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Economic seafood industries issues in Sri Lanka:

Challenges for the sectors in developing countries due to institutions, environmental challenges in aquaculture and data poor fisheries

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Paper III:

Suthamathy Nadarajah and Arne Eide (2022). A simple method of evaluating the state of data-poor fisheries: Exemplified by major Indian Ocean fisheries. Manuscript.

Thesis Introduction

The seafood sector is one of the world's fastest growing industries, and Asia is the main producer. Seafood products are an important source of animal protein, vitamins, and minerals. A growing world population, increased trade, and more health awareness have led to increasing worldwide demand for seafood products. However, the growth and development of the seafood sector are constrained by some essential factors in some countries. This thesis addresses some of the challenges facing the seafood sector in Asia, with particular emphasis on my home country, Sri Lanka.

The thesis focuses on three specific challenges for the seafood industry: (1) the quality and capacity of national institutions; (2) the importance of environmental factors for aquaculture production; and (3) how to monitor and, hopefully, manage fisheries with few and uncertain observations (data-poor fisheries). Each challenge has been studied empirically using proper methodologies and presented in individual papers.

The first section of this introductory part presents the thesis background, followed by a brief description of Asian seafood production. In this section, the institutional perspectives of and environmental challenges for aquaculture production in Asia are discussed by combining the main research findings from Paper 1 and Paper 2. A brief presentation about the seafood sector in Sri Lanka is given in Section 3, which reviews the impact of the historical event on the development of marine and aquaculture sectors in the country. Section 4 presents the management practices being implemented in the seafood sector in Sri Lanka, and discusses the further need to improve working management systems.

The scientific contributions provided by the thesis, before some concluding remarks, are summed up in a section.

1. Thesis Background

The seafood sector provides food supply, food security, poverty alleviation, and income generation and is significant in Asia and in many developing nations. Millions of people in Asia depend on fisheries or aquaculture production for their livelihood, either directly or indirectly (Jentoft & Eide, 2011). It is estimated that in 2018 nearly 85 per cent of the global population engaged in fisheries and aquaculture was found in Asia (Anon., 2020). The global fish production was around 179 million tons in 2018, valued at 401 billion US dollars. About half the quantity came from the aquaculture sector and was valued at 250 billion US dollar. Nearly 90% of total global fish food has been used for human consumption, and the world's per capita fish consumption was 20.5 kg in 2018.

The global aquaculture sector is most important as a source of seafood for human consumption. Moreover, it is a means by which to satisfy future demand for seafood products for the growing population. It is expected the world's population will be around 9 billion in 2050. Although global aquaculture production is increasing gradually, the overall production growth rate has decreased in recent years. The average annual growth rate of global farmed aquatic animals (including finfish, crustaceans, molluscs, and other aquatic animals) was 5.8% from 2001 to 2010 and 4.5% from 2011 to 2018. The growth rate of the global production of aquatic plants has also declined recently, by 0.7% in 2018 (Anon., 2020). The global capture fisheries have been gradually stagnating since 1990.

The Asian region dominates the total global food fish production. In 2018, the total Asian capture production was around 50 million tons, while the farmed fish production in Asia was about 72.8 million tons (Anon., 2020). Farmed fish production in Asia constituted about 90% of the total global farmed food fish production. Given the significant contribution by the Asian aquaculture and fisheries sectors to the global supply of seafood, sustainable development of the Asian seafood sector is essential and needs to be taken into consideration.

Seafood production involves sets of different factors and depends on the interaction between these factors. Climatic conditions, available technology, seafood markets, management strategies, and national and international institutions are all essential factors of seafood production. Some of these factors may appear as internationally traded commodities (e.g. technology), while other factors are naturally given or determined by available natural resources and the level of economic development in a country. Differences in these factors could be the reasons for the uneven annual growth rate of the seafood sector among countries as well as regions. A continuous and sustainable development of the seafood sector in every country is essential to meet the seafood demand in the country as well as globally.

This thesis focuses on the importance of some of these factors. The first factor studied is the role of institutions in aquaculture production (Paper 1). This was studied by analysing the relationship between the annual growth rate in aquaculture production of the major aquaculture producing countries and the quality of institutions in those countries over the last three decades (1984–2013) using econometric models. The second factor studied is the environmental challenges, i.e. how a changing climate may affect aquaculture production in the Asian region (Paper 2). The study analyses the vulnerability and resilience of fresh and brackish water aquacultures, mainly carp, tilapia, catfish, gourami, shrimp, crayfish, and crab production in major Asian producing countries. The third factor is related to fisheries and the lack of information about their stock status of fisheries. How can crucial information be obtained from data-poor fisheries (Paper 3) from a management perspective? The stock status of major Indian ocean fisheries has been evaluated using a proposed simple stock assessment method.

The main findings of the three papers are to be used to discuss the growth and development of Asian seafood production and Sri Lankan seafood industry from a future perspective.

2. Asian Seafood Production

Asia dominates the global seafood industry, producing a total of 123 million tons of food fish (including capture fisheries and farmed fish), almost 70% of the global fish production in 2018 (Anon., 2020). The development in capture fisheries, inland fisheries, and aquaculture sectors in Asia, particularly after the 1980s, has led to a dramatic growth in production. Four Asian countries (China, Indonesia, India, and Viet Nam) are among the top seven largest producers in the global capture fisheries. These fisheries are characterized by multi-gear, multi-species, and open access to the fish stock resources. Asia has the largest fishing fleet, estimated to be around 3.1 million vessels in 2018, 68% of the global fleet (Anon., 2020). However, fisheries in the region have not been strictly managed in many countries, while fishing activities are monitored to some extent.

Fish farming has been an integral part of Asian agriculture since ancient times, although aquaculture has experienced a tremendous growth in Asian countries after the 1970s (De Silva & Davy, 2010). The rapid expansion has been driven in particular by technological development and new market opportunities (Dey et al., 2005; Kumar & Engle, 2016). Of 51 countries in the Asian region, 47 countries are practising aquaculture (Anon., 2017). China, India, Viet Nam, Indonesia, Bangladesh, Thailand, Myanmar, the Philippines, Japan, and the Republic of Korea are the ten biggest aquaculture producers within the region. China is by far the largest aquaculture producer in the world.

The Asian aquaculture sector is very diverse, including a vast range of fresh, brackish, and marine water aquaculture species, different production systems, small to large scale, and extensive to intensive methods. However, freshwater aquaculture is dominant within the region. Natural water reservoirs, dams, and mangrove ecosystems are widely used for aquaculture.

More than 100 different species are cultivated within the Asian region (Anon., 2017). This includes finfishes, molluscs, crustaceans, and other aquatic invertebrates. By volume, finfish species, mainly carp, tilapia, and pangasius, dominate the total Asian farmed fish production. In 2018, finfish production from inland aquaculture was about 48 million tons, or 66 per cent of the total Asian farmed fish production. Next to finfish, the production of crustacean species is the largest in terms of quantity. In terms of value, however, shrimp is the most important aquaculture product produced in Asia, traded internationally.

In the early history of aquaculture development, extensive and semi-intensive methods of farming were carried out by conventional techniques. As technology has developed, farming systems have gradually been modified in many countries into intensive industries. Both mono- and polyculture production systems are widely used (Dey et al., 2005). In Asia, integrated fish farming systems have also been practising successfully (De Silva & Davy, 2010). Examples of the integrated farming systems are gher (prawn-fish-rice) farming in Bangladesh and rice-fish farming in China and the Philippines (Rahman et al., 2011; Wang et al., 2014). Up to now, there has been a considerable amount of small-scale subsistence farming in many Asian countries, representing the main source of livelihood. The majority of commercial aquaculture farms in the largest aquaculture countries are, however, operating on either a medium or large scale, mainly targeting international markets.

Although statistics on total Asian aquaculture production show that the sector has grown tremendously, aquaculture production in some Asian countries, notably Japan, the Republic of Korea, and Thailand, has fallen in recent years. Disease outbreaks, unexpected natural disasters, poor management, poor institutional qualities, and market failures are often identified as reasons for the declines in production and value (Anon, 2013; Anon, 2014). Furthermore, in some countries, including Sri Lanka, Bangladesh, and Pakistan, the sector is still an infant industry, requiring financial and technical support for development. Growing global seafood demand creates new markets for Asian producers. Hence, the Asian aquaculture sector is not only important for the producers but for the global supply of seafood products.

2.1 ***The Institutional Perspective***

Institutions are key components in the overall management of natural resource industries, guiding the people involved in production and marketing. Institutions include governmental policy, laws, rules and regulatory measures, planning, programmes (training, extension services, and financial assistance), and controls.

In the case of aquaculture, policies, rules, and regulations for aquaculture production are generally formulated by the respective governing authorities in a country, such as the Ministry of Fisheries and Aquatic Resources or the Ministry of Agriculture and its respective departments and directorates. International organizations, including the Food and Agriculture Organization (FAO), Global Aquaculture Alliance, and the Aquaculture Stewardship Council (ASC), are providing several services and guidance for aquaculture production without interfering environments. Aquaculture producers are informed to follow the formulated regulations. The government authorities in each country monitor farming activities.

The first paper investigates the role of institutions in aquaculture growth and development. The annual growth rate in production has a weak, negative correlation with all indices governance (WGI), corruption (CPI), and competitiveness (GCI) used as institutional quality proxies. The results of the study suggest that the annual growth rate in aquaculture production has not been significantly influenced by the quality of institutions (WGI and CPI). However, it is shown to be statistically significant (at 10% level) that when the competitiveness of countries (GCI) increases, the quantity of aquaculture production decreases.

These results contrast the findings in resource curse literature, which shows that high-quality institutions positively affect economic growth. The effect of institutions in marine resource-based industries' performance is different from that of other natural resource industries. In the case of the aquaculture sector, effective institutions limit the quantity of production (Paper 1). However, having effective institutions would be helpful in managing the sector properly in the long run and help to minimize negative externalities caused by the production.

Scores of selected good governance indicators show that many countries in Asia (China, India, Indonesia, Viet Nam, Bangladesh, Thailand, and the Philippines), listed among the top ten aquaculture producers, had poor-quality institutions. Statistical analysis suggests that the annual growth rate in aquaculture production in terms of value is negatively affected by the corruption level in the Asian region (Paper 1). Although Asian countries perform well in aquaculture production, the sustainability and adaption of standard procedures are still not adequate compared to the aquaculture countries in the European region.

National and international institutions may have a positive indirect effect on the growth and development of the aquaculture sector. Therefore, it would be beneficial to improve the quality of national institutions and develop international cooperation. Major aquaculture-producing countries in the Asian region, particularly emerging producers like Sri Lanka, need to give priority to amending the existing policies, regulations, and laws and develop new mechanisms for the effective implementation of management policies in aquaculture production.

