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On the relationship between aquaculture and food security: Why does aquaculture contribute more in some developing countries than it does in others?

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Abstract

As much as 78% of fish production is subject to international trade competition. While this may be positive for economic growth, it may be at odds with achieving food security. The purpose of this paper is to review the relationship between aquaculture and food security, focussing on trade and markets in some developing countries that account for more than 90% of aquaculture output. The international trade in fish products largely involves the movement of high value species from developing to developed countries and the opposite in reverse, which can contribute to food security. Countries where food security is not improving tend to rely on small-scale aquaculture production of species that are not desired in the main markets, themselves relying on imported fish to meet domestic demand. This suggests that an aquacultural revolution in these countries may contribute to food security, as well as economic growth.

Keywords: Aquaculture, developing countries, trade, food security, opportunities, constraints

1. Introduction

With the population expected to increase to 9.8 billion by 2050 ^[1] the world faces a huge challenge to increase food production and eliminate hunger. Food deficits in many of the poorer countries in the world are expected to increase in line with population growth, with the role of international trade becoming ever more important in achieving global food security ^[2]. Increasing global food production, while mitigating the impacts of climate change and resource degradation, mean that achieving sustainable development goals, particularly food security and nutrition in low-income countries, presents a major challenge.

While production from capture fisheries has stagnated at around 90 million tonnes, aquaculture, which did not exist as a commercial form of fish production until the early 1980s, has grown rapidly in many countries. The growth in aquaculture has meant that year on year total fish output has increased. This impressive growth is attributed to a variety of factors – but the main cause, as reported by De Silva ^[3], has been the transformation of aquaculture from an “art” to a “science”. This led to the development of techniques to optimise yields with lower inputs (e.g. reliance on wild stocks for feed inputs), gains in efficiency and husbandry, (e.g. polyculture, vertical integration) government assistance (e.g. institutions, policy, research and development) and the diffusion of best practice across countries and continents. Increases in efficiency through innovation, economies of scale and market-orientated production, has increased access to the large international markets – in particular the big fish markets of the EU, the US and Japan.

This paper addresses the current role of aquaculture and its potential to deliver food security in some case study countries spanning three continents – Africa, Asia and South America. Specifically, the paper addresses the role of trade and markets on aquaculture development in eight case study countries (Bangladesh, Brazil, China, India, Kenya, Philippines, Vietnam and Zambia) that were reviewed as part of the European Union funded Aquaculture for Food Security, Poverty Alleviation and Nutrition Project.

The next section presents an overview of aquaculture production in the developing countries considered in this paper.

Section 3 focusses on trade in fish products and whether this represents a concern for achieving food security in developing countries, or is a positive development for achieving food security. Section 4 considers policy implications, constraints and opportunities for further development of aquaculture, and the role and impact of trade in developing countries in contributing to food security objectives. Finally, section 5 concludes.

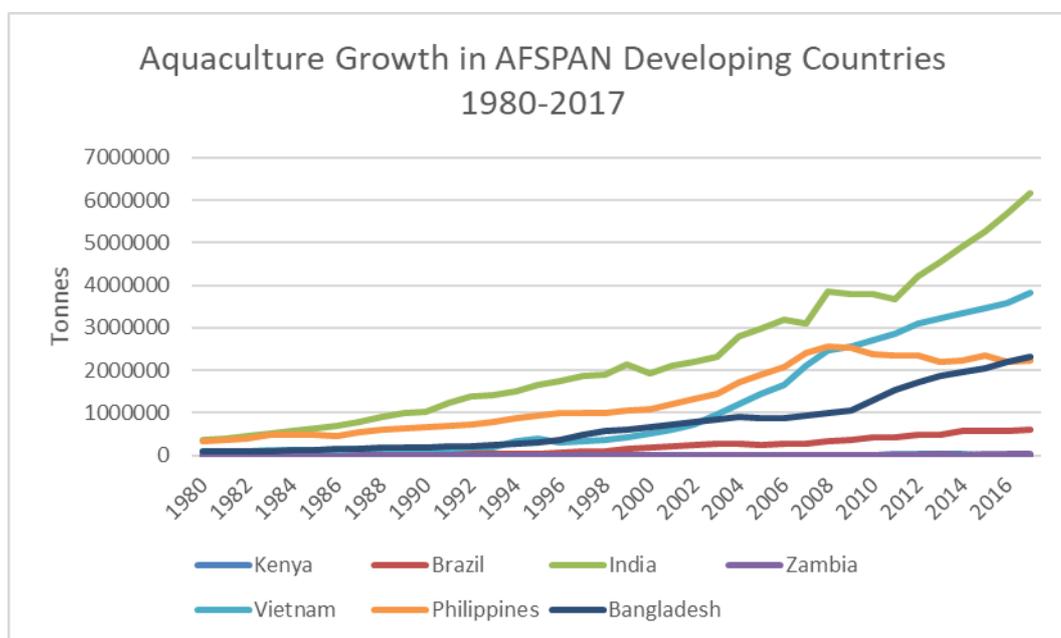
2. Aquaculture development and production in developing countries

