results of the analysis, which may be useful for private decision-makers regarding species selection or for public policy with respect to the development of freshwater fish farming industries.

TABLE 19
Freshwater fish farming comparative advantage (southern sub-Saharan Africa)

Country	Species	Production quantity (tonnes)				RCA		RCAV		
		1985–89	1990–94	1995–99	2000–03	1985–89	2000–03	Sub-period I[1]	Sub-period II	Sub-period III
Lesotho	Carp	22	11	7	8	6.64	17.01	-8%	-6%	35%
	Catfish	2	3	1	0	0.30	0.00	8%	6%	-35%
	Tilapia	0	0	0	0	0.00	0.00	0%	0%	0%
	Others	0	0	0	0	0.00	0.00	0%	0%	0%
Mayotte	Carp	0	0	0	0	--	0.00	--	--	0%
	Catfish	0	0	0	0	--	0.00	--	--	0%
	Tilapia	0	0	1	3	--	2.43	--	--	0%
	Others	0	0	0	0	--	0.00	--	--	0%
Namibia	Carp	0	0	0	0	--	0.00	--	0%	0%
	Catfish	0	0	0	0	--	0.00	--	0%	0%
	Tilapia	0	0	0	0	--	0.00	--	0%	0%
	Others		4	5	13	--	3.02	--	0%	0%
South Africa	Carp	6	34	34	26	0.47	1.49	1%	20%	-5%
	Catfish	70	510	24	76	2.81	1.29	5%	-56%	-3%
	Tilapia	13	49	43	188	0.27	1.53	-6%	32%	12%
	Others		0	4	8	0.00	0.08	0%	4%	-4%
Swaziland	Carp	0	0	20	20	0.00	5.23	0%	13%	27%
	Catfish	0	0	13	6	0.00	0.47	0%	8%	2%
	Tilapia	0	0	38	39	0.00	1.46	0%	24%	37%
	Others	22	46	88	0	21.45	0.00	0%	-45%	-66%

[1] Sub-period I goes from the second half of the 1980s (1985–89) to the first half of the 1990s (1990–1994); sub-period II goes from the first half of the 1990s (1990–94) to the second half of the 1990s; and sub-period III goes from the second half of the 1990s (1995–99) to the early 2000s (2000–03).

TABLE 20
Freshwater fish farming comparative advantage (northern SSA)

Country	Species	Production quantity (tonnes)				RCA		RCAV		
		1985–89	1990–94	1995–99	2000–03	1985–89	2000–03	Sub-period I[1]	Sub-period II	Sub-period III
Libyan Arab Jamahiriya	Carp	37	78	100	100	7.25	17.01	0%	0%	0%
	Catfish	0	0	0	0	0.00	0.00	0%	0%	0%
	Tilapia	0	0	0	0	0.00	0.00	0%	0%	0%
	Others	0	0	0	0	0.00	0.00	0%	0%	0%
Sudan	Carp	0	0	0	0	0.00	0.00	0%	0%	0%
	Catfish	0	0	0	200	0.00	0.78	0%	0%	15%
	Tilapia	52	207	1,000	1,000	1.87	1.87	0%	0%	-23%
	Others	0	0	0	100	0.00	0.23	0%	0%	8%

[1] Sub-period I goes from the second half of the 1980s (1985–89) to the first half of the 1990s (1990–1994); sub-period II goes from the first half of the 1990s (1990–94) to the second half of the 1990s; and sub-period III goes from the second half of the 1990s (1995–99) to the early 2000s (2000–03).

We find that neighbouring countries may have similar comparative advantage patterns. Examples include:

- Former USSR Asian members' strong comparative advantage in carp.
- Iran (Islamic Republic of), Iraq and Turkey's strong comparative advantage in carp.
- Nepal and Pakistan's strong comparative advantage in carp.