2.2 The Resilience of Asian Aquaculture Production to Climate Change Consequences

Environmental challenges are often noted as one of the reasons for the fluctuation in aquaculture production and are also expected to threaten production in the future. Climatic factors, such as ambient temperature, amount of precipitation, solar radiation, water salinity, amount of nutrients, and oxygen, all have an effect on the growth and reproduction of living organisms. An increase in annual mean temperatures, changes in precipitation rates, ocean acidification, sea-level rise, and increased occurrence of extreme weather events (flooding, drought, and storms) are widely identified as features of climate change. Observed and predicted impacts of climate change on atmospheric conditions, ocean, and terrestrial resources suggest that the agriculture, fishery, and aquaculture sectors are likely to be affected by climate change (Porter et al., 2014). In the case of the aquaculture sector, the expectation is that climate change may constrain aquaculture production either directly or indirectly, by affecting factors of importance for production, such as water temperature, pH, salinity and oxygen content, farming areas, water, and feed availability, and market factors (De Silva & Soto, 2009). The impact climate change may have on the aquaculture sector is expected to vary between geographical regions.

The Asian aquaculture sector is a very diverse sector in terms of species, farming systems, farming environments, and intensity of practice. Different aquaculture species and farming systems will have different degrees of resilience to environmental challenges. Knowing the Asian aquaculture sector's capacity to produce seafood products good quantity, environmental challenges must be considered by the Asian producers during farming activities, such as the selection of species, farming environments, techniques, methods, and scale of operation. Paper 2 studies the adapting capacity and resilience of selected aquaculture species and farming systems, practising in the selected Asian countries, to the expected climate change consequences. The findings of this paper have values for better farming practices from a management perspective.

The findings of Paper 2 indicated that the fresh and brackish aquaculture sectors in the major Asian aquaculture-producing countries are greatly diversified in terms of species, farming techniques, and farming methods. China has the largest diversity of species and values, followed by Bangladesh, Indonesia and Viet Nam. Diversity index analysis shows that farming has become diversified over the period in terms of species. None of the countries depended solely on one species.

It seems not all the consequences will affect aquaculture production. The vulnerability assessment indicates that there is the potential to adapt to possible temperature increases in most of the aquaculture industry involving carp, tilapia, catfish, and shrimp species. Seawater intrusion during coastal flooding could negatively impact freshwater aquaculture production. Aquaculture activities often collapse due to coastal flooding and salinization of water that occur during the monsoon rainy season in Asian countries, including India, Bangladesh, Viet Nam and Sri Lanka. Therefore, these countries must take care when farming in coastal regions. Results suggest freshwater fish farming in coastal areas may be affected more severely than brackish water aquaculture because freshwater species are unable to tolerate high saline levels. If crustacean aquaculture species are cultured in coastal areas, these species would survive even in saline conditions. It is advisable to move freshwater aquaculture in high land areas with proper conditions. In the intensive farming techniques, the use of fishmeal is comparatively high, particularly in shrimp farming. In order to cope with the shortage in fishmeal, should it occur, other supplementary protein sources must be used for ration formulation. In some countries, soybean meal has been used for ration formation.

Among the four main species cultured in Asia, shrimp aquaculture is more resilient than carp, tilapia, and catfish, to climate change consequences such as warmer temperatures, seawater intrusion, and fishmeal shortage. Other species, such as gourami, crab, and crayfish are also less resilient. Carp is the dominant species in China, Bangladesh, India, Myanmar, and Sri Lanka. In comparison, shrimp is the dominant species in the Philippines, Thailand, Indonesia, and Viet Nam. Based on the dominant species in a country, species vulnerability to climate change, and the economic importance of the sector, the aquaculture industry in Viet Nam, Bangladesh, Myanmar, and China may be said to be more vulnerable to changes than in the Philippines, Thailand. However, the countries noted earlier (excluding Myanmar and together with Indonesia) have broadly diversified farming in terms of species. This feature would enable the aquaculture sector to adapt to climate change. In general, aquaculture production in Asia could scope the environmental challenges by selecting species based on region, and making proper modifications of farming systems, technology, and infrastructure facilities in the future.

3. The Seafood Sector in Sri Lanka

Sri Lanka is an island located in the Indian Ocean and rich in marine resources. Fishing has been the livelihood of coastal communities in Sri Lanka since ancient times, and marine fishing has gradually developed into an income-generating industry. The aquaculture industry is a new and emerging industry in Sri Lanka. The Exclusive Economic Zone (EEZ) of Sri Lanka is 517,000 km^2 large, and the sum of brackish water lagoons and estuaries cover a water area of 1580 million km^2 (Anon., 2019). These resources provide great opportunities to develop the seafood sector, particularly the aquaculture sector in the country. More than ten per cent of the Sri Lankan population depend on the seafood sector, either directly or indirectly, while the sector's contribution to the Sri Lankan gross domestic product (GDP) was only 1.4% in 2018. However, the sector provides about 70% of the population's total animal protein requirement (Anon., 2019).

The Sri Lankan seafood sector includes coastal fisheries, the high seas, and inland fisheries and aquaculture. The fisheries sector has been facing difficulties due to civil wars and natural disasters over the last decades. Nevertheless, Figure 1 shows that the Sri Lankan marine fish production has grown steadily and the total catch in 2018 was close to half a million tons, about 43% from high sea fisheries (Anon., 2019). Technological developments, subsidy programmes, improved infrastructure facilities, and foreign market opportunities, are important factors explaining this development (Amarasinghe, 2001; Kariyawasam et al., 2010).

Figure 1 highlights two historical events that affected the growth and development of Sri Lankan fisheries during the period 1950 to 2015. Fisheries activities, particularly in the north and eastern part of the island, were considerably affected by the three-decade-long civil war (1983–2009), and fish production showed slightly fluctuating patterns during this period. However, government organizations could not monitor and manage fisheries activities properly during this period, including the registration of fishing fleets, monitoring of fishing gear usage, collection of statistics on production, allocation of subsidies, etc. Fishers had also faced several problems because they could not get a high enough price for their products because of limited market facilities. Nevertheless, also during this period the growth of the capture fishery was substantial.

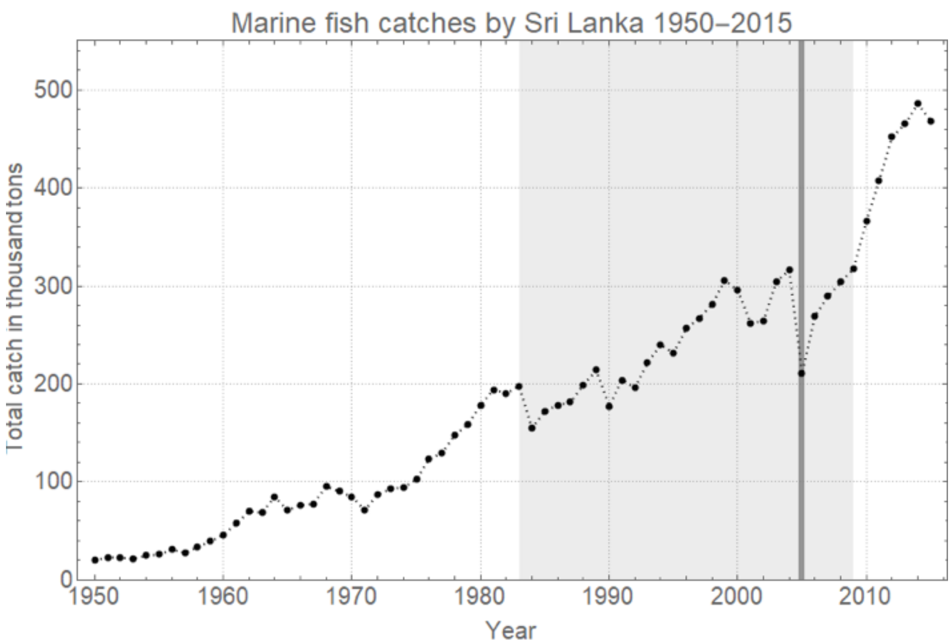

Figure 1: Capture production in Sri Lanka during the period 1950 to 2015. The shaded area indicates the period of civil war. The thick vertical line indicates the year 2006 in which the fisheries were largely affected by the 2004 Indian Ocean tsunami.

In 2010, the Sri Lankan government also took a number of initiatives to develop the sector. The 2004 Indian Ocean tsunami severely affected coastal fisheries and the disaster caused the largest drop in catch production during the period (the drop is indicated by the vertical line in Figure 1). However, since 2006, fisheries production has increased tremendously. It is important to note that this natural disaster also affected the north, east and western regions of the island. Both these historical events caused considerable changes in the number and composition of the fishing fleet operating in Sri Lankan waters and the number of fishers involved in the industry.

One issue that has been given some international attention is the recent increase in the number of vessels employed in Sri Lankan fisheries. The number of registered vessels and active fishers operating in Sri Lankan waters has increased steadily over the past decades (Table 1). However, a significant increase in the fleet size was seen shortly after the Indian Ocean tsunami disaster in December 2004 (Anon., 2007a) and further enhanced after the end of the civil war in 2009 (Table 1). The increase related to the tsunami may be surprising since 16,101 coastal fishing vessels were reported as destroyed and 7,105 damaged in the disaster (Anon., 2007b; Dissanayake & Sigurdsson, 2005). However, the dramatic increase in vessels due to international support after the tsunami more than compensated the losses and the fishing fleet increased beyond previously reported levels. A fishing boat census with the support from the FAO and the Icelandic International Development Agency (ICEIDA) was conducted in 2006, covering 12 fishery districts of Sri Lanka. According to the census, already two years after the tsunami the numbers of fishing boats in many fisheries districts were considerably higher than before the tsunami (Anon., 2007b; Kariyawasam et al., 2010; Premawardana, 2010).

Table 1 presents the number of vessels within different fishing fleets in Sri Lanka during the period 1972–2018. Inboard engine multiday boats (IMULs) were introduced in the late 1980s, whereafter offshore fisheries started to contribute notably to the total marine production. As can be seen in Table 1, the numbers of IMULs and outboard engine fibreglass reinforced plastic boats (OFRPs) increased significantly during the period. The number of IMULs decreased during the 1990s and this fleet experienced a steep increase after the tsunami in 2006. The increase of vessels in the OFRP fleet has been steady since the start of the millennium, but primarily after the end of the civil war in 2010. The provision of fishing fleets and credit facilities by national and international agencies to fishers as aids to rebuilding coastal community livelihood played an important role in increasing the capacity of the fishing fleet. Many fishers using traditional vessels got OFRP boats, which caused a decline in the number of non-motorized (NMT_Bs) and motorized boats (MTBs). Another important reason for the changes in the official vessel statistics is the fact that most fishers have become aware of benefits linked to having a registered fishing boat. Registered boats receive subsidies or compensation for damages to vessels and fishing gears. The processes of organized registration also have improved and more effort has been made to make fishers aware of this in order to improve national statistics. Recent statistics show nearly 50,000 registered fishers between 2005 and 2010. Improved registration procedures in addition to an actual increase in the number of boats might be the reason of the sudden change in the number of active fishers.