Total fish production reached an all-time high in 2018 at 179 million tonnes ^[4], with almost 90% utilised for direct human consumption. Total aquaculture production in 2018, amounted to around 82 million tonnes, accounting for 46.8 percent of total fish production ^[4]. While overall growth has slowed in recent years, significant double-digit growth has been recorded in some countries, particularly in Asia – contributing to the increased value of global exports that stood at USD 152

billion in 2016. By 2017, more than 50% of the value of aquaculture exports originated from developing countries for the first time. Given the stagnant output from the world's capture fisheries, the role of aquaculture in contributing to per capita fish consumption, which can be as high as 50kg in some countries e.g. the Seychelles, continues to increase. Further, growth in aquaculture continues to outpace growth in beef and pork combined - only poultry consumption is growing at a faster rate than fish consumption ^[4].

2.1 Production and trade in the AFSPAN case study countries

Growth and diversification in some developing countries has been particularly impressive. However, this trend has not been seen in all countries. As shown in Figure 1 (which excludes China for reasons of scale), the case study countries that are discussed in this paper highlight the disparate growth in aquaculture around the world, albeit with a general increasing trend.



Source: FAO Fishstat

Fig 1: Aquaculture growth in AFSPAN Developing Countries

In Brazil, one of the world's emerging economies, where some economic sectors are stalling, growth in aquaculture has been double-digit for some time. In comparison, total fisheries production has grown at just 1.7% per year during the same period. This has increased total production to 581,000 tonnes ^[5]. While the traditional production of Nile tilapia accounts for around 50% of production, farmers have diversified to higher value species, such as shrimp, in an attempt to enter lucrative export markets. However, as discussed later in the paper, there are several constraints to further developing the aquaculture sector in some developing countries for export markets, and in particular weak links in the supply chain, as problems such as disease, lack of market information, institutional support and trade barriers limit export potential. In Brazil, for example, exports declined sharply during the period 2003-2013 and this trade deficit is expected to grow ^[6]. India has also recorded impressive growth. Historically, production in India largely focussed on the main carp species, where export to the main fish consumption areas, such as the EU, US and China is limited for various reasons e.g. lack of

demand in the main export markets. However, diversification to species suitable for export markets has led to sectoral growth. In India, along with carp, prawn and shrimp are produced, with 65% and 90% exported, respectively. In particular, processed products are exported to the main fish consumption markets. The adoption of modern farming techniques coupled with institutional change, have resulted in socioeconomic benefits (in terms of employment and foreign exchange earnings), as well as improvements in food security and nutrition. Total aquaculture production grew from around 1.9 million tonnes in 2000 to 5.7 million tonnes in 2016. Exports of seafood has grown three fold during the period 2006-2016, currently standing at over USD 5.5 billion ^[5]. Similar to other low-income African countries, fish consumption remains an important source of protein in Zambia. However, domestic production is too low to meet domestic demand and the species produced are largely not market orientated. Therefore, only a small proportion of aquaculture products are exported to international markets. Aquaculture accounts for only 13% of fish consumption in

Zambia (mainly consisting of tilapia species), yet over 50% of the population consume protein from fish. Further, the majority of fish imported from China is tilapia - demonstrating there is domestic demand that could be met by increased tilapia production in the country. However, most producers are small-scale or subsistence farmers and lack the resources to increase production.