TABLE 21
Freshwater fish farming comparative advantage (central sub-Saharan Africa)

Country	Species	Production quantity (tonnes)				RCA		RCAV		
		1985–89	1990–94	1995–99	2000–03	1985–89	2000–03	Sub-period I[1]	Sub-period II	Sub-period III
Cameroon	Carp	33	8	4	7	1.70	0.55	-8%	-15%	1%
	Catfish	9	3	3	62	0.22	1.45	-2%	1%	24%
	Tilapia	98	56	56	147	1.32	1.65	10%	14%	-25%
	Others	0	0	0	0	0.00	0.00	0%	0%	0%
Central African Republic	Carp	0	0	0	0	0.00	0.00	0%	0%	0%
	Catfish	3	3	4	0	0.07	0.00	-1%	2%	-3%
	Tilapia	143	217	123	123	1.83	2.43	1%	-2%	3%
	Others	0	0	0	0	0.00	0.00	0%	0%	0%
Democratic Republic of the Congo	Carp	0	0	0	0	0.00	0.00	0%	0%	0%
	Catfish	0	0	0	5	0.00	0.01	0%	0%	0%
	Tilapia	622	696	1 205	2 682	1.87	2.42	0%	0%	0%
	Others	0	0	0	0	0.00	0.00	0%	0%	0%
Congo	Carp	0	0	0	0	0.00	0.00	0%	0%	0%
	Catfish	0	0	0	0	0.00	0.00	0%	0%	0%
	Tilapia	139	206	135	26	1.87	2.43	0%	0%	0%
	Others	0	0	0	0	0.00	0.00	0%	0%	0%
Gabon	Carp	0	0	0	0	0.00	0.00	0%	0%	0%
	Catfish	0	0	0	3	0.00	0.08	0%	0%	2%
	Tilapia	2	8	166	200	1.87	2.30	-34%	59%	1%
	Others		4	9	8	0.00	0.11	34%	-59%	-3%

[1] Sub-period I goes from the second half of the 1980s (1985–89) to the first half of the 1990s (1990–1994); sub-period II goes from the first half of the 1990s (1990–94) to the second half of the 1990s; and sub-period III goes from the second half of the 1990s (1995–99) to the early 2000s (2000–03).

- The Philippines and Taiwan, Province of China's strong comparative advantage in tilapia.
- Thailand, Cambodia, Indonesia and Malaysia's strong comparative advantage in catfish.
- Caribbean countries' (except Cuba) strong comparative advantage in tilapia.
- Central American countries' (except Mexico) strong comparative advantage in tilapia.
- Tanzania, Mozambique and Zimbabwe's strong comparative advantage in tilapia.

We also find that countries in spatial proximity can nevertheless have very distinct specialization patterns. Examples include:

- In East Asia during the early 2000s, Japan's strong comparative advantage in carp vs. South Korea's advantage in catfish.
- In the Middle East, Saudi Arabia's strong comparative advantage in tilapia vs. Iran (Islamic Republic of) and Iraq's advantage in carp.
- In South Asia, Sri Lanka's complete specialization in tilapia farming vs. the region's high concentration on carp.
- In Southeast Asia, Cambodia's strong comparative advantage in carp farming vs. the region's general weak advantage in that species.
- In the Caribbean during the early 2000s, Cuba's extremely weak comparative advantage in tilapia farming vs. the region's strong advantage in that species.
- In Central America during the early 2000s, Mexico's weak comparative advantage in tilapia farming vs. the region's strong advantage in that species.

- In South America during the early 2000s, Brazil's strong comparative advantage in carp and catfish together with weak advantage in tilapia vs. Colombia and Ecuador's weak advantage in carp and catfish mixed with a strong advantage in tilapia.
- In eastern SSA, Madagascar's complete specialization in carp farming vs. the region's focus on tilapia.
- In western SSA, Nigeria's weak comparative advantage in tilapia vs. the region's strong comparative advantage in that species.

We find that in some cases countries in spatial proximity converge to similar comparative advantage patterns (e.g. Thailand, Indonesia and Malaysia; the Philippines and Taiwan, Province of China, Kenya and Uganda) while in other cases they maintain distinct patterns (e.g. Sri Lanka in South Asia; Madagascar in eastern SSA) or even diverge (e.g. Cuba in the Caribbean; Mexico in Central America; Uganda and Zambia; Nigeria and Côte d'Ivoire).

The interesting question now is how to extract useful information from these comparative advantage patterns and apply it to aid public and private decision-making processes. It would be very convenient if a straightforward mathematical formula could be developed for this purpose, yet we think the process may have to depend on a great deal of discretion. We illustrate this point with several examples in the following paragraphs.