The time series shows that the number of inboard engine multiday boats (IMULs) is increasing greatly compared to inboard engine single dayboats (IDAYs), and that the number of non-motorized boats (NMT_Bs) is decreasing over the same period. This reveals that the fleet technically has been improved over the period. However, it is questionable whether the catch per unit of effort (CPUE) has increased or decreased as a consequence of this change. Another question is the profitability of the fisheries. As seen from t Table 1, the fishing effort employed in fishing has been increasing and the unit cost of production might have increased over the period, which would affect the profit generated by the fisheries.

Other constraints limiting growth and development of the fisheries economy are illegal fishing activities by neighbouring countries, poor knowledge about the state of the biological resources, lack of detailed statistical data on fishery production, lack of post-harvest processing industry, and marketing. These limitations must be overcome in order to achieve a sustainable usage of marine resources.

As in several other nations in the Asian region, also Sri Lankan marine fisheries require upgrading the existing management measures to ensure sustainable utilization of marine resources. Poor knowledge about the state of the biological resources, lack of detailed statistical data on fishing fleets and gears, open access nature of fisheries, multiple species, diversified fishing activities, all together constraints the fisheries governing organization to manage the fisheries especially control fishing fleets number. It can be seen in the Table 1 the number of fishing fleets increases continuously. Further, political parties governing country also influences the fisheries governing organization activities because time to time political parties change policies setup.

Table 1: Number of operating fishing boats by type in Sri Lankan water and number of fishers involved in fishing during the period 1972 to 2018. IMUL is an abbreviation for *Inboard Multi-day Boats*, IDAY: *Inboard Single-day Boats*, OFRP: *Out-board engine Fiberglass Reinforced Plastic Boats*, MTB: *Motorized Traditional Boats*, and NMT_BS: *Non-motorized Traditional Boats*.

Year	Type of operating fishing boats					Number of fishers
	IMUL	IDAY	OFRP	MTB	NMT_BS	
1972	874	1019	874	2344	14453	58514
⋮	⋮	⋮	⋮	⋮	⋮	⋮
1990	2364	·	9758	973	14580	·
⋮	⋮	⋮	⋮	⋮	⋮	⋮
1995	1639	1357	8564	1060	14649	83776
1996	1130	1543	8334	978	15525	118776
⋮	⋮	⋮	⋮	⋮	⋮	⋮
2000	1430	1170	8690	1205	15100	·
2001	1572	993	8744	640	15200	115014
2002	1614	1112	9033	776	15600	142300
2003	1530	1486	11020	618	15040	148830
2004	1581	1493	11559	674	15260	151800
2005	1328	1164	11010	1660	14739	160300
2006	2394	907	13860	1842	16347	143150
2007	2460	1060	15200	1680	16640	158650
2008	2809	1940	15847	2959	17042	162470
2009	2934	958	17193	2126	18243	171470
2010	3346	1177	18770	2680	20165	212920
2011	3872	1120	22890	2960	22630	215430
2012	4080	890	23160	2340	22800	218550
2013	4111	802	23134	2514	21739	219400
2014	4447	876	23982	2720	21963	221350
2015	4218	719	24028	1872	19501	221560
2016	3996	986	24282	1839	19766	218830
2017	4196	868	22394	2185	17247	220870
2018	4581	918	24132	2201	18754	218130

Sources: Anon., 2007a; Anon., 2015; Anon., 2016a; Anon., 2016b; Premawardana, 2010; Wijayaratne & Gudmundsson, 2001; Wijayaratne and Maldeniya, 2003

Aquaculture is a new branch of the seafood industry in Sri Lanka, and coastal aquaculture was started in Sri Lanka in early 1980. The contribution from the inland and aquaculture sector in terms of total fish production is currently rather small – about 88,000 tons in 2018 (Anon., 2019). However, economically the sector's contribution is comparatively higher, particularly by the shrimp industry.

Since the 1980s shrimp farming has been practised in the western part of Sri Lanka, and after the end of the civil war in 2009 it expanded to the eastern part of the island. Carp farming was recently introduced in Sri Lanka and now many carp species are cultured on a small scale. The tilapia production has bloomed by the stocking of artificially bred fingerlings in water reservoirs. The aquaculture sector has gradually diversified in Sri Lanka in terms of species over the period (Paper 2). Both carp and tilapia are farmed in reservoirs using culture-based farming techniques, while shrimp are cultured mostly in ponds using intensive or semi-intensive farming techniques. Sri Lanka has receiving significant amounts of foreign exchange through shrimp exporting. Both carp and tilapia production have been consumed domestically and these farming are carried out as subsistence livelihood activities. Although fish farming in Sri Lanka is growing, the diversification in terms of farming methods, and techniques is still low.

The National Aquatic Resources Research and Development Agency (NARA) and the National Aquaculture Development Authority (NAQDA) of Sri Lanka are undertaking programmes and research projects to develop and improve inland fisheries and aquaculture production. For example, they have been producing fingerlings and prawn post-larvae and stocking in major reservoirs annually for many years. In 2018, NAQDA released nearly 110 million fingerlings into different water bodies in Sri Lanka (Anon., 2019).

The aquaculture sector has been facing many challenges, including disease outbreak, a lack of financial support, lack of technology, inadequate infrastructure facilities, civil war, and adverse climatic events etc. (Drengstig, 2020). Shrimp aquaculture was badly affected by a virus disease outbreak that occurred in 1990 due to the epizootic viral diseases *monodon* baculovirus (MBv) and white spot syndrome virus (WSSv), and consequently in 1998 due to yellow-head disease (YHD). This last condition occurred due to a “self-pollution effect” i.e., the industry was affected due to unhygienic practices. These disease incidents led to heavy losses for the industry. Meanwhile, other issues – such as the usage of medicine in production, the destruction of mangrove forests for farm construction, the improper methods of waste disposal – created a number of socio-economic problems that also had a negative impact on industrial growth; production drastically declined and farming areas were narrowed down between 1998 and 2004. During that period, shrimp production fluctuated and thereafter fish farming has developed gradually from the year 2005 onward. Civil war (1980–2009) also had an unfavorable effect on aquaculture expansion: shrimp production was begun on the eastern coast of Sri Lanka in the early 1980s but was abandoned due to the civil war. Presently, the aquaculture sector is moving with the aim of sustainable development.

The sustainable development concept includes social, economic, and environmental aspects. Producing seafoods without interfering with the ecosystems’ balance is important to ensure environmental aspects are fulfilled for sustainable development. Producers in Sri Lanka failed to consider the ecosystems’ balance and the social welfare of communities living in farming areas during the early stages of aquaculture production and instead they targeted the economic benefits from that industry. The outcome of manner was visible in the case of the shrimp industry.

All the above noted incidents (excluding adverse climatic events) are related to national institutions, which indicated that the country had very weak national institutions during the early stages of aquaculture production that led to an impact on the growth and development of the aquaculture sector. Paper 1 includes Sri Lanka; the score for good governance indicators (WGI, CPI, GCI) also shows that the country still has poor-quality governance. The findings also suggested that corruption levels in Asian countries had a negative impact on the annual growth rate in aquaculture production value (Paper 1). Therefore, it is clear that Sri Lankan national institutions need to be further upgraded to avoid the previous incidents that hampered aquaculture production and to develop the aquaculture sector in a sustainable manner.

Adverse climatic events, including cyclones, heavy monsoon rains, coastal flooding, droughts, and erosion, that occur in the country often affect aquaculture production more. Shrimp culture is more dominant in the country in terms of value, the species being more resilient against warming and seawater intrusion (Paper 2), thus shrimp farming could adopt change to some extent if all other management practices are carried out in a proper manner. Carp and tilapia are freshwater species cultured in the country using a culture-based system and extensive techniques. These species are vulnerable to warming and seawater intrusion (Paper 2); care must be taken to reduce salinization due to seawater intrusion if there are cultured species in the coastal area of the country. Intensive techniques may help to control changes in ambient temperature. Since the aquaculture industry in Sri Lanka is more vulnerable to climate change (Paper 2), the producers in the country need to modify the existing farming methods and select suitable species and farming environments to cope with environmental challenges.

4. Fisheries Management in Sri Lanka

Marine fisheries in Sri Lanka are open access, multispecies and multi-gear fisheries. Since 1940, the Department of Fisheries has undertaken fisheries management and administration. In 1991, the Department of Fisheries was redesigned and renamed the Department of Fisheries and Aquatic Resources (DFAR), with a separate division for fisheries management. At present, DFAR is under the Ministry of Fisheries and Aquatic Resources Development (MFAR), managing the fishing activities. The expressed objective is to provide an optimum contribution to the national economy and strength the socio-economic status of the fisher communities. Fisheries and aquatic resources also need to be maintained in a sustainable manner and this vision is expected to be achieved through proper management. The management will be adopting new technologies and be in compliance with national and international laws and treaties, providing a productive contribution to the Sri Lankan economy through sustainable development of the fishing industry. Six institutions are functioning to implement the policies formulated by the ministry of fisheries and aquatic resources development towards sustainable utilization of fisheries and aquatic resources.

Fisheries management measures include issuing entry licences that have to be renewed annually, monitoring vessels, which is carried out by a vessel monitoring system (VMS) unit as well as by a monitoring, controlling and surveillance unit (MCS) in particular on the high sea. Usage of fishing gear is also monitored and limited by the authority – in particular some fishing gear that could cause resource overexploitation are banned by the authority from being used in coastal fisheries. There is no other strict control of inputs to or outputs from the fisheries. The well-known fisheries output control measures are total allowable catch (TAC), individual transferable quotas (ITQs) or non-transferable quotas, which are still not introduced in Sri Lankan fisheries. Since Sri Lanka is a developing country, poverty and unemployment are big issues in the country whereby the government provides subsidies to fisheries rather than implementing a strict control system.