Likewise, in Kenya, aquaculture production is characterised by small-scale production (only growing to 15,000 tonnes in 2016) for domestic consumption^[5]. Similarly, to Zambia, imports of fish from China have pushed down prices. Further, in Kenya, there is a significant bias towards consuming meat, with fish not considered a substitute good.

In the Philippines, total fish production has been increasing since the 1960s, reaching 5.16 million tonnes in 2010. Production from aquaculture peaked in 2010 at 2.6 million tonnes, but has since declined to 2.2 million tonnes in 2016^[5]. The Philippines are a net exporter, exporting over 75% of total seafood production, including high value species like shrimp, tuna and grouper to the main fish consuming markets around the world. The Philippines has a strong trade relationship with China, who account for over 50% of the Philippines total seafood exports. However, since 2011 growth has slowed. The FAO^[6] predict that the share of the Philippines output in global trade will decline by 25% by 2030 and imports will increased by around 30% to satisfy increased domestic demand. This will result from increased purchasing power as the Philippines economy continues to grow.

In Bangladesh, aquaculture has accounted for over 50% of total fish production since 2011. Production grew from less than 100,000 tonnes in 1980, to more than 2.2 million tonnes by 2016, making Bangladesh the fifth biggest producer in Asia^[5]. Fish production in Bangladesh currently accounts for more than 50% of total protein intake. Growth in the sector rose sharply since the mid-1990s, although growth has not been consistent, with some periods recording only very low growth or actual declines. However, since the 1990s, aquaculture has grown as an export orientated industry. This can be attributed to several factors, but importantly because government have strongly supported aquaculture production as a method of increasing exchange earnings. The production of shrimp has been strongly supported for export to large markets like the EU – which more than trebled during the period 1995 to 2012. However, exports of shrimp remain vulnerable to regulatory barriers in export markets. For example, bans on the import of Bangladeshi shrimp to the EU in the late 1990s and early 2000s. Nevertheless, following the implementation of fully traceable robust production methods, Bangladesh has achieved the List 1 country status for exporting fish products to the EU - indicating that Bangladesh has policies and procedures fully harmonised with the legislation and policies of EU countries – including safety standards that satisfy the EU.

Some countries are far more export orientated than others. For example, in terms of volume, Bangladesh is not a big player in global exports – but in terms of value, because shrimp accounts for around 60% of exports, Bangladesh is one of the largest exporters in terms of value. This suggests that aquaculture in Bangladesh has (or has the potential to) contributed significantly to economic growth through exchange earnings, which in turn can be interpreted as contributing to food security (as fish is a substitute product for alternative and cheaper fish). It is estimated by the World Fish

Centre that more than 3 million Bangladeshis will have benefited from aquaculture growth through better income and nutrition by 2022.

Vietnam has seen a vast expansion in the output of fish products. Both fisheries and aquaculture have made important contributions to food security, poverty reduction and increased livelihoods. Aquaculture production has grown from less than 100,000 tonnes in 1980 to more than 3.6 million tonnes in 2016. Similarly, to Bangladesh, Vietnam's aquaculture industry has grown strongly as an export orientated industry. By 2016, Vietnam was the world's third largest exporter (by value), with Pangas catfishes and shrimp accounting for much of the export earnings of over USD 7.3 billion. The sector provides an important source of food for the country's population – it is estimated that seafood products meet around 40% of total food production^[6].

Coupled with strong economic growth in the last decade or so, increasing incomes have increased import demand, especially of high value fish like salmon through increased purchasing power. Vietnam is also a significant third country processor, importing raw fish for processing and re-export^[6]. Seafood production was included in economic restructuring plans for the country, which involved converting resources used in inefficient agricultural production (especially in coastal areas) to seafood production centres.

Finally, China, the world's largest importer and exporter of aquaculture products, has witnessed an increasing growth trend in output, producing more than the rest of the world combined each year since 1991. China has also been the largest exporter of fish products since 2002^[6], although increased domestic demand has slowed export growth in recent years. However, the importance of aquaculture to food security and nutrition in China increases as the share of aquaculture output in total fish production continues to grow. It currently accounts for over 70% to total fish production - and is expected to grow further^[6], contributing to increased levels of food security.