- Cambodia, whose RCA index of 0.47 in the early 2000s is much lower than that of neighboring countries such as Thailand (5.64) and Malaysia (7.52), may want to find out whether its weak revealed comparative advantage in tilapia farming reflects its inherent characteristics that make it more suitable for culturing other species (e.g. carp) or its unexploited potential for farming of that species.
- Sri Lanka, as a tilapia-farming country in a carp-farming region, should inquire why its freshwater fish farming industry is so different from its neighbours'. Likewise, other countries in the region (e.g. India and Bangladesh) need to make sure that the absence of tilapia development does not represent a missed opportunity.
- Caribbean countries may want to examine Cuba's freshwater fish farming industry to understand why its annual carp farming production increased from 1 000 tonnes in 1985–89 to 14 000 tonnes in the early 2000s while its annual tilapia production has nevertheless declined from 3 000 tonnes to only 600 tonnes. If this structural change reflects Cuba's success in culturing carp as a high-quality exotic species, then other Caribbean countries should consider whether they can achieve similar success by fostering their comparative advantage in carp farming.
- Similarly, Central and South American countries should study Mexico and Brazil's comparative advantage in carp and catfish farming. Certainly it is not proper for countries to blindly follow the specialization patterns of the region's leading fish farming nations, yet these patterns can provide valuable lessons and experience.
- For countries in a region (e.g. SSA) where fish farming is underdeveloped, fish farming experience of countries in other regions can also help. It is not without reasons that carp remains the number-one freshwater aquaculture species. Yet fish farming tradition and technology as well as local culture and taste may make carp a disadvantageous species in a foreign region such as SSA. However, the successful carp farming experiences in Brazil and Mexico should provide grounds for encouragement. In addition, SSA countries need to examine why Madagascar has complete specialization in carp farming.

A country's comparative advantage pattern depends on many factors, some of which (e.g. geographic position, climate, natural resources) are inherent and invariant while others (e.g. farming technology, human resources, and even local tastes) can be altered or developed. Therefore, the key is not really to "pick" the winners. Rather, policy decision-making should help avoid "loser species" that are inherently inappropriate and then assist other species to become "winner species".

5. Summary

This study attempts to develop a systematic framework for assessing countries' comparative advantage in competing aquaculture species. The framework is based on two common approaches used in economics for comparative advantage assessment. One is the "domestic resources cost" (DRC) or "benefits-costs" (BC) approach; the other is the "revealed comparative advantage" (RCA) approach.

The DRC/BC approach evaluates and compares the social profitability of activities that compete for limited resources. The lower the DRC ratio for an activity is, the more efficient the activity utilizes domestic resources; hence the stronger its comparative advantage would be. Also, a low DRC ratio indicates a large profit margin and thus greater sustainability. Due to lack of data we have not provided an empirical application of the DRC/BC approach, which is conceptually straightforward and empirically well-developed with many references.

The RCA approach compares countries' specialization patterns to reveal their comparative advantage patterns. A country with a relatively high specialization in an activity is assumed to have a strong comparative advantage in that activity. Dynamically, a country that has increased its specialization in an activity more than other countries is presumably gaining comparative advantage in that activity. Data availability allowed us to illustrate two empirical applications of the RCA approach. One was an assessment of major shrimp farming countries' comparative advantages in exporting cultured shrimp to three major international markets; the other is an assessment of countries' comparative advantage in production of three freshwater farming species.

The RCA and DRC/BC approaches can provide complementary information useful for commercial and policy decision-making. An RCA assessment can help identify specialization patterns that deserve attention, while a DRC/BC assessment can focus attention on the factors that shape these patterns. For example, the RCA assessment in section 4 shows that Sri Lanka's freshwater fish farming is completely specialized in tilapia while its South Asian peers (e.g. Bangladesh, India, Nepal and Pakistan) have virtually no specialization in the species. These striking differences beg questions on existing inefficiencies in regional aquaculture development. Although the possibility exists that tilapia is inherently unsuitable for South Asian countries except Sri Lanka, it is also possible that the former countries have not fully exploited their potential for tilapia farming. To better understand why aquaculture development has diverged, further investigation on regional tilapia farming is warranted.

