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An investigation of scientific research and patent output of major aquaculture producers and their impact on the economic growth (2001–2016): A scientometric evaluation

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ABSTRACT

This article investigates the development of science and technology of aquaculture production of major global producers through a scientometric analysis based on publications and patents, along with the developmental impact on economic growth. Our analysis shows that, during the 2001-2016 period, China and Japan were the only major aquaculture-producing countries active in science and technology, along with fish farming production. Further analysis showed that the major aquaculture producing countries are weaker in technology and innovation than in science. However, this study could not directly confirm the impact of science and innovation developments of aquaculture and fish farming on economic growth. Nevertheless, given the variables, the article recommends that in order for aquaculture and fish farming to foster economic growth in terms of science and technology, each country must first direct its programs to focus on science and technology in these fields. At a country level, the sector is dependent on a knowledge-based economy, as well as the support from public organizations to improve greater research and development, foreign direct investments, strong patent policies, trade protection, increased quality of human capital, and openness to trade in the economic growth culture.

Index terms: aquaculture, fish farming, science, publications, technology, patents.

Ideias centrais

- A aquicultura é o setor de produção agroalimentar de mais rápido crescimento no mundo.
- As necessidades e as oportunidades para a gestão do conhecimento mudam em resposta ao desenvolvimento tecnológico.
- Os avanços do setor de piscicultura ocorreram pela implementação de novas tecnologias.
- Entre os principais produtores de aquicultura, ainda é fraca a integração ciência-tecnologia.

Uma investigação da pesquisa científica e produção de patentes dos principais produtores da aquicultura e seus impactos sobre o crescimento econômico (2001−2016): Uma avaliação cienciométrica

RESUMO

Este artigo investiga o desenvolvimento científico e tecnológico da produção de aquicultura de grandes produtores globais, por meio de uma análise da cienciometria baseada em publicações e patentes, junto com o impacto desse desenvolvimento sobre o crescimento econômico. Nossa análise mostra que, durante o período de 2001−2016, a China e o Japão foram os únicos grandes países produtores de aquicultura que estavam ativos em ciência e tecnologia junto com a produção de peixes. Uma análise posterior mostrou que os principais países produtores de aquicultura são mais fracos em tecnologia e inovação do que em ciência. No entanto, este estudo não pôde confirmar diretamente o impacto do desenvolvimento da ciência e da inovação em aquicultura e piscicultura sobre o crescimento econômico. Dadas as variáveis, o artigo recomenda que, para que a aquicultura e a piscicultura fomentem o crescimento econômico em termos de ciência e tecnologia, cada país deve primeiro focar seus programas na ciência e tecnologia nesses campos. Em nível de país, o setor também depende de uma economia baseada no

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conhecimento, do apoio de organizações públicas para melhorar a P&D, investimentos estrangeiros diretos, fortes políticas de patentes, proteção comercial, maior qualidade do capital humano e abertura ao comércio na cultura do crescimento econômico.

Termos para indexação: aquicultura, piscicultura, ciência, publicações, tecnologia, patentes.

INTRODUCTION

Over the last 30 years, aquaculture has grown at 8.8 % annual average and continues to grow more rapidly than other leading food-producing sectors. For this reason, it is deemed the fastest growing agro-food production sector in the world (Toufique & Belton, 2014; FAO, 2018). Global human fish consumption is also rapidly increasing. For instance, from 1961 to 2015, food fish consumption per capita grew at 1.5 percent per year on average (FAO, 2018). Farmed fish production has also exceeded wild capture fisheries in seafood intended for human consumption (Golden et al., 2017). In 2016, aquaculture food fish production comprised a total of 80.0 million tonnes. China alone has produced more farmed food fish than all the other countries combined. Moreover, since 1991, the sector has been annually dominated by China as the significant farmed food fish producer. The other major producers and their rankings in 2016 were India, Indonesia, Viet Nam, Bangladesh, Egypt, Norway, Chile, Myanmar, Thailand, Philippines, Japan, Brazil, and the Republic of Korea (FAO, 2018).

According to Bostock & Seixas (2015, p.863): “As the aquaculture sector develops and matures, the needs as well as the opportunities for knowledge management are changing […], at least partly in response to technological and social developments.” Furthermore, research is thought as a primary and necessary support service required for the technological development of aquaculture and production efficiency. As a matter of fact, over the past two decades, advances in the sector have been attained through the