Year by year, the government has decided acts and rules in order to respond to the recommendations suggested by international organizations – i.e. The Indian OceanTuna Commission, the European Union (EU), Food and Agriculture Organization (FAO). The Fisheries and Aquatic Resources Act, No. 2 of 1996, was the principal legislation governing the fishing industry of Sri Lanka, which was amended several times: Acts No. 4 of 2000, 4 of 2004, 22 of 2006, 35 of 2013, 2 of 2015, 2 of 2016 and 11 of 2017. At present the Act No. 11 of 2017 is used for fisheries management. Nevertheless, the effectiveness of these acts and rules are doubtful. Recently, the Ministry of Fisheries and Aquatic Resources Development, in association with the departments and consultation from the Fisheries and Aquaculture Department of the Norwegian Ministry of Trade, Industry and Fisheries, has formulated a new National Fisheries and Aquaculture Policy to ensure sustainability of the fisheries and aquaculture industry (Anon., 2018).

Due to Illegal, Unreported and Unregulated (IUU) fishing activities in Sri Lanka, the European Union (EU) banned Sri Lanka from importing seafood to the EU in 2014 October. Sri Lanka had also failed to comply with the Indian Ocean Tuna Commission and other international management and conservation agreement. Several measures, including the strengthening of existing MCS systems were taken by the Sri Lankan government to solve these issues and the EU removed the ban in May 2016. These incidents prove that overall fisheries management and enforcement were lacking in the country, particularly with regard to the implementation of regulations and control systems.

For a proper fisheries management system, it is essential to know about the status of the exploited stocks. Stock assessment analysis provides knowledge on how much of the fisheries resource has been utilized and the available amount for future utilization. Stock assessment analysis often requires detailed information about the fisheries. Most of the fisheries in the Asian region are data-poor fisheries, including Sri Lanka, where fisheries statistics are often recorded either in an aggregate or grouped manner. Respective organizations fail to document fisheries information due to lack of facilities or because of financial issues. In this situation, it would be a better option to develop a simple method to assess the stock using available information on fisheries. In Paper 3, the state of Indian Ocean fisheries was evaluated using the proposed simple stock assessment method. This simple method enables us to find out the stock status of a fishery even when limited formation about the fisheries is available. Results reveal that only some species are in a healthy condition, while most of the species – particularly economically important species – are closer to being in a critical condition therefore have to be managed either through input control measures or output control measures in order to achieve the sustainable use of marine fisheries. Since Sri Lanka is fishing in the Indian Ocean and the region is shared by many developing nations, proper cooperation among the nations is essential.

Contributions of the Thesis

This thesis highlights three areas of concern for Asian seafood production, with special reference to the Sri Lankan challenges. These challenges also constitute the topics of the three papers included in this thesis, each of them focusing one specific challenge of high importance for the further development of Asian seafood industry in the future.

The first challenge is to build and maintain governance institutions and routines that make it possible to monitor and control activities in fishing and fish farming; to accommodate an environment where products are fairly traded internationally and domestically; and to cope with unexpected shocks, both in nature and markets, in a rational and competent manner. Institutions are a qualitative factor indirectly influencing the growth and development of natural resource industries; here, in this thesis, their role was evaluated quantitatively.

The second challenge focuses on the capacity of the growing aquaculture production to cope with environmental fluctuations and shocks that may be caused by climate and other environmental reasons, or changing market conditions and competition. The collection of information, including species, biological details, farming systems, methods used, provides a brief literature review about Asian aquaculture sector in one picture. The study finds out which species are more vulnerable to the consequences of climate change and which species could adopt changes if they occur. Furthermore, the paper suggests strategies and policy recommendations on how to cope with climate change consequences and trying to predict what would be happen in seafood markets.

The last challenge focuses on the capture fisheries and the lack of exact knowledge regarding the current and future resource base of this activity. Fisheries in developing countries are often referred to as "data-poor fisheries" because of the lack of biological data necessary for performing state-of-the-art stock assessment procedures. This problem is partly linked to the fact that most developing countries' fisheries are multispecies fisheries that need to be assessed by methods that are still poorly developed. However, many of the most important fisheries in Asia are single-species fisheries that, in principle, could employ advanced stock assessment techniques, but where crucial information is missing. The obvious solution is to wait for this information to appear. Another, and more realistic solution, is to develop methods to make the best out of existing data. In practice, such information is simple, aggregated annual catch records. The study proposed a simple method with which to evaluate stock status where fisheries information is limited.

Conclusion

The different topics of the thesis reflect that seafood economics is a multifaceted subject that demands a multidisciplinary approach including different methodologies. Overall, this thesis indicated that the seafood sector in developing countries in Asia can continue to contribute to the global seafood supply when the challenges are overcome by adopting proper strategies. Although we found that institutions play a minor role in growth and development of aquaculture, better rules and regulation measures have to be undertaken if aquaculture systems are to be modified to scope environmental challenges or when countries decide to use sophisticated technologies in fish farming. Further, appropriate controlling strategies are essential to overcome the externalities created by aquaculture production in the long run. Existing management procedures for marine fisheries in developing nations should be improved in order to avoid overexploitation of fish stock.

In the case of the Sri Lankan seafood sector, all the stakeholders – including the commercial fisherman, the artisanal fisherman, aquaculture producers, authorities and local organizations – involved in fisheries need to be worked together to achieve the noted objectives by the fisheries ministry. Rules, regulations, laws, and policies need to be amended and activities have to be carefully monitored by respective authorities to ensure they are followed by the stakeholders. Since most of the fisheries stock are overfished and overfishing in the Indian Ocean, the Sri Lankan government has to focus on marine fisheries to control the amount of effort (fishing fleets) employed in the Sri Lankan EEZ area, rather than providing subsidies to fishermen to develop the marine sector. Furthermore, the government has to work on leading negotiations and agreements to solve the problem of illegal fishing by neighbour countries.

Sri Lanka is an emerging aquaculture producer; the perceived quality of its seafood products is very important for exporters to the global seafood market. Aquaculture producers must follow all the standard procedures recommended by the respective authorities to avoid externalities and to produce safe seafood products. The aquaculture industry in Sri Lanka is expected to be vulnerable to climate change and the producers need to modify the existing farming methods, selecting suitable species and farming environments to cope with the environmental challenges.

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PART II PAPERS

Paper I

Suthamathy Nadarajah and Ola Flaaten (2017). Global aquaculture growth and institutional quality. *Marine Policy*, *84*, 142–151.

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Global aquaculture growth and institutional quality

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ABSTRACT

The global aquaculture sector has grown continuously over the past 40 years, though unevenly among countries. Differences in factors such as inputs, climate, management, technology, markets, social environment, and institutions might be reasons for the disparities in growth. This study focuses on institutions, by analyzing the relationship between annual growth in the production of the major aquaculture countries and the quality of their institutions over three decades (1984–2013). Based on an ex-ante set of criteria, seventy-four aquaculture countries from five different regions - Africa, the Americas, Asia, Europe and Oceania - were selected. Annual percentage change in total aquaculture production, in terms of quantity and value, was used as a proxy for sector development. Three indices - governance, corruption, and competitiveness - were used as institutional quality proxies. Empirical results suggest that the aquaculture growth did not significantly correlate with the quality of institutions. By region, Africa had the fastest growth in the aquaculture sector, though from a low base, with 7.35% and 9.28% higher annual percentage change in aquaculture quantity and value respectively, than the Asian region. While, the European region experienced significantly lower annual percentage change in aquaculture quantity, a difference of 3.78% compared to the Asian region. Furthermore, the study found that total aquaculture production was not positively correlated with eco-label certification. The study is concluded by discussing the "aquaculture paradox."

1. Introduction

Over the past 40 years, the global aquaculture sector has grown continuously and the sector is currently an important contributor to total global seafood production; according to the Food and Agriculture Organization (FAO) of the United Nations, it contributed 44.1% in 2014 [1]. Global supply from aquaculture has grown at an annual average of 8.6% between 1980 and 2012 [2], whereas the capture fish production gradually stagnated. The average annual percentage change in global aquaculture production in terms of value is 3.9% in the period 1984–2014. This development has mainly been driven by productivity growth [3,4] and an increasing demand for seafood [5]. Global food fish production through aquaculture was 73.8 million tons in 2014, and total global aquaculture production, including farmed aquatic plants, was 101.1 million tons, valued at US$ 165.8 billion [1]. Asia dominates this production, accounting for 88.91% by volume in 2014.

The dietary contribution of seafood is important in terms of animal protein and micro nutrients. Statistics on world per capita fish consumption show that the consumption has increased gradually. In 2013, world per capita fish consumption was 19.7 kg [1]. The continuous growth in aquaculture production has boosted the average consumption of seafood at the global level. The global aquaculture sector's contribution to the supply of seafood for human consumption surpassed that of capture fisheries in 2014 [1]. Aquaculture is now more important than fisheries as a source for seafood for human consumption. Fish consumption is estimated to increase further in countries in Asia, Africa, America, and European regions during 2010–2030 [6]. Given the contribution by the global aquaculture sector to food security, the sustainable development of the aquaculture sector is an important requirement to meet future demand from a world population of 9.6 billion by 2050.

Despite the production increase, the overall rate of growth in the aquaculture sector is decreasing on a global scale (see Fig. 1). Furthermore, disparities in aquaculture growth among aquaculture countries has been observed for many years. Generally, aquaculture production depends on several factors, and the interactions between them, including fingerlings, feed, farming area, climatic factors, farming systems, management practices, market factors, social environment, and institutions. An increase in factor inputs increases aquaculture outputs. However, feed waste, feces, escapement and pathogens may cause negative externalities among producers and between the aquaculture industry and other parts of the economy. Differences in input factors in aquaculture production might be reasons for the growth disparities. Marine resource abundance, farming practices, technology,

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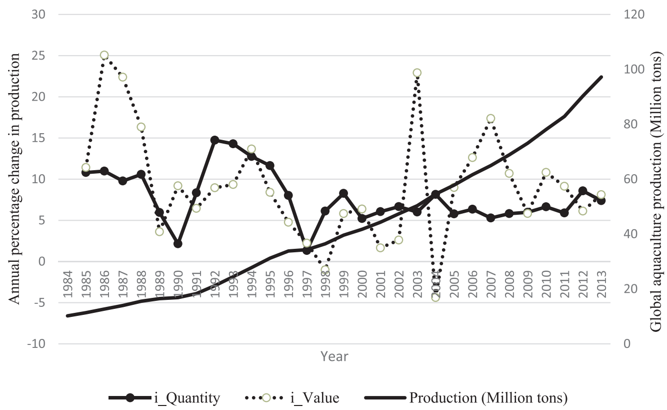

Fig. 1. Average annual change in total global aquaculture production (1984–2013). *Source*: FishStat, FAO, 2015.

and markets have been discussed as critical factors that contributed to the growth experienced in recent decades [7–9].