In this regard, the DRC/BC approach may help. The cost structures of tilapia farming in Sri Lanka and shadow prices in India can be used to calculate the DRC ratio for potential tilapia farming in India; this ratio could then be compared to other freshwater farming enterprises such as carp (or perhaps shrimp farming, which tends to compete with tilapia farming for resources). If potential tilapia farming has a lower DRC ratio than other species in India, then aquaculturists and policymakers need to consider whether to give tilapia farming a first-push. From another angle, Sri Lanka may want to look into its underperformance in carp farming in a region with high specialization in this species.

There are many such patterns deserving similar attention. The following are just a few examples: Madagascar's complete specialization in carp while carp farming is losing ground in SSA in general; gradual decline in specialization in carp farming in Honduras, Guatemala, and Panama while Mexico manages to maintain its specialization in the species; the changes in Malaysia's freshwater fish farming specialization patterns

and the similarity of Malaysia and Thailand's specialization patterns (Figure 8); SSA countries with relatively high specialization in catfish (e.g. Uganda, Kenya, Nigeria, Ghana) versus those with relatively low specialization in this species or those whose specialization in it is declining (e.g. South Africa).

A thorough identification and analysis of these patterns are beyond the scope of this study. Yet the comparative advantage assessment framework developed here provides a useful tool for the task.

References

Aguilar-Manjarrez, J. & Nath, S.S. 1998. *A strategic reassessment of fish farming potential in Africa*. CIFA Technical Paper No. 32. Rome, FAO. 170 pp.

Balassa, B. 1965. Trade liberalization and 'revealed' comparative advantage. *Manchester School of Economic and Social Studies* 33: 92–123.

Bojnec, S. 2001. Trade and revealed comparative advantage measures: regional and Central and East European agricultural trade. *Eastern European Economics* 39(2): 72–98.

Bowen, H.P. 1983. On the theoretical interpretation of indices of trade intensity and revealed comparative advantage. *Review of World Economics (Weltwirtschaftliches Archiv)* 119(3): 464–72.

Bowen, H.P. & Pelzman, J. 1984. United States. export competitiveness: 1962–77. *Applied Economics* 16(3): 461–73.

Chen, K., Xu, L. & Duan, Y. 2000. Ex-post competitiveness of China's export in agri-food products: 1980–96. *Agribusiness* 16(3):281–294.

Donges, J.B. & Riedel, J. 1977. The expansion of manufactured exports in developing countries: an empirical assessment of supply and demand issues. *Review of World Economics (Weltwirtschaftliches Archiv)* 113(1): 58–85.

FAO. 1996. *List of animal species used in aquaculture*. FAO Fisheries Circular No. 914 FIRI/C914. Rome.

FAO. 2000. *The state of world fisheries and aquaculture*. Rome. (also available at http://www.fao.org/sof/sofia/index_en.htm)

FAO. 2002. *The state of world fisheries and aquaculture*. Rome. (also available at http://www.fao.org/sof/sofia/index_en.htm)

FAO. 2004. *The state of world fisheries and aquaculture*. Rome. (also available at http://www.fao.org/sof/sofia/index_en.htm)

FAO. 2006. *The state of world fisheries and aquaculture*. Rome. (also available at http://www.fao.org/sof/sofia/index_en.htm)

FAO. 2008. *FishStat Plus – universal software for fishery statistical time series*. Rome.

Hassan, R.M., Fairbanks, D.H.K., Magagula, G. & Faki, H. 1999. *Analyzing comparative advantage and trade options in South Africa: guidelines for a unified approach*. Technical Paper No. 100. Washington, DC, USAID.

Havrila, I. & Gunawardana, P. 2003. Analyzing comparative advantage and competitiveness: an application to Australia's textile and clothing industries. *Australian Economic Papers* 42(1): 103–117.

Hiley, M. 1999. The dynamics of changing comparative advantage in the Asia-Pacific region. *Journal of the Asia Pacific Economy* 4(3): 446–467.

Jooste, A. & van Zyl, J. 1999. *Regional agriculture trade and changing comparative advantage in South Africa*. SD Technical Paper No. 94, Washington, DC, USAID.

