

1 **On the relationship between aquaculture and food**
2 **security: why does aquaculture contribute more in**
3 **some developing countries than it does in others?**

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20 **Abstract**

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

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33 **Keywords:** Aquaculture; developing countries; trade; food security; opportunities; constraints.

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38 1.0 Introduction

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

46 While production from capture fisheries has stagnated at around 90 million tonnes,
47 aquaculture, which did not exist as a commercial form of fish production until the early
48 1980s, has grown rapidly in many countries. The growth in aquaculture has meant that year
49 on year total fish output has increased. This impressive growth is attributed to a variety of
50 factors – but the main cause, as reported by De Silva ^[3], has been the transformation of
51 aquaculture from an “art” to a “science”. This led to the development of techniques to
52 optimise yields with lower inputs (e.g. reliance on wild stocks for feed inputs), gains in
53 efficiency and husbandry, (e.g. polyculture, vertical integration) government assistance (e.g.
54 institutions, policy, research and development) and the diffusion of best practice across
55 countries and continents. Increases in efficiency through innovation, economies of scale and
56 market-orientated production, has increased access to the large international markets – in
57 particular the big fish markets of the EU, the US and Japan.

58 This paper addresses the current role of aquaculture and its potential to deliver food
59 security in some case study countries spanning three continents – Africa, Asia and South
60 America. Specifically, the paper addresses the role of trade and markets on aquaculture
61 development in eight case study countries (Bangladesh, Brazil, China, India, Kenya,

62 Philippines, Vietnam and Zambia) that were reviewed as part of the European Union funded
63 Aquaculture for Food Security, Poverty Alleviation and Nutrition Project.

64 The next section presents an overview of aquaculture production in the developing
65 countries considered in this paper. Section 3 focusses on trade in fish products and whether
66 this represents a concern for achieving food security in developing countries, or is a positive
67 development for achieving food security. Section 4 considers policy implications, constraints
68 and opportunities for further development of aquaculture, and the role and impact of trade in
69 developing countries in contributing to food security objectives. Finally, section 5 concludes.

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71 **2.0 Aquaculture development and production in developing countries**

72 Total fish production reached an all-time high in 2018 at 179 million tonnes ^[4], with
73 almost 90% utilised for direct human consumption. Total aquaculture production in 2018,
74 amounted to around 82 million tonnes, accounting for 46.8 percent of total fish production ^[4].
75 While overall growth has slowed in recent years, significant double-digit growth has been
76 recorded in some countries, particularly in Asia – contributing to the increased value of
77 global exports that stood at USD 152 billion in 2016. By 2017, more than 50% of the value of
78 aquaculture exports originated from developing countries for the first time. Given the
79 stagnant output from the world’s capture fisheries, the role of aquaculture in contributing to
80 per capita fish consumption, which can be as high as 50kg in some countries e.g. the
81 Seychelles, continues to increase. Further, growth in aquaculture continues to outpace growth
82 in beef and pork combined - only poultry consumption is growing at a faster rate than fish
83 consumption ^[4].

84 **2.1 Production and trade in the AFSPAN case study countries**

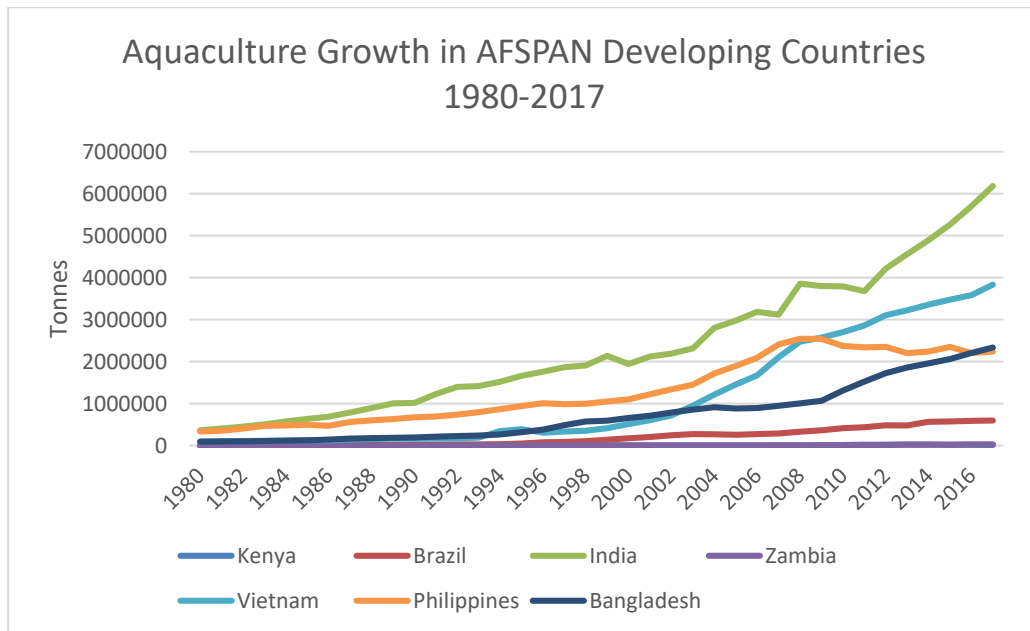
85 Growth and diversification in some developing countries has been particularly
86 impressive. However, this trend has not been seen in all countries. As shown in Figure 1
87 (which excludes China for reasons of scale), the case study countries that are discussed in this
88 paper highlight the disparate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