This study focuses on institutions and investigates empirically whether the quality of national institutions has influenced aquaculture growth and development. The role of the qualitative factor institutions, in aquaculture production could also be a determinant, in particular in the long run. Institutions are key components in the overall management of natural resource industries, guiding the people involved in their task of production and marketing. Institutions include governmental policy, laws, rules and regulatory measures, planning, programs (training, extension services, and financial assistance) and controls. Institutions may change over time to create improved environment for technological change and economic development [10].

2. Background

“Why do some countries produce so much more output per worker than others?” was the key question posed by Hall and Jones [11], as well as in the voluminous literature in the field of growth and development economics. This cross-country study of 127 entities found that designated social infrastructure (institutions and government policies) is of great importance for economic development and productivity. A good social infrastructure creates a favorable environment that supports production, encourages capital accumulation, skill acquisition, invention, and technology transfer. There is a “powerful and close association between output per worker and measures of social infrastructure” [11], considering input and output data.

The role of institutions in the performance of resource economies has been discussed in the “resource curse literature” [12–14]. The resource curse - that natural resource abundance is harmful to economic growth- is a finding from an earlier study on the economic development history of resource economies conducted by Sachs and Warner [15]. They concluded that resource abundance is not a blessing, but rather it hampers economic growth. The main causes of this, identified based on theory and the study of many countries, include rent-seeking behavior, civil war, armed conflict, political instability, and the decay of institutional quality. Empirical studies have identified a negative correlation between resource abundance and economic growth [14,15].

However, researchers who later studied the same research questions partly argued the findings of earlier studies and partly introduced new elements to explain the anomalies found.[1] They have suggested that a hidden factor determines whether natural resource abundance is a blessing or a curse, namely the quality of institutions [12,13]. These studies demonstrate, both theoretically and empirically, that a country could attain economic growth through its abundant natural resources if it maintains high-quality institutions. Weak institutions provide opportunities for rent seekers to keep some production outside the formal economy and to employ resources for unproductive rent seeking, causing negative impacts for the overall economy and low economic growth [12]. However, institutions alone do not determine the outcomes of resource use. The type of resource also influences economic results [13]. The natural resources considered in the literature as contributors to economic growth are mainly valuable mineral resources, including crude oil, gas and diamonds, all of which are highly traded internationally.

Marine renewable resources are also valuable natural resources. The fishery and aquaculture sectors play a significant role in achieving socioeconomic development. Seafood products are highly traded internationally, about 78% of seafood products estimated to be exposed to international trade competition [16–18]. In 2014, more than 200 countries reported exports and imports of seafood products [1]. Since the quality of institutions is proved to be a crucial factor contributing to economic growth through non-renewable resource-based industries, what would be the effect of institutions on the performance of limited renewable resource-based industries? This question was recently studied for the fishery sector, but in a different manner than that of previous studies on nonrenewable resources, as fisheries in most countries play a minor role in the national economy [19]. A major finding of this empirical study was that national institutions do not play a significant role in the harvest growth rate, and this statistical finding contrasts with the previous finding in the resource curse literature that institutions have a significant influence on the contribution of resource industries to the growth of the gross domestic product (GDP). In this context the fisheries sector is a special case compared to other natural resource-based industries.

Although both fisheries and aquaculture are similar industries in producing food fish, the aquaculture sector differs from the fishery sector in some important ways [9]. The aquaculture sector is a man-made ecosystem, generating both positive and negative consequences for the surrounding natural ecosystems [20]. Aquaculture is in some respects more similar to agriculture than to fisheries, in particular since the stock of animals is private property [9]. On the other hand, aquaculture fish are to a high degree exposed to and create externalities, as noted above [20]. This is particularly the case for cage-reared fish, such as salmon in Chile and Norway [21], but also for pond-raised species, such as shrimp in Sri Lanka and Vietnam. This distinct industry requires special management measures to overcome the externalities. As a component of the management system, institutions might influence aquaculture production in different ways. Therefore, this study aims to examine the extent to which national institutions influence aquaculture production and value (see Fig. 2).

Comparative analyses of the determinants of the general economic performance of countries traditionally use macroeconomic indicators such as GDP per capita (level and change) as the dependent variable [11,12,15]. On the other hand, there are numerous sectorial studies where the sector output (net or gross, level or change) is the dependent variable. This literature includes studies of the primary industries agriculture [22,23] and fisheries [19]. The quoted agriculture studies focused on output levels whereas the quoted fishery study focused on annual change. The main reasons for this difference appears to be the availability or lack of cross-sectional data as well as time series data. For aquaculture, input data, to the best of our knowledge, is not available the same way internationally, and we have rather to perform a study of output growth for quantity and value. The relationship between the annual growth rate in aquaculture production of the major aquaculture countries and the quality of institutions in those countries over the last three decades (1984–2013) is analyzed using econometric models.

[1] These research questions ask why growth rates differ among resource-rich countries even though they depend on similar natural resources, and why the growth rates of many resource-rich economies are lower than those of economies less abundant in valuable natural resources.

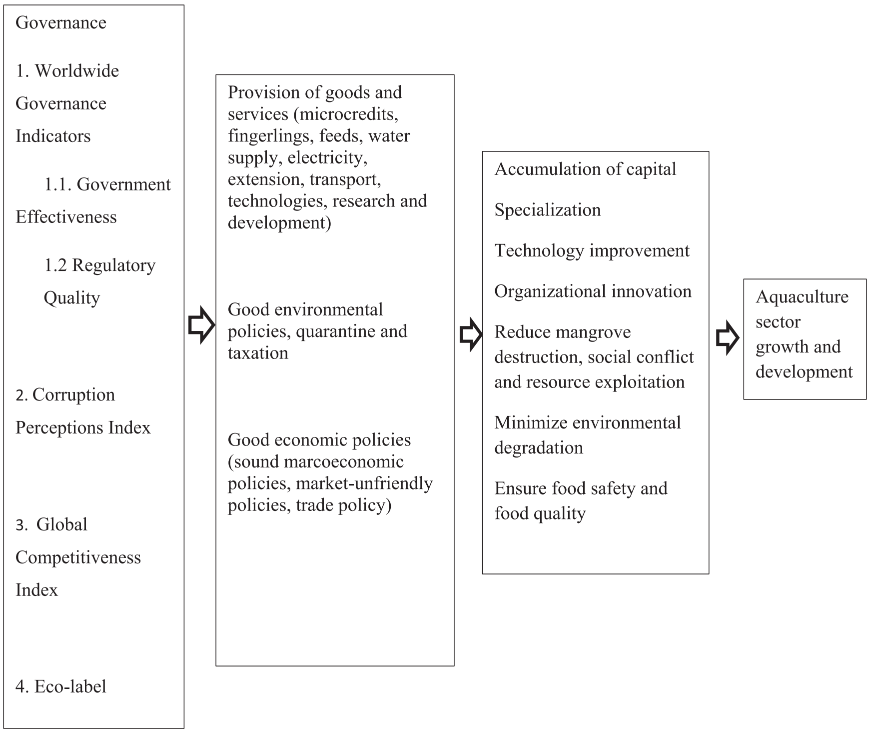

Fig. 2. Governance and aquaculture growth elements.

3. Methods and data

The main hypothesis is that growth and development of the aquaculture sector depend on the quality of national institutions, i.e. that high-quality institutions have a positive effect on aquaculture production. The research questions to be discussed are: How and to what extent is aquaculture performance influenced by national institutions, through correlation? Do the countries performing well in the aquaculture sector have effective national institutions? Is the aquaculture sector a special case compared to other natural resource-based industries, requiring special institutional arrangements for sustainability? Do the countries performing well in the aquaculture sector use any standard procedures (e.g. eco-label certification)?

3.1. Aquaculture countries and production data

The study includes many aquaculture countries in order to provide a global picture. Generally, the FAO considers the top 30 countries when listing the largest aquaculture producers in the world. This study considers double that number, analyzing the top 60 countries. The countries were selected using the criteria that a country should belong to at least one of the following categories:

- One of the 60 largest aquaculture countries in terms of quantity (in tons) for the years 1984–1985, 1994–1995, 2004–2005, or 2012–2013.
- One of the 60 largest aquaculture countries in terms of value (in US$) for the years 1984–1985, 1994–1995, 2004–2005, or 2012–2013.

Initially 79 countries were selected based on the above criteria, including the former nations the Soviet Union and Yugoslavia. Three countries-Belize, the Faroe Islands and French Polynesia-were omitted from the econometric analysis, as scores for the good governance indicators chosen in this study are not available for these countries. Finally, 74 countries were included in the main econometric analysis.

The study used the latest data published by the FAO [24] for aquaculture production in its Fisheries and Aquaculture Statistics (FishStat) database. FishStat contains data for aquaculture production from 1950 to 2013. Data for the quantity of aquaculture production are available from 1950, but data for the value of aquaculture production are only available from 1984. Thus, the study covers the period 1984–2013, even though the global aquaculture sector has a long history of over 50 years. Total aquaculture production including all species (finfish, crustaceans, molluscs and aquatic plants) was taken into account. Data for total aquaculture production in terms of quantity (in tons) and value (in US$) from 1984 to 2013 were collected from the FAO database using the FishStatJ software. The present day countries Belarus, the Russian Federation and Ukraine belonged to the Soviet Union, and Croatia belonged to Yugoslavia. Therefore, it was necessary to estimate the figures for aquaculture production in these countries during the period in which they were united. The approximate figures for the quantity and value of aquaculture production were estimated using the data for the former nations (Soviet Union and Yugoslavia) in the FAO database.[2] The selected countries were grouped into five different regions-Africa, the Americas, Asia, Europe, and Oceania-by following the FAO classification.

The annual percentage change and the average annual percentage change in aquaculture production (quantity and value) in the period 1984–2013 were calculated for each country. The terminal years, 1985 and 2013, used to calculate the average annual percentage change, are the average of two adjacent years (1984–1985 and 2012–2013); this average annual percentage change is the compounded annual change in production.

[2] The approximate figures for Belarus, the Russian Federation and Ukraine from 1984 to 1987 and for Croatia from 1984 to 1991 were calculated in the following way, using the example of Belarus: Aquaculture production for the Soviet Union in 1984 was multiplied by the proportion of Belarussian production of the average of the former Soviet countries' total aquaculture production in the period 1988–1989. This proportion was assumed to be constant and multiplied by the aquaculture production of the Soviet Union in the respective years.
The former Soviet countries included: Armenia, Azerbaijan, Belarus, Estonia, Georgia, Kazakhstan, Kyrgyzstan, Latvia, Lithuania, Tajikistan, Moldova, the Russian Federation, Turkmenistan, and Ukraine.
The former SFR Yugoslavia countries included: Croatia, Bosnia, Herzegovina, Montenegro, Macedonia, Serbia, and Slovenia.