Kaliba, A.R. & Engle, C.R. 2003. Impact of different policy options on profits of private catfish farms in Chicot County, Arkansas. *Aquaculture Economics and Management* 7(5): 309–318.

Kannapiran, C.A. & Fleming, E.M. 1999. *Competitiveness and comparative advantage of tree crop smallholdings in Papua New Guinea*. Working Paper Series in Agricultural and Resource Economics No. 99–10. Armidale, Australia, University of New England (also available at http://www.une.edu.au/economics/publications/gsare/AREwp99-10.PDF)

Kapetsky, J.M. 1994. *A strategic assessment of warm-water fish farming potential in Africa*. CIFA Technical Paper No 27. Rome, FAO. 67 pp.

Kapetsky, J.M. & Nath, S.S. 1997. *A strategic assessment of the potential for freshwater fish farming in Latin America*. COPESCAL Technical Paper No. 10. Rome, FAO. 128 pp.

Lee, W.-C., Chen, Y.-H., Lee, Y.-C. & Liao, I.C. 2003. The competitiveness of the eel aquaculture in Taiwan, Province of China, Japan, and China. *Aquaculture* 221: 115–124.

Ling, B.-H., Leung P.S. & Shang, Y.C. 1996. Export performance of major cultured shrimp producers in the Japanese and United States markets. *Aquaculture Research* 27(10): 775–786.

Ling, B.-H., Leung P.S. & Shang, Y.C. 1999. Comparing Asian shrimp farming: the domestic resource cost (DRC) approach. *Aquaculture* 175(1): 31–48.

Machena, C. & Moehl, J. 2001. Sub-Saharan African aquaculture: regional summary. *In* R.P. Subasinghe, P. Bueno, M.J. Phillips, C. Hough, S.E. McGladdery & J.R. Arthur, eds. *Aquaculture in the Third Millennium. Technical Proceedings of the Conference on Aquaculture in the Third Millennium, Bangkok, Thailand, 20–25 February 2000*, pp. 341–355. NACA, Bangkok and FAO, Rome.

Magagula, G.T. & Faki, H.M. 1999. *Comparative economic advantage of alternative agricultural production options in Swaziland*. Technical Paper No. 103, Washington, DC, USAID.

Memedovic, O. 1994. *On the theory and measurement of comparative advantage: an empirical analysis of Yugoslav trade in manufactures with the OECD countries, 1970–1986*. Amsterdam, Tinbergen Institute. (PhD dissertation)

Monke, E.A. & Pearson, S. R. 1989. *The policy analysis matrix for agricultural development*. Ithaca, NY, Cornell University Press. (also available at http://www.stanford.edu/group/FRI/indonesia/documents/pambook/pambook.pdf)

Mucavele, F.G. 2000. *Analysis of comparative advantage and agricultural trade in Mozambique*. Technical Paper No. 107. Washington, DC, USAID. (also available at http://www.afr-sd.org/publications/mozambique107.pdf)

Nakhumwa, T.O., Ng'ong'ola, D.H., Minde, I.J., Lungu, V. & Mapemba, H.E. 1999. *Comparative economic advantage in agricultural trade and production in Malawi*. Technical Paper No. 93. Washington, DC, USAID (also available at http://pdf.usaid.gov/pdf_docs/PNACG108.pdf)

Odhiambo, M.O., Kristjanson, P. & Kashangaki, J. 1996. *Comparative cost of production analysis in East Africa: implications for competitiveness and comparative advantage*. Washington, DC, USAID. 114 pp. (also available at http://www.eldis.org/assets/Docs/25970.html)

Richardson, J. D. (1971a). Constant-market-shares analysis of export growth. *Journal of International Economics* 1(2): 227–39.

Richardson, J. D. (1971b). Some sensitivity tests for a "constant-market-shares" analysis of export growth. *The Review of Economics and Statistics* 53(3): 300–304.

Richardson, J.D. & Zhang, C. 1999. *Revealing comparative advantage: chaotic or coherent patterns across time and sector and United States. trading partner?* NBER Working Paper No. W7212. Cambridge, MA, USA.

Saasa, O.S., Chiwele, D., Mwape, F. & Keyser, J.C. 1999. *Comparative economic advantage of alternative agricultural production activities in Zambia*. Technical Paper No. 104. Washington, DC, USAID.