3. The role and impact of trade in fish in developing countries

The international trade in fish products has grown rapidly, with increasing amounts of trade taking place between developed and developing countries year on year^[6]. The contentious issue that has arisen, and has been addressed by several authors,^[7-10] is whether this trade is beneficial to developing countries. However, as noted by Asche *et al*^[7] the results of these studies (to some extent) depends on the lens used to address the question. For example, some studies take the standpoint that trade in food products from countries that do not have enough food e.g. some developing countries to countries where production has grown faster than consumption for decades e.g. some developed countries, is a negative development. However, other studies consider the role of trade in fish products from an economic viewpoint – contesting the positives for economic development (as exchange earnings can be invested in infrastructure, health and education, for example), as well as food security, nutrition and poverty alleviation.

Nevertheless, trade flows, including the international trade continue to increase. In 2016, about 45% of the global seafood production was subject to international trade, and as much as 78% of fish and seafood products are estimated to be exposed to international trade competition^[11]. The balance of exports and imports in developing countries is heavily in

favour of exports (in terms of value), with developing countries accounting 54% of exports in terms of value and only 23% of imports. The converse is seen regarding volume [6].

However, while overall food output has increased in recent years, largely because of increasing aquaculture output, the absolute number of undernourished people had increased from 784 million in 2015 to 821 million in 2017 [12]. This raises issues regarding the impact of the international trade in fish products. This may (in part) be linked with the fact that food security in some countries has worsened at the same time as aquaculture has grown. For example, in some countries this has been due to a change in policy focus to increasing urbanisation to stimulate economic growth.

While export markets around the world have grown rapidly, with some local or regional markets, now global markets, the rate at which producers in some developing countries are able to take advantage of these new export markets has been variable. Diffusion of best practice, technological advances and the interpretation and understanding of market signals and information, along with improvements in health and sanitation standards, are required for developing countries to take advantage of world markets. Some countries, notably Bangladesh, Brazil and Vietnam have found international markets volatile, having exports rejected in the case of Vietnam, to bans on imports of aquaculture products in the case of Bangladesh. Further, population and economic growth in developing countries increases demand for seafood products – resulting in a lower share being available for export markets.

However, as reported by Asche *et al* [7], who studied international trade flows of seafood products in over 150 developing countries and more than 50 developed countries, a clear pattern emerges. The results indicate that developing countries export high-value fish products (mainly to developed countries) and import low-value food (including fish from other developing countries). Considering that food is substitutable, the impacts of seafood trade for developing countries are thus positive, as the surplus in value is greater than the surplus in volume. However, as noted by the FAO [6], there are a limited number of studies that focus on the trade of fish products. As countries often supply poor data on the volume and value of trade, detailed assessments of the impact of trade on development objectives is not well understood.

With regard to trade restrictions, tariffs are generally not considered a barrier to trade in fish products, as they are generally low. There is some tariff escalation for processed products, although the growth in third country processing in developing countries indicates that tariffs are not a barrier to trade. The World Trade Organisation (WTO) principle of most-favoured nations generally prevents members from discriminating against trading partners [6]. Further, the generalised system of preferences means that tariffs can be reduced (or removed altogether) to facilitate market access for developing countries. However, as noted by the FAO [6], market access problems relating to non-tariff barriers (e.g. food safety issues) are more of a concern for developing countries. However, many developing countries apply higher tariffs than developed countries, reflecting fiscal and protective measures. While this does not affect the international trade, it may affect regional trade between developing countries. A growing trend in recent years, however, has been the growth in reciprocal preferential trade deals between developing countries. This has resulted from

strong economic growth in some developing countries and the resulting link between economic growth and increased fish consumption.

Consequently, the increase in regional trade has been growing quicker than the international trade in fish products for some years. This may also be reflective of the increasing price trend in fish products in the last decade or so. To further assist developing countries to export fish products, the WTO's Trade Facilitation Agreement, implemented in 2017, is designed to reduce restrictive non-tariff barriers to trade – recognising that technical regulations are non-discriminatory and in developing countries the high-cost and relatively low capacity affect compliance (thus acting as a barrier to trade). The Trade Facilitation Agreement encourages the cooperative development of international standards and conformity assessment systems [6], which is beneficial for developing countries.