3.2. Good Governance Indicators

Institutions comprise a qualitative feature that can be assessed using indices. For the last two decades, the quality of national institutions has been assessed using good governance indictors produced by international organizations. It is not possible to select a single indicator as a measure that can completely explain the quality of national institutions. National institutions include the whole government policy framework of a country to guide and influence all economic activities, including the aquaculture sector. Even though the aquaculture industry is a food-producing sector, it is a highly competitive, business-oriented sector in the world. Therefore, three indices were selected: the World Bank's Worldwide Governance Indicators (WGI), Transparency International's Corruption Perceptions Index (CPI) and the World Economic Forum's Global Competitiveness Index (GCI) (see Fig. 2). In addition to these three indices, another three aspects were included in the econometric analysis: Membership of the Organization for Economic Cooperation and Development (OECD), use of an eco-label certification program and region.

3.2.1. Worldwide Governance Indicators (WGI)

The WGI reports [25] the quality of governance on six dimensions for 215 countries over the period 1996–2014. The World Bank and the Brookings Institution developed the WGI score on a scale ranging from − 2.5 (bad) to 2.5 (good), using over 32 different data sources, including commercial information providers, surveys of firms and households, nongovernmental organizations, and public sector organizations. As the World Bank defines it:

> *Governance consists of the traditions and institutions by which authority in a country is exercised. This includes the process by which governments are selected, monitored and replaced; the capacity of the government to effectively formulate and implement sound policies; and the respect of citizens and the state for the institutions that govern economic and social interactions among them.*

By definition, the ability of the government to produce and implement policies and deliver public goods and services is referred to as government effectiveness. Aquaculture production depends on the availability and accessibility of aquaculture inputs and facilities: fingerlings, medicine, feed, electricity, water supply, transport facility and market facilities. Generally, provision of these inputs and facilities is determined by government progress. So that, within the six dimensions of governance, two indicators (government effectiveness and regulatory quality) were chosen to calculate the WGI score used in this study. The average score of these indicators was used as the country's WGI score. The WGI scores for the selected aquaculture countries were collected from World Bank reports (1996–2013). Over the period 1996–2002, the World Bank published the WGI scores every two years, so the score for a given year was assumed to be valid also for the adjacent year.

3.2.2. Corruption Perceptions Index (CPI)

Control of corruption is one of the six dimensions of governance in the WGI. However, there is also another specialized index available to explain the level of corruption, named the "Corruption Perceptions Index (CPI)", by Transparency International. Data for this index is available from 1995 annually. Therefore CPI was selected, which enable more data.

The CPI measures the perceived level of public sector corruption in countries worldwide, providing a ranking. The CPI scores range from zero (highly corrupt) to ten (very clean). Scores for the selected countries were collected from annual reports for the period 1995–2013 [26].

Environmental degradation is a consequence of a corrupt system. Highly corrupt situations provide opportunity for individuals to act freely: usage of natural water reservoirs, destruction of mangrove forests, usage of banned medicine and illegal farming. So this index could explain how a country practices good governance measures to reduce the environmental degradation caused by aquaculture.

3.2.3. Global Competitiveness Index (GCI)

The GCI is a comprehensive index for measuring national competitiveness. Competitiveness is defined as the set of institutions, policies, and factors that determine the level of productivity of a country [27]. The index is used to evaluate the capability of a country to achieve economic growth and provide information regarding productivity and competitiveness. Since 2005, the World Economic Forum has annually ranked countries, providing a score on a scale from one to seven. The determinants of economic growth are grouped into 12 "pillars", including institutions, for the calculation; the weighted average of the many different components is the final score. The GCI scores for the chosen countries were collected from the reports for the period 2004–2013 [28].

3.2.4. Eco-label Index

Eco-labeling is a form of certification program, aiming to avoid the negative environmental and socioeconomic effects caused by aquaculture (pollution, disease incidence, social conflict) and improve its sustainability. Recently, most aquaculture countries have adopted certification to ensure that their farming activities are undertaken in an environmentally friendly manner. Some of the countries included in this study practice ecolabel certification and others do not. Thus, to study the effect of eco-label certification on aquaculture production, eco-labeling was included in the econometric model as a dummy variable. Best Aquaculture Practices (BAP) and Aquaculture Stewardship Council (ASC) certification were chosen to represent eco-label certification; each is described in turn below:

- BAP certification was established in 2002 to promote responsible practices across the aquaculture industry. The BAP standards were developed by the Global Aquaculture Alliance, focusing on biodiversity conversion and environmental, social, food safety, and traceability issues. The certification program is implemented through the Aquaculture Certification Council, an agency that provides certification licenses to the entire aquaculture production chain, including farms, hatcheries, and seafood processing plants. The agency inspect all practices and product quality, and reviews records.
- The Aquaculture Stewardship Council (ASC) was founded in 2010 by the World Wide Fund for Nature (WWF) and the Dutch Sustainable Trade Initiative (IDH). It aims to transform aquaculture toward environmental sustainability and social responsibility, using efficient market mechanisms that create value across the chain. The ASC provides standards for the farmed seafood chain of custody. The standards for certification have been developed and are implemented in accordance with the International Social and Environmental Accreditation and Labeling Alliance (ISEAL) guidelines.

3.2.5. Organization for Economic Cooperation and Development (OECD)

The OECD is an international economic organization established in 1960. Its mission is to promote policies that will improve the economic and social well-being of people around the world. Originally, the United States, Canada, and 18 European countries signed; since then, another 14 countries have become members of the organization. Recently some countries have joined as partners in the OECD. Most members are economically developed countries and employ good strategies to manage their natural resources. Our study includes 28 OECD member countries, with membership included as a dummy variable to investigate how OECD countries perform in aquaculture compared to non-OECD countries.

3.2.6. Region

Aquaculture was more popular in developed countries in the early years, but globalization has seen the aquaculture sector expand more rapidly in developing nations. To test the regional effect, we ran regressions replacing OECD with regional dummy variables. We follow regional categories according to the FAO grouping, denoting Africa, the Americas, Asia, Europe, and Oceania as R1, R2, R3, R4, and R5 respectively. The global aquaculture sector is currently dominated by the Asian region with around 88.9% of global aquaculture production coming from Asian countries [1]. Thus, the Asian region (R3) was chosen as the benchmark to study the regional effect.

3.2.7. Model

As discussed above, most studies in the resource curse literature have used GDP growth as the dependent variable to study the role of institutions in the economic performance of resource-rich economies. However, this paper uses another approach, taking the annual growth rate of the industry output as the dependent variable. This is a similar approach to that used for fisheries [19] and agriculture [23]. Differences and similarities among aquaculture, fishery and agriculture vary between countries. This may explain why the aquaculture sector administratively is a subsector of the fishing industry in most countries while it is a subsector of agriculture in some other countries, such as China. The contribution of the aquaculture sector to the GDP is not reported separately, but is combined with marine fishery or agriculture in national statistical reports. Due to the lack of available GDP and profitability data, annual percentage change in total aquaculture production in terms of quantity and value was used as proxy for sector development. The basic econometric model given in Eq. (1) and (2) illustrate the relationship between the annual growth rate and the institutions:

$$i = \beta_1 + \beta_2 WGI + \beta_3 CPI + \beta_4 GCI + \beta_5 OECD + \beta_6 BAPASC + \beta_7 R1 + \beta_8 R2 + \beta_9 R4 + \beta_{10} R5 + e \quad (1)$$

Eq. (1) is a multiple linear regression and will be estimated using the ordinary least square method (OLS). It explains the relationship between the average annual percentage change in production and national institutions.

$$i = \beta_1 + \beta_2 WGI + \beta_3 CPI_{jt} + \beta_4 GCI_{jt} + \beta_5 OECD_{jt} + \beta_6 R1_{jt} + \beta_7 R2_{jt} + \beta_8 R4_{jt} + \beta_9 R5_{jt} + e_{jt} \quad (2)$$

Eq. (2) is a panel regression and will be estimated using the pooled least square method. It explains the relationship between the annual percentage change in production and national institutions.

i is the annual percentage change in production, WGI, CPI, and GCI are the indices representing the quality of institutions, OECD is a dummy variable for membership, BAP_ASC represents BAP and/or ASC eco-labeling certification, R is a regional category and e is the error term. The subscript *j* denotes the *j*th individual (74 countries) and *t* denotes time (29 years).

The entire set of data used in this study is an unbalanced panel data set. The main limiting factor is the lack of score for indices over the full period, as discussed above. The econometric analysis was done in two different ways using the R statistical software (version 3.1.1), as set out below.

1) Cross-country regression (Eq. (1)): The average annual percentage change in production in the period 1984–2013, as the dependent variable, was regressed against all good governance indices, as well as the dummy variables, using the ordinary least squares (OLS) method. The average score for each index in the last two years (2012 and 2013) was used in this regression. The data set used for this regression is given in the Appendix A, Table A1.
2) Panel data regression (Eq. (2)): The panel data include 74 countries, data for production over the 29-year period, and scores for the indices (WGI, CPI, and GCI) for 20 years. The annual percentage change in production, as the dependent variable, was regressed against the scores for the three good governance indices in the respective year and the OECD and region dummies. Lack of time series information regarding eco-labeling is the reason for omitting the ecolabel index. Initially, all three panel data regression models-pooled, fixed effects and random effects-were estimated and tested using formal methods [29]. Random effects models for quantity data and pooled models for value data were selected based on the test results; Breusch-Pagan Lagrange Multiplier test, Hausman test and Breusch-Godfrey/Wooldridge test [30,31]. The fixed effects model is unable to estimate the coefficient on the time-invariant such as the OECD and region dummy variables, therefore the random effects model is suited and there is no endogeneity problem in these models. Regressions 5 and 7 are random effects models and regressions 6 and 8 are pooled models (Table 1). To test the regional effect, regressions 7 and 8 were estimated by replacing OECD with regional dummy variables; the Asian region (R3) was considered as the benchmark.

4. Results

Appendix Table A1 reports the average annual percentage change in production (quantity and value) over the period 1985–2013 for the 74 aquaculture countries and the scores on the indices (WGI, CPI, GCI) for those countries (average of the two latest years, 2012 and 2013). The scores for WGI, CPI and GCI show that the quality of institutions varies among the selected aquaculture countries. The list for the top ten aquaculture producers include countries with poor-quality institutions (China, India, Indonesia, Vietnam, Bangladesh Thailand and Philippines) as well as with high-quality institutions (Chile, Norway, and Japan). There are small aquaculture producers having high quality institutions (Sweden, Finland, and Iceland). Thus, globally, it is a mixed picture.