Siggel, E. & Ssemogerere, G. 2004. Uganda's policy reforms, industry competitiveness and regional integration: a comparison with Kenya. *Journal of International Trade & Economic Development* 13(3): 325–357.

Sukume, C., Makudze, E., Chimedza, R.M. & Zitsanza, N. 2000. *Comparative economic advantage of crop production in Zimbabwe*. Technical Paper No. 99. Washington, DC, USAID.

Suranovic, S.M. 2008. *International trade theory and policy* (available at http://internationalecon.com/Trade/tradehome.php).

Thompson, H. 2006. *International economics: global markets and competition*. Second edition. Singapore, World Scientific Publishing Co.

UNIDO. 1986. *International comparative advantage in manufacturing: changing profiles of resources and trade*. Publication Sales No. E86 II B9. Vienna, United Nations Industrial Development Organization.

United Nations. 2008. *United Nations commodity trade statistics database – UN Comtrade*. New York, NY, United States, Statistics Division of the United Nations (available at http://comtrade.un.org/)

USAID. 1999. *Analysis of the comparative economic advantage of alternative agricultural production options in Tanzania*. Technical Paper No. 102. Washington, DC, USAID. (also available at http://www.afr-sd.org/publications/102tanz.pdf)

Vollrath, T. 1991. A theoretical evaluation of alternative trade intensity measures of revealed comparative advantage. *Review of World Economics (Weltwirtschaftliches Archiv)* 127(2): 265–280.

Warr, P.G. 1994. Comparative and competitive advantage. *Asian-Pacific Economic Literature* 8(2): 1–14.

Yeats, A.J. 1985. On the appropriate interpretation of the revealed comparative advantage index: implications of a methodology based on industry sector analysis. *Review of World Economics (Weltwirtschaftliches Archiv)* 121(1): 61–73.

Yeats, A.J. 1992. What do alternative measures of comparative advantage reveal about the composition of developing counties' exports? *Indian Economic Review* 27(2): 139–54.

APPENDIX 1

RCA Indices

In the following we present some major RCA indices reported in the literature. For additional variants and other RCA indices, Memedovic (1994) and Vollrath (1991) provide more thorough reviews.

- Standard Balassa's RCA index

$$RCA_{ij}^{1} = \frac{\dfrac{X_{ij}}{\sum_{i} X_{ij}}}{\dfrac{\sum_{j} X_{ij}}{\sum_{i}\sum_{j} X_{ij}}}$$

where X_{ij} represents country i's export of product j. $RCA_{ij}^{1} > 1$ indicates country i has a comparative advantage in production of j; the greater the index, the stronger the advantage. $RCA_{ij}^{1} < 1$ indicates that country i has a comparative disadvantage in production of j; the smaller the index, the greater the disadvantage.

- RCA index suggested by Donges and Riedel (1977)

$$RCA_{ij}^{2} = \frac{\dfrac{X_{ij} - M_{ij}}{\sum_{i} X_{ij} + M_{ij}}}{\dfrac{\sum_{j} X_{ij} - \sum_{j} M_{ij}}{\sum_{i} X_{ij} + \sum_{j} M_{ij}}}$$

where X_{ij} and M_{ij} represent country i's export and import of product j. $RCA_{ij}^{2} > 1$ indicates country i has a comparative advantage in production of j; the greater the index, the stronger the advantage. $RCA_{ij}^{2} < 1$ indicates that country i has a comparative disadvantage in production of j; the smaller the index, the greater the disadvantage.

- RCA index suggested by Bowen (1983)

$$RCA_{ij}^{3} = \frac{\dfrac{T_{ij}}{Y_{i}}}{\dfrac{\sum_{i} Q_{ij}}{Y_{w}}}$$

where Q_{ij} and t_{ij} represent country i's production and net trade (i.e. production minus consumption) of product j while Y_i and Y_w represent country i's GNP and the world GNP, respectively. $RCA_{ij}^{3} > 0$ indicates country i has a comparative advantage in production of j; the greater the index, the stronger the advantage. $RCA_{ij}^{3} < 0$ indicates

that country *i* has a comparative disadvantage in production of *j*; the smaller the index, the greater the disadvantage.