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95 Source: FAO Fishstat

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96 Figure 1 – Aquaculture growth in AFSPAN Developing Countries

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97 In Brazil, one of the world’s emerging economies, where some economic sectors are
 98 stalling, growth in aquaculture has been double-digit for some time. In comparison, total
 99 fisheries production has grown at just 1.7% per year during the same period. This has
 100 increased total production to 581,000 tonnes ^[5]. While the traditional production of Nile
 101 tilapia accounts for around 50% of production, farmers have diversified to higher value
 102 species, such as shrimp, in an attempt to enter lucrative export markets. However, as
 103 discussed later in the paper, there are several constraints to further developing the aquaculture
 104 sector in some developing countries for export markets, and in particular weak links in the
 105 supply chain, as problems such as disease, lack of market information, institutional support
 106 and trade barriers limit export potential. In Brazil, for example, exports declined sharply
 107 during the period 2003-2013 and this trade deficit is expected to grow ^[6].

108 India has also recorded impressive growth. Historically, production in India largely
 109 focussed on the main carp species, where export to the main fish consumption areas, such as

110 the EU, US and China is limited for various reasons e.g. lack of demand in the main export
111 markets. However, diversification to species suitable for export markets has led to sectoral
112 growth. In India, along with carp, prawn and shrimp are produced, with 65% and 90%
113 exported, respectively. In particular, processed products are exported to the main fish
114 consumption markets. The adoption of modern farming techniques coupled with institutional
115 change, have resulted in socioeconomic benefits (in terms of employment and foreign
116 exchange earnings), as well as improvements in food security and nutrition. Total aquaculture
117 production grew from around 1.9 million tonnes in 2000 to 5.7 million tonnes in 2016.
118 Exports of seafood has grown three fold during the period 2006-2016, currently standing at
119 over USD 5.5 billion ^[5].

120 Similar to other low-income African countries, fish consumption remains an
121 important source of protein in Zambia. However, domestic production is too low to meet
122 domestic demand and the species produced are largely not market orientated. Therefore, only
123 a small proportion of aquaculture products are exported to international markets. Aquaculture
124 accounts for only 13% of fish consumption in Zambia (mainly consisting of tilapia species),
125 yet over 50% of the population consume protein from fish. Further, the majority of fish
126 imported from China is tilapia - demonstrating there is domestic demand that could be met by
127 increased tilapia production in the country. However, most producers are small-scale or
128 subsistence farmers and lack the resources to increase production.

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

133 In the Philippines, total fish production has been increasing since the 1960s, reaching
134 5.16 million tonnes in 2010. Production from aquaculture peaked in 2010 at 2.6 million
135 tonnes, but has since declined to 2.2 million tonnes in 2016 ^[5]. The Philippines are a net
136 exporter, exporting over 75% of total seafood production, including high value species like
137 shrimp, tuna and grouper to the main fish consuming markets around the world. The
138 Philippines has a strong trade relationship with China, who account for over 50% of the
139 Philippines total seafood exports. However, since 2011 growth has slowed. The FAO ^[6]
140 predict that the share of the Philippines output in global trade will decline by 25% by 2030
141 and imports will increased by around 30% to satisfy increased domestic demand. This will
142 result from increased purchasing power as the Philippines economy continues to grow.