Appendix Table A2 summarizes the correlation between the main variables. The average annual change in production has a weak, negative correlation with all explanatory variables. Columns (1)–(4) in Appendix Table A3 show the cross-country regression results for Eq. (1). Most of the signs of the coefficients of good governance indicators (WGI, CPI, and GCI) are negative, but the *t*-values indicate that the coefficients are not significantly different from zero, indicating that institutions do not have a significant influence on aquaculture production. For BAP_ASC, the coefficient is negative, but not statistically significant, which suggests that eco-label certification doesn't have a measurable effect on aquaculture production. These cross-country regression results (Regression 1–4) might not be precise. As can be seen, the correlation matrix (Appendix Table A2) indicates that the good governance indicators chosen in this study are highly correlated, resulting in multicollinearity problems. Furthermore, the tests undertaken to verify models indicates that this model has problems and may be mis-specified.

Panel-data regression could be the best way to overcome the problems encountered in the cross-country regression. The panel data regression results are given in columns (1)–(4) in Table 1. Regressions 5 and 7 are random effects models and regressions 6 and 8 are pooled models (Eq. (2)). The results indicate that the annual growth rates in aquaculture production are not significantly influenced by the quality of institutions (WGI and CPI). Even though the sign of the coefficient for GCI is negative, it is statistically significant at the 10% level (regression 5), showing that when the competitiveness of countries increases (including policies, rules, regulatory measures), the quantity of aquaculture production decreases.

The sign of the coefficient for OECD membership is negative, but the coefficient is not statistically different from zero (Table 1, regressions 5

Table 1
Panel data regression results.

	Regression5 i^{qty}	Regression 6 i^{val}	Regression 7 i^{qty}	Regression 8 i^{val}
Intercept	26.951**	31.400***	24.900**	25.150*
	(2.544)	(2.658)	(2.239)	(1.960)
WGI	−0.174	2.813	−0.105	2.070
	(−0.067)	(0.997)	(−0.042)	(0.737)
CPI	0.328	−0.239	0.133	−0.590
	(0.332)	(−0.227)	(0.137)	(−0.544)
GCI	−4.890*	−4.802	−4.324	−3.258
	(−1.86)	(−1.633)	(−1.587)	(−1.032)
OECD	−3.181	−4.281		
	(−1.251)	(−1.615)		
R1 (Africa)			7.350**	9.285***
			(2.444)	(2.860)
R2 (America)			−0.669	−0.606
			(−0.296)	(−0.248)
R4 (Europe)			−3.786*	−2.775
			(−1.661)	(−1.124)
R5 (Oceania)			0.204	1.348
			(0.036)	(0.222)

Notes: The numbers in parentheses are *t*-values; i^{qty}, i^{val} are annual changes in quantity and value, respectively (dependent variable). *, **, and *** denote significance at the 10%, 5%, and 1% levels, respectively.

and 6). These results indicate that both OECD countries and non-membership countries experienced similar development in the aquaculture sector over the period 1985–2013. However, the model (Eq. (3)) estimated using the top 30 aquaculture producers' production value and institutional quality shows that OECD member countries have had 5.30% lower annual growth in aquaculture value compared to non-OECD countries.[3]

The results for regressions 7 and 8 (Table 1) indicate that in terms of region, Africa had the fastest growth in the aquaculture sector, though from a low base, with a 7.35% higher annual percentage change in aquaculture quantity as well as a 9.28% higher annual percentage change in aquaculture value than the Asian region. The European region experienced significantly lower annual percentage growth in aquaculture quantity, a difference of 3.78% compared to the Asian region.

The scores for the good governance indicators selected in this study show that the quality of institutions in many Asian countries is poor. It could be that weak institutions provide opportunities to overexploit marine resources and create an unstable market situation. To check this claim, we ran regressions for 26 countries' aquaculture production and national institutional quality. The regression result (Eq. (4)) indicates the sign of the coefficient for CPI is negative and significant at the 10% level (*t*-value in parenthesis) revealing that the annual growth rate (value) is negatively affected by the corruption level in the Asian region.

$$i^{val} = 33.107(2.207) + 2.323(0.638)\,\text{WGI} + 0.438(0.340)\text{CPI} - 5.544(-1.612)\text{GCI}–5.3(-1.743)\text{OECD} \quad (3)$$

$$i^{val} = 30.079(1.430) + 5.951(1.172)\text{WGI} - 3.642(-1.8333)\text{CPI} -1.463(-0.308)\text{GCI}–4.436(-0.973)\text{OECD} \quad (4)$$

[3] In this study, we selected 74 aquaculture countries, including top aquaculture producers, small producers, and aquaculture producers where the aquaculture industry is still in its infancy. Therefore, in addition to main econometric work, the research question was tested using the data for the top 30 aquaculture producers based on the average aquaculture quantity in 2012 and 2013. Detailed results can be provided by the corresponding author on request.

5. Discussion and conclusion

At the outset, the main hypothesis was that high-quality institutions would have positive effects on aquaculture production. This hypothesis was partly based on the latest findings in the resource curse literature, in particular that high-quality institutions increase the economic benefits to a country through natural resource industries [12,13], and partly based on the suggestion often cited in the aquaculture literature that good governance measures have to be implemented by aquaculture countries with a view to the future [16,32]. The statistical results for 74 countries do not support these expectations. The econometric analysis suggest that the aquaculture growth rate has a weak, though hardly statistically significant, negative correlation with the quality of institutions. There is a similar result that stringent environmental regulations are negatively related to aquaculture growth [33]. Panel-data regression results indicated that the annual growth rates in aquaculture production are not significantly influenced by the quality of institutions (WGI and CPI). While, the sign of the coefficient for GCI is negative, it is weakly significant (at a 10% level). As overall, empirical results suggest that the quality of national institutions did not have significant effect on aquaculture growth.

If so, why have aquaculture countries been demanded to follow high quality institutions (policies, rules, laws, regulatory measures) by international organizations in recent decades? To answer this, consideration was given to the important turning points in the global aquaculture sector. First, this is the average picture. However, as noted above, the results among the aquaculture nations are mixed. Second, aquaculture has been a part of the agricultural sector since ancient times [4], it has become more popular as an animal food-producing sector over the last few decades, and has expanded since wild capture started to stabilize. The global aquaculture sector has been described as going through several notable phases, categorized based on changes identified in the patterns of production and farming methods [34]. Remarkable changes occurred in the aquaculture sector from the 1990s onwards, when it was recognized worldwide that the practice of aquaculture might degrade the environment and threaten biodiversity and the sustainability of the sector itself. A number of disease incidents were recorded in many aquaculture countries, e.g. Chile. To reduce the negative impacts caused by aquaculture and to sustain production, several new policies, rules and regulatory measures were formulated by international organizations (governmental and nongovernmental), based on measures deemed necessary at the time to guide aquaculture countries. Even though, how well aquaculture standards address environmental and ethical issues is still debatable. A study carried out as a part of Sustaining Ethical Aquaculture Trade project indicates that there are weaknesses in the current ethical framework of standards related to aquaculture [35]. Regulatory measures most often used are command and control instruments like feed quotas, water use limits and aquaculture moratoriums to control effluents, especially of nitrogen. These restrictions might limit aquaculture production in some countries where there are inadequate technologies, skilled manpower and financial support for carrying out farming based on the recommended methods. This could be the reason why there is a weak negative correlation between the aquaculture growth rates and the quality of institutions.

On the other hand, institutions may have an indirect positive influence on the development of the aquaculture sector. Proper licensing reduces the negative impacts caused by aquaculture. Extension services, training programs, provision of fingerlings and vaccines improve farming. Microcredit schemes, insurance and incentives support aquaculture farmers when production is limited by climatic constraints. Improving infrastructure facilities in a country (electricity, irrigation and roads) facilitates aquaculture production. Technology and skills transfer increase aquaculture productivity. Trade policies help to reduce price fluctuations and market failures and increase aquaculture value.

Aquaculture production in some industrialized countries (the United States of America, Spain, France, Italy, Japan and the Republic of Korea) has fallen in recent years. The reason noted in the FAO report is that these countries import seafood from other countries where the cost of production is lower [2]. This trading strategy has indirectly caused a reduction in the quantity of aquaculture. In a sense, these industrialized countries could enjoy many benefits through this trading strategy, satisfying their seafood requirements and reducing the environmental damage caused by aquaculture, and thus managing marine resources from a long-term perspective. Implementation of strict environmental regulation has also been suggested as one of the reasons for the reduction in aquaculture production in the United States of America and European countries [36–38].

The trend in aquaculture production over time shows that total aquaculture production from the Asian and African regions has been increasing continuously compared to that in other regions, i.e. the Americas, Europe and Oceania. Expansion of farming areas and technology transfer could be reasons for the continuous increase in aquaculture quantity in the Asian and African regions. Countries that show a more or less stable production trend might have reached their maximum expansion capacity in aquaculture. The Asian and African regions predominantly include less-developed or developing countries, where aquaculture farming is practiced as a source of livelihood to overcome problems including poverty, malnutrition and unemployment, and to derive foreign exchange earnings. This rapid expansion has been most pronounced in countries with abundant marine resources, including mangrove forests, inland water reservoirs, and extensive coastal margins [8]. There have been depredations as a result: Huge areas of mangrove forest have been destroyed for shrimp farming, wild capture have been used as feed, lagoons and rivers have been exploited as water sources for intensive farming, and coastal margins have been occupied for mariculture [20].

As noted above, aquaculture production depends on several factors and the interaction between these factors. Most inputs, except labor, are traded internationally, whereas institutions are mainly national. In this study, only the institutions were considered, omitting other factors from the econometric analysis, mainly due to lack of data. Therefore the simple claim that different growth rates among the countries are solely due to the variation in the quality of institutions, cannot be verified. The variation in the annual aquaculture growth rate among countries could be due to differences in factors such as marine resource abundance, climate, species diversity (finfish, crustaceans, molluscs and aquatic plants), farming techniques, and markets that are important for production.

Marine resources abundance provide opportunities to use various farming environments (freshwater, brackish water and mariculture) and to adapt diversified farming systems (ponds, pens/cage, paddy fields, culture based fisheries, integrated farming). Intensified farming and improved nutrition contributes to increased yield per area unit [7]. Aquatic species are selected based on climate factors in the region, especially precipitation and temperature. Extreme weather events and natural disasters that occurred in recent years caused significant impact on aquaculture production. For example, in 2011, the aquaculture sectors in Thailand and Japan suffered due to catastrophic natural disasters [39].

Seafood is an important source of animal protein. It is projected that fish supply from the global aquaculture sector will continue to increase up to 93.6 million tons in 2030 based on observed regional trends in seafood production and consumption, and using a global, partial-equilibrium, multi-market model. Aquaculture expansion is expected in Asian and African regions during 2010–2030 [6]. Current statistics on fish production and the predicted fish production from the global aquaculture indicate continued significance of aquaculture in global seafood supply.

In this context, the aquaculture sector is a special case compared to other natural resource industries, this is termed the “aquaculture paradox.” Effective institutions limit the quantity of aquaculture production, but they may help to reduce the negative impacts caused by this industry. The role of institution on growth of natural resources industries and overall economic growth varies with type of natural resource used as inputs- recall the resource curse discussion above. It could have been expected that the aquaculture performance of countries would change over time, depending on opportunities and constraints. Growing seafood demand creates new market opportunities for aquaculture producers. Primary food producing sectors, including aquaculture, are highly related to climate factors and likely to be affected by climate change [40]. A policy implication of the “aquaculture paradox” is for countries to consider all input factors, including institutions, although the quality of national institutions on the average does not seem to matter much, statistically speaking. Having effective institutions in aquaculture production would help to internalized negative externalities caused by aquaculture, conserve marine resources, and sustain the contribution to global seafood production in the long term.

One suggestion for future study is that it would be better to estimate the econometric model by including many explanatory variables (input and price factors, including fuel oil) that may influence production, if and when such data becomes internationally available.

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Appendix A

See Tables A1–A3.

Table A1
Average annual change in aquaculture production in the period 1985–2013 for the 74 countries and the quality of institution in those countries.

	Name	Production		Average annual change (%)		Indices		
		Quantity	Value	i^{qty}	i^{val}	WGI	CPI	GCI
1	China	55,528.05	71,082.38	9.22	10.86	−0.15	3.95	4.84
2	India	4384.04	9802.33	7.09	10.49	−0.33	3.60	4.30
3	Indonesia	11,373.53	9305.99	12.48	11.96	−0.25	3.20	4.47
4	Chile	1060.63	6777.76	17.43	23.64	1.38	7.15	4.63
5	Vietnam	3307.29	6129.33	11.72	12.58	−0.48	3.10	4.15
6	Norway	1284.49	6031.87	13.41	13.09	1.74	8.55	5.30
7	Japan	1050.50	5164.12	−0.46	2.56	1.30	7.40	5.40
8	Bangladesh	1792.94	4162.74	9.65	11.83	−0.88	2.65	3.68

(continued on next page)

Table A1 *(continued)*

	Name	Production		Average annual change (%)		Indices		
		Quantity	Value	i^{qty}	i^{val}	WGI	CPI	GCI
9	Thailand	1164.52	3324.84	8.00	12.12	0.22	3.60	4.53
10	Philippines	2457.68	2198.43	5.78	5.50	0.00	3.50	4.26
11	Egypt	1057.64	2049.84	12.23	16.65	−0.71	3.20	3.68
12	Korea, Republic of	1521.34	1835.75	2.60	6.98	1.05	5.55	5.07
13	Ecuador	327.32	1638.25	8.24	7.09	−0.74	3.35	4.06
14	Myanmar	909.57	1607.76	18.96	18.00	−1.60	1.80	3.23
15	Brazil	477.52	1380.63	13.54	12.67	−0.01	4.25	4.37
16	Taiwan	347.79	1282.49	1.21	2.60	1.16	6.10	5.29
17	United States of America	430.54	1108.42	1.00	3.17	1.39	7.30	5.48
18	United Kingdom	198.83	1034.85	8.41	9.48	1.60	7.50	5.41
19	Iran	310.95	911.59	10.16	10.71	−1.04	2.65	4.15
20	Turkey	223.33	903.27	16.10	17.51	0.40	4.95	4.45
21	France	203.71	886.44	−0.10	4.64	1.26	7.10	5.08
22	Canada	172.67	880.79	10.86	15.54	1.73	8.25	5.24
23	Australia	76.65	856.74	7.59	12.81	1.70	8.30	5.11
24	Greece	141.09	815.37	14.46	17.04	0.47	3.80	3.90
25	Malaysia	582.79	809.15	8.13	12.35	0.82	4.95	5.05
26	Nigeria	266.30	755.52	12.89	16.51	−0.86	2.60	3.62
27	Peru	98.99	675.61	10.33	11.65	0.16	3.80	4.27
28	Mexico	156.27	670.60	9.53	15.03	0.39	3.40	4.35
29	Russian Federation	151.00	519.65	0.10	4.13	−0.38	2.80	4.23
30	Italy	162.62	514.44	1.72	3.94	0.59	4.25	4.44
31	Spain	243.94	502.19	−0.19	2.91	1.03	6.20	4.59
32	New Zealand	98.64	382.13	7.71	15.35	1.80	9.05	5.10
33	Honduras	61.43	319.11	17.02	17.89	−0.46	2.70	3.79
34	Colombia	89.53	283.62	16.64	15.30	0.21	3.60	4.19
35	Saudi Arabia	23.17	234.08	21.61	25.32	0.07	4.50	5.15
36	Pakistan	145.48	219.46	10.14	10.41	−0.76	2.75	3.47
37	Uganda	96.98	213.56	28.63	35.98	−0.41	2.75	3.49
38	Ireland	35.15	157.97	3.38	9.90	1.53	7.05	4.92
39	Lao	104.95	157.42	12.41	13.86	−0.83	2.35	4.08
40	Netherlands	53.28	145.75	−1.81	3.29	1.77	8.35	5.46
41	Cambodia	82.00	143.89	12.76	13.00	−0.61	2.10	4.01
42	Denmark	55.10	133.51	2.98	3.15	1.88	9.05	5.24
43	Korea, Democratic People's Republic	508.35	116.22	−1.24	−3.45	−2.22	0.80	2.42[a]
44	Iraq	19.55	100.29	5.28	7.85	−1.18	1.70	2.55[a]
45	Poland	33.73	100.07	1.86	3.11	0.85	5.90	4.46
46	Venezuela, Bolivarian Republic	26.35	99.26	12.33	15.14	−1.36	1.95	3.41
47	Germany	25.82	98.78	−4.01	−1.10	1.54	7.85	5.50
48	Israel	21.24	96.45	1.97	5.62	1.20	6.05	4.98
49	Guatemala	17.40	86.01	15.01	14.19	−0.47	3.10	4.03
50	Nepal	35.26	83.30	9.27	12.14	−0.90	2.90	3.58
51	Costa Rica	28.68	82.27	18.87	19.61	0.52	5.35	4.35
52	Tunisia	10.38	70.82	15.60	22.82	−0.14	4.10	4.06
53	Croatia	11.23	68.53	1.84	4.89	0.56	4.70	4.09
54	Portugal	9.10	67.20	1.30	3.04	0.97	6.25	4.40
55	Ukraine	23.45	65.32	−4.62	−1.49	−0.62	2.55	4.10
56	Ghana	29.98	63.99	15.39	18.09	0.01	4.55	3.74
57	Sweden	13.56	61.39	5.19	7.75	1.90	8.85	5.51
58	South Africa	6.00	57.42	8.95	11.25	0.39	4.25	4.37
59	Finland	13.14	57.00	1.02	0.85	2.01	8.95	5.55
60	Nicaragua	25.38	55.78	25.18	21.40	−0.58	2.85	3.79
61	Czech Republic	20.06	51.66	0.16	0.03	0.99	4.85	4.47
62	Madagascar	10.87	46.97	13.66	16.58	−0.86	3.00	3.40
63	Iceland	7.24	43.76	14.64	14.74	1.28	8.00	4.70
64	Sri Lanka	19.86	43.45	17.22	14.91	−0.19	3.85	4.21
65	Belarus	14.52	42.89	−0.16	3.06	−1.02	3.00	2.83[a]
66	Panama	7.90	37.29	4.64	3.05	0.35	3.65	4.50
67	Hungary	15.03	37.01	−0.52	3.56	0.78	5.45	4.28
68	Cuba	27.88	36.78	6.51	7.79	−1.02	4.70	3.57[a]
69	Bulgaria	9.06	27.13	−1.17	1.01	0.34	4.10	4.29
70	Romania	10.51	26.81	−5.10	−5.03	0.18	4.35	4.10
71	Austria	3.18	23.76	−0.86	2.98	1.53	6.90	5.19
72	Singapore	4.40	20.77	4.68	6.88	2.04	8.65	5.64
73	China, Hong Kong	3.93	20.54	−2.60	−0.23	1.86	7.60	5.44
74	Syria	5.10	16.76	2.64	4.94	−1.43	2.15	2.5[a]
	Total 74 countries	93,328.39	149,915.33					
	Global total	93,741.08	151,141.79					

Notes: Aquaculture quantity (in thousands tons) and value (million US$), scores for indices are the average for 2012–2013.

[a] Inserted by interpolation, using other indices (WGI and CPI).

Table A2
Correlation between the main variables.

	i^{qty}	i^{val}	WGI	CPI	GCI	OECD	BAP_ASC
WGI	−0.327	−0.232	1.000				
CPI	−0.316	−0.227	0.9444	1.000			
GCI	−0.268	−0.203	0.902	0.850	1.000		
OECD	−0.316	−0.217	0.737	0.733	0.582	1.000	
BAP_ASC	−0.118	−0.124	0.340	0.340	0.457	0.310	1.000

Notes: i^{qty}, i^{val} are the average annual percentage change in aquaculture quantity and value, respectively.

Table A3
Cross-country regression results.

	Regression 1 i^{qty}	Regression 2 i^{val}	Regression 3 i^{qty}	Regression 4 i^{val}
Intercept	5.514	9.994	8.023	12.685
	(0.423)	(0.731)	(0.678)	(1.066)
WGI	− 2.045	−1.111	−0.517	0.914
	(−0.634)	(−0.329)	(−0.190)	(0.333)
CPI	− 0.003	− 0.010	−0.018	−0.041
	(−0.025)	(−0.083)	(−0.180)	(−0.410)
GCI	0.901	0.355	0.210	−0.242
	(0.309)	(0.116)	(0.081)	(−0.093)
OECD	− 2.173	− 1.301		
	(−0.791)	(−0.452)		
BAP_ASC	− 0.203	− 0.767	0.023	−0.013
	(−0.101)	(−0.364)	(0.013)	(−0.008)
R1 (Africa)			6.971**	9.731***
			(2.562)	(3.555)
R2 (America)			4.394**	3.641*
			(2.163)	(1.781)
R4 (Europe)			−5.241**	−5.311**
			(−2.471)	(−2.489)
R5 (Oceania)			1.037	4.688
			(0.207)	(0.929)

Notes: The numbers in parentheses are *t*-values; i^{qty}, i^{val} are average annual changes in quantity and value, respectively (dependent variable). *, **, and *** denote significance at the 10%, 5%, and 1% levels respectively.

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Paper II

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Paper III

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