- RCA indices suggested by Vollrath (1991)

$$RCA_{ij}^{4} = \frac{X_{ij}/X_{ik}}{X_{nj}/X_{nk}} - \frac{M_{ij}/M_{ik}}{M_{nj}/M_{nk}}$$

$$RCA_{ij}^{5} = \ln\left(\frac{X_{ij}/X_{ik}}{X_{nj}/X_{nk}}\right)$$

$$RCA_{ij}^{6} = \ln\left(\frac{M_{ij}/M_{ik}}{M_{nj}/M_{nk}}\right)$$

where X_{ij} and X_{ik} represent country *i*'s exports of product *j* and its total exports of other products; X_{nj} and X_{nk} represent the exports of product *j* and the total exports of other products by the rest of the world; M_{ij} and M_{ik} represent country *i*'s import of product *i* and its total imports of other products; finally, M_{nj} and M_{nk} represent imports of product *j* and total imports of other products by the rest of the world. According to Vollrath (1991, p. 276), "a positive RCA_{ij}^{4}, RCA_{ij}^{5}, or RCA_{ij}^{6} reveals a comparative advantage, while a negative value reveals a comparative disadvantage".

APPENDIX 2

A proper measure for comparative advantage variations

Since Balassa's RCA index is a measure of comparative advantage at a point in time, it seems natural to use the difference between RCA indices at the beginning and end of a period to measure the change of comparative advantage during the period.

Although this has been a common practice,[1] its theoretical justification has not been established. In the following we derive a measure of comparative advantage variation with theoretical foundation; the result shows that the direct use of the difference between RCA indices at different times to measure revealed comparative advantage variation is not generally appropriate.

Methodologically, we first derive what country *i*'s RCA index for product *j* would have been at time *t*+1 if it maintains its comparative advantage in the product during the period between time *t* and *t*+1. Then we can use the deviation of its actual $RCA_{ij,t+1}$ from this benchmark RCA index to measure its comparative advantage variation during the period.

According to equation (3), country *i*'s revealed comparative advantage in any product *j* is measured by the ratio between its share in export market *j* and its world market share. Thus, country *i*'s comparative advantage in market *j* relative to market *k* can be measured by the ratio between its shares in the two markets, i.e. $s_{ij,t}/s_{ik,t}$. Therefore, country *i* would experience no change in its comparative advantage pattern between time *t* and *t*+1 if its market share ratios for any two markets remain constant during the period, i.e.

$$\frac{\tilde{s}_{ij,t+1}}{\tilde{s}_{ik,t+1}} = \frac{s_{ij,t}}{s_{ik,t}}, \forall\, j,k, \tag{A.1}$$

where $\tilde{s}_{ij,t+1}$ represents what country *i*'s share in market *j* would have been under no comparative advantage variations.

According to equation (A.1), a country would experience no comparative advantage variation when its market share in every market grows at the same rate, i.e.

$$\forall\, j, \frac{\tilde{s}_{ij,t+1}}{s_{ij,t}} = \alpha, \tag{A.2}$$

where α is a positive constant.

Given the total export of product *j* at time *t*+1 (i.e $E_{j,t+1}$), had country *i* experienced no comparative advantage variation between time *t* and *t*+1, its export of product *j* would have been

$$\tilde{E}_{ij,t+1} = \tilde{s}_{ij,t+1} E_{j,t+1},$$

which, according to equation (A.2), gives,

$$\tilde{E}_{ij,t+1} = \alpha s_{ij,t} E_{j,t+1} \tag{A.3}$$

[1] For example, Bojnec (2001); Hiley (1999); Havrila and Gunawardana (2003); and Yeats (1992).