143 In Bangladesh, aquaculture has accounted for over 50% of total fish production since
144 2011. Production grew from less than 100,000 tonnes in 1980, to more than 2.2 million
145 tonnes by 2016, making Bangladesh the fifth biggest producer in Asia ^[5]. Fish production in
146 Bangladesh currently accounts for more than 50% of total protein intake. Growth in the
147 sector rose sharply since the mid-1990s, although growth has not been consistent, with some
148 periods recording only very low growth or actual declines. However, since the 1990s,
149 aquaculture has grown as an export orientated industry. This can be attributed to several
150 factors, but importantly because government have strongly supported aquaculture production
151 as a method of increasing exchange earnings. The production of shrimp has been strongly
152 supported for export to large markets like the EU – which more than trebled during the period
153 1995 to 2012. However, exports of shrimp remain vulnerable to regulatory barriers in export
154 markets. For example, bans on the import of Bangladeshi shrimp to the EU in the late 1990s
155 and early 2000s. Nevertheless, following the implementation of fully traceable robust
156 production methods, Bangladesh has achieved the List 1 country status for exporting fish
157 products to the EU - indicating that Bangladesh has policies and procedures fully harmonised

158 with the legislation and policies of EU countries – including safety standards that satisfy the
159 EU.

160 Some countries are far more export orientated than others. For example, in terms of
161 volume, Bangladesh is not a big player in global exports – but in terms of value, because
162 shrimp accounts for around 60% of exports, Bangladesh is one of the largest exporters in
163 terms of value. This suggests that aquaculture in Bangladesh has (or has the potential to)
164 contributed significantly to economic growth through exchange earnings, which in turn can
165 be interpreted as contributing to food security (as fish is a substitute product for alternative
166 and cheaper fish). It is estimated by the World Fish Centre that more than 3 million
167 Bangladeshis will have benefited from aquaculture growth through better income and
168 nutrition by 2022.

169 Vietnam has seen a vast expansion in the output of fish products. Both fisheries and
170 aquaculture have made important contributions to food security, poverty reduction and
171 increased livelihoods. Aquaculture production has grown from less than 100,000 tonnes in
172 1980 to more than 3.6 million tonnes in 2016. Similarly, to Bangladesh, Vietnam’s
173 aquaculture industry has grown strongly as an export orientated industry. By 2016, Vietnam
174 was the world’s third largest exporter (by value), with Pangas catfishes and shrimp
175 accounting for much of the export earnings of over USD 7.3 billion. The sector provides an
176 important source of food for the country’s population – it is estimated that seafood products
177 meet around 40% of total food production ^[6].

178 Coupled with strong economic growth in the last decade or so, increasing incomes
179 have increased import demand, especially of high value fish like salmon through increased
180 purchasing power. Vietnam is also a significant third country processor, importing raw fish
181 for processing and re-export ^[6]. Seafood production was included in economic restructuring

182 plans for the country, which involved converting resources used in inefficient agricultural
183 production (especially in coastal areas) to seafood production centres.

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

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193 **3.0 The role and impact of trade in fish in developing countries**

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

206 Nevertheless, trade flows, including the international trade continue to increase. In
207 2016, about 45% of the global seafood production was subject to international trade, and as
208 much as 78% of fish and seafood products are estimated to be exposed to international trade
209 competition ^[11]. The balance of exports and imports in developing countries is heavily in
210 favour of exports (in terms of value), with developing countries accounting 54% of exports in
211 terms of value and only 23% of imports. The converse is seen regarding volume ^[6].

212 However, while overall food output has increased in recent years, largely because of
213 increasing aquaculture output, the absolute number of undernourished people had increased
214 from 784 million in 2015 to 821 million in 2017 ^[12]. This raises issues regarding the impact
215 of the international trade in fish products. This may (in part) be linked with the fact that food
216 security in some countries has worsened at the same time as aquaculture has grown. For

217 example, in some countries this has been due to a change in policy focus to increasing
218 urbanisation to stimulate economic growth.

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

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

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

255 Consequently, the increase in regional trade has been growing quicker than the
256 international trade in fish products for some years. This may also be reflective of the
257 increasing price trend in fish products in the last decade or so. To further assist developing
258 countries to export fish products, the WTO's Trade Facilitation Agreement, implemented in
259 2017, is designed to reduce restrictive non-tariff barriers to trade – recognising that technical
260 regulations are non-discriminatory and in developing countries the high-cost and relatively
261 low capacity affect compliance (thus acting as a barrier to trade). The Trade Facilitation
262 Agreement encourages the cooperative development of international standards and
263 conformity assessment systems ^[6], which is beneficial for developing countries.

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

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282 **4.0 Constraints and opportunities to increase export orientated aquaculture in**
283 **developing countries**

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

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

- 294 • Production constraints
- 295 • Processing constraints
- 296 • Marketing constraints
- 297 • Institutional and Policy constraints

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

300 Production constraints are often the root cause of the lack of trade opportunities, both
301 regional and international ^[15]. Some of the most significant production constraints in
302 developing countries include lack of market information and understanding (e.g., producers
303 produce only what they can and are not influenced by markets). In countries where fish

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

322 In many developing countries, a significant barrier to export results from a lack of
323 processing facilities. Processing plants are not well developed and often processing is
324 undertaken on the farm. This type of processing does not meet the stringent food safety
325 criteria of export markets and Hazard Analysis and Critical Control Points (HACCP)
326 principles are not in place. Countries like Bangladesh, China, Vietnam and more recently
327 India, have understood the requirements for highly processed fish products in developed
328 markets and have implemented programmes to incentivise production to meet market

329 demands in international markets (including processing standards). In order to stimulate
330 exports and promote investment in export-oriented activities, the Government of Bangladesh
331 provide a number of fiscal and financial incentives, and has established institutions to
332 implement the incentive schemes and extend trade facilitation services. However, most of the
333 benefit of these schemes is directed to larger producers targeting lucrative export markets.
334 Concerning food security, focus on small-scale farmers producing species for
335 domestic/regional markets is needed. Further, it is estimated that processing facilities operate
336 at a fraction of their capacity due to a lack of fish to process. Those facilities approved by the
337 EU for processing and export are not available for small-scale producers, where production
338 systems do not meet stringent criteria (e.g. food safety, traceability and HACCP).

339 Since the 1990s, government support and institutional development in India has led to the
340 diversification from traditional carp species for export to regional markets, to prawn and
341 shrimp production for export to the EU, US and Japan. Similarly, growth in shrimp farming
342 in Vietnam has been strong in recent decades. However, as markets have become more
343 demanding of food safety standards, exports have become volatile, as standards were
344 perceived to have dropped. This has led to several examples of Vietnamese exports being
345 rejected in the main markets as farmers struggle to meet standards. In China, the main
346 constraint relating to slower growth in recent years has been non-technical barriers to trade in
347 the main markets, particularly the US.

348 Along with the technological advances that have been made over the last 30 years, which
349 has enabled the vast growth in aquaculture, institutional changes have also been required to
350 facilitate this growth. In countries that have grown by targeting export markets (e.g. China,
351 Vietnam, Bangladesh, India and the Philippines), governments and institutional arrangements
352 have strongly supported growth in aquaculture. In other words, aquaculture has strongly
353 featured in economic and food security development plans (the so-called pro-poor growth

354 plans). In other countries, including Kenya and Zambia, and to a lesser extent Brazil, this has
355 not been the case. Production remains small-scale characterised by a lack of knowledge and
356 facilities to increase production of species desired in international markets.

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

369 However, the type of production and scale, and the extent to which producers understand
370 market signals and demands also impact trade, particularly with respect to developed
371 markets. In developing countries, the supply chain is often underdeveloped and production is
372 largely centred on what can be produced, based on poor knowledge, lack of access to seed,
373 feed, equipment, technical expertise and so on. Therefore, a significant amount of what is
374 produced is often only suitable for sale in local markets and perhaps regionally. For example,
375 in Brazil, some species such as tambaqui, are only recognised in local markets, where as
376 other species such as tilapia and shrimp are recognised in much larger national/international
377 markets. Therefore, the latter are able to contribute to economic growth, although a
378 development strategy for aquaculture could enable resources to be better utilised to increase

379 economic development and income sharing in rural areas away from the big cities. To
380 improve the contribution of fish production to economic development objectives in
381 developing countries, one of which is to improve the equitable distribution of income,
382 requires focus on supply chain management and enhancement – otherwise access to
383 international markets is limited.

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397 **5.0 Conclusion**

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

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

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421 **Competing Interests Statement**

422 The authors have no competing interests to declare.

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