However, the general consensus is that the international trade from developing countries to developed countries is positive and globalisation and markets opening up to free trade are beneficial to global development. This consensus dates back to the economics ideas of David Ricardo in the early 19th Century – in particular comparative advantage – which states free trade results in the efficient use of resources (i.e. land, labour and capital), which takes further importance given the current pressures of climate change, resource use and degradation. In the countries studied in this paper, international trade in aquaculture products has contributed to economic growth e.g. Bangladesh, India and the Philippines. It has also contributed to food security and nutrition through trade, as export earnings allow for exported fish products to be substituted (e.g. Bangladesh, India and Vietnam). However, the role of aquaculture in some countries e.g. Kenya and Zambia is less clear. Production remains low - in the case of Zambia - not enough to meet demand. Therefore, low value fish are imported from other developing countries – exerting pressure on prices.

4. Constraints and opportunities to increase export orientated aquaculture in developing countries

Food safety and traceability in supply chains is a key determinant of access to international markets [13-14]. Broadly speaking, a consumer focussed approach, and increased collaboration between supply chain members, increases competitiveness of the whole supply chain and thus opportunities for all members. The overall opportunity being increased access to international markets [15]. Diffusion of best practice between members, and a communication strategy that keeps all members informed about market demands, are important aspects of supply chains functioning to increase export opportunities.

Supply chains in high-income countries tend to be very sophisticated and traceable [16]. The constraints to increasing export opportunities in the AFSPAN case study countries can be classified as:

- Production constraints
- Processing constraints
- Marketing constraints
- Institutional and Policy constraints

These constraints represent challenges as well as opportunities for supply chain management, although the categories are not mutually exclusive.

Production constraints are often the root cause of the lack of

trade opportunities, both regional and international [15]. Some of the most significant production constraints in developing countries include lack of market information and understanding (e.g., producers produce only what they can and are not influenced by markets). In countries where fish production remains low, e.g. Kenya and Zambia, there is little emphasis on production for export beyond regional markets. Fish is not seen as a substitute, but because of low production and competing imports, an expensive alternative to traditional meat consumption. In Zambia, for example, fish has a more significant role in food security, as production is higher, although of species destined for local/regional markets. This is less because of a meat bias as seen in Kenya, but more because producers do not have access to market information, or the facilities (e.g. lack of inputs such as seed and feed) and ability (e.g. know-how) to produce species for export to international markets. Access to smartphones in some countries has proven a significant development in better understanding market signals e.g. quantities and prices. However, in Africa, for example, less than 30% of the population has access to mobile phones. Further in countries like Kenya and Zambia, production is often very small-scale, undertaken away from the main consumption centres (e.g. the big cities that in some developing countries are rapidly growing), with poor infrastructure and production techniques. Key elements of the fish production process to meet stringent regulations in international markets like the EU, (such as post harvesting procedures, access to ice and cold storage, poor transportation, poor coordination with market demands e.g. type of product, fresh vs. frozen, whole fish vs. fillets etc.), and a general lack of knowledge and know how to improve the production process restricts access to such markets [15].

In many developing countries, a significant barrier to export results from a lack of processing facilities. Processing plants are not well developed and often processing is undertaken on the farm. This type of processing does not meet the stringent food safety criteria of export markets and Hazard Analysis and Critical Control Points (HACCP) principles are not in place. Countries like Bangladesh, China, Vietnam and more recently India, have understood the requirements for highly processed fish products in developed markets and have implemented programmes to incentivise production to meet market demands in international markets (including processing standards). In order to stimulate exports and promote investment in export-oriented activities, the Government of Bangladesh provide a number of fiscal and financial incentives, and has established institutions to implement the incentive schemes and extend trade facilitation services. However, most of the benefit of these schemes is directed to larger producers targeting lucrative export markets. Concerning food security, focus on small-scale farmers producing species for domestic/regional markets is needed. Further, it is estimated that processing facilities operate at a fraction of their capacity due to a lack of fish to process. Those facilities approved by the EU for processing and export are not available for small-scale producers, where production systems do not meet stringent criteria (e.g. food safety, traceability and HACCP).

Since the 1990s, government support and institutional development in India has led to the diversification from traditional carp species for export to regional markets, to prawn and shrimp production for export to the EU, US and Japan. Similarly, growth in shrimp farming in Vietnam has been strong in recent decades. However, as markets have

become more demanding of food safety standards, exports have become volatile, as standards were perceived to have dropped. This has led to several examples of Vietnamese exports being rejected in the main markets as farmers struggle to meet standards. In China, the main constraint relating to slower growth in recent years has been non-technical barriers to trade in the main markets, particularly the US.

Along with the technological advances that have been made over the last 30 years, which has enabled the vast growth in aquaculture, institutional changes have also been required to facilitate this growth. In countries that have grown by targeting export markets (e.g. China, Vietnam, Bangladesh, India and the Philippines), governments and institutional arrangements have strongly supported growth in aquaculture. In other words, aquaculture has strongly featured in economic and food security development plans (the so-called pro-poor growth plans). In other countries, including Kenya and Zambia, and to a lesser extent Brazil, this has not been the case. Production remains small-scale characterised by a lack of knowledge and facilities to increase production of species desired in international markets.

In some of the case study countries reported on here, large operations have the ability to produce quantities required to meet long-term sales contracts (for example, China, Bangladesh, Vietnam). Some of them can vertically integrate, or build processing plant facilities to deliver frozen or value-added products (e.g., for shrimp value addition can take several forms, such as cooked, peeled and deveined, butterflied, breaded) to domestic or international markets. Farms can have several production units (ponds or cages) numbered and sized to have daily harvests. At this scale, a continuous flow of aquaculture products is required to sustain a processing facility running at two or more shifts a day. In addition, production scale can restrain access to larger and more distant markets, due to either freight costs, product presentation (fresh, frozen, cooked, etc.) and/or quality standards required by local regulations. These issues significantly affect trading destinations, *i.e.*, domestic, local or regional, and/or international.

However, the type of production and scale, and the extent to which producers understand market signals and demands also impact trade, particularly with respect to developed markets. In developing countries, the supply chain is often underdeveloped and production is largely centred on what can be produced, based on poor knowledge, lack of access to seed, feed, equipment, technical expertise and so on. Therefore, a significant amount of what is produced is often only suitable for sale in local markets and perhaps regionally. For example, in Brazil, some species such as tambaqui, are only recognised in local markets, where as other species such as tilapia and shrimp are recognised in much larger national/international markets. Therefore, the latter are able to contribute to economic growth, although a development strategy for aquaculture could enable resources to be better utilised to increase economic development and income sharing in rural areas away from the big cities. To improve the contribution of fish production to economic development objectives in developing countries, one of which is to improve the equitable distribution of income, requires focus on supply chain management and enhancement – otherwise access to international markets is limited.

5. Conclusion

Given the disagreement in the literature regarding the impact

of aid on development ^[17-19], particularly the link between aid and growth, we consider that development economics can be defined as finding an intervention that generates more income than it costs. Aquaculture is already helping some countries progress their development objectives – and in light of expected increases in the world’s population and the growing impacts of climate change – the role of aquaculture is expected to take on more importance over the coming decades.

However, the extent to which the rapid growth in aquaculture has contributed to development objectives – economic growth, food security and poverty reduction – has been dependent on several factors. Notably, this includes government support for aquaculture development, including the processes and strategies to incentivise and facilitate market orientated production. Countries that have adopted aquaculture development within pro-poor growth strategies, such as Bangladesh, China, India, and Vietnam have seen the economic benefits of aquaculture growth through international trade - as noted by Asche *et al.* ^[7], and the resulting improvements in food security and poverty reduction. However, some African countries, including Kenya and Zambia, where aquaculture has grown modestly in the last decades, and where production remains small-scale, have not benefited from the rapid global development in aquaculture. In particular, small-scale extensive farms have played a vital role in feeding local communities, but there is a lack of support for export-orientated production.

6. Competing Interests Statement

The authors have no competing interests to declare.

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