Accordingly, country *i*'s specialization in production *j* would have been

$$\tilde{c}_{ij,t+1} = \frac{\tilde{E}_{ij,t+1}}{\sum_{j_k} \tilde{E}_{ij_k,t+1}},$$

which, substituted in equation (A.3), gives

$$\tilde{c}_{ij,t+1} = \frac{s_{ij,t} E_{j,t+1}}{\sum_{j_k} s_{ij_k,t} E_{j_k,t+1}} \tag{A.4}$$

Then, given its actual total export $E_{i,t+1}$, country *i*'s constant-comparative-advantage benchmark export of product *j* would be

$$\tilde{E}_{ij,t+1} = \tilde{c}_{ij,t+1} E_{i,t+1},$$

which, substituted in equation (A.4), gives

$$\tilde{E}_{ij,t+1} = \frac{s_{ij,t} E_{j,t+1} E_{i,t+1}}{\sum_{j_k} s_{ij_k,t} E_{j_k,t+1}} = \frac{(1+g_j) c_{ij,t} E_{i,t+1}}{\sum_{j_k} c_{ij_k,t} (1+g_{j_k})}. \tag{A.5}$$

Since $\tilde{E}_{ij,t+1}$ represents what country *i*'s export of product *j* would have been under no comparative advantage variation, the deviation of its actual export of product *j* (i.e., $E_{ij,t+1}$) from this constant-comparative-advantage benchmark would provide a measure of the country's comparative advantage variation between time *t* and *t*+1.

Similar to how the RCA index is defined, a "revealed comparative advantage variation" (RCAV) index can be defined as

$$RCAV_{ij} = \frac{E_{ij,t+1}/E_{i,t+1}}{E_{j,t+1}/E_{t+1}} - \frac{\tilde{E}_{ij,t+1}/E_{i,t+1}}{E_{j,t+1}/E_{t+1}} = RCA_{ij,t+1} - \beta RCA_{ij,t} \tag{A.6}$$

where $\beta = \dfrac{1+g}{1+\sum_j c_{ij,t} g_j}$,

$g_j = (E_{j,t+1} - E_{j,t})/E_{j,t}$ represents the growth rate of world exports of product *j* between time *t* and *t*+1, and

$g = (E_{i+1} - E_t)/E_t$ represents the growth rate of total world exports of all products.

The RCA index can be expressed in two equivalent forms (see equations 3 and 4). Likewise, the RCAV index defined in equation (A.6) can be manifested as

$$RCAV_{ij} = \frac{s_{ij,t+1}}{s_{i,t+1}} - \frac{\tilde{s}_{ij,t+1}}{s_{i,t+1}} \tag{A.6.1}$$

or

$$RCAV_{ij} = \frac{c_{ij,t+1}}{c_{j,t+1}} - \frac{\tilde{c}_{ij,t+1}}{c_{j,t+1}}. \tag{A.6.2}$$

A positive $RCAV_{ij}$ index implies that country i has increased its comparative advantage in product j; the higher the index is, the greater the advantage gain is. A negative $RCAV_{ij}$ index would have the exact opposite implication.

It is not difficult to see that

$$\sum_j c_{j,t} g_j = g,$$

where $c_{j,t} = E_{j,t}/E_t$ represents the proportion of world cultured shrimp exports sold to market j. Thus, β would be unity when $c_{ij,t}$ is identical to $c_{j,t}$ for every market j, i.e. according to equation (4), when country i's RCA index for every market j is equal to unity (i.e. $g_j = g, \forall j$). Otherwise, β would generally be different from unity. Therefore, when the sizes of markets are changed disproportionately, direct use of the variation of RCA indices to measure comparative advantage variation would not be appropriate in general.

For example, LAC country Uruguay had catfish RCA indices of 55.48 and 35.78 respectively during 1990–94 and 1995–99, which seemingly indicates that it has *reduced* its comparative advantage in catfish between the first and second half of the 1990s. However, the country's specialization in catfish has actually *increased* from 69 percent during 1990–94 to 77 percent during 1995–99. The corresponding RCAV index, which is positive at 4.65, properly reflects this comparative advantage *gain*.

Comparative advantage analysis is a useful tool of economics that can be used to compare relative costs of production and identify species and markets with the greatest likelihood of success. Two different approaches are normally used to assess comparative advantage: the Domestic Resource Cost (DRC) and the Revealed Comparative Advantage (RCA) methods. The DRC approach is dynamic but requires data on production costs which may be hard to obtain. The RCA method is more descriptive and has less predictive potential than the DRC approach but required data are normally available. This paper illustrates the concept of comparative advantage and some of its policy implications by presenting two case studies (on shrimp export markets and aquaculture production of freshwater finfish) using the RCA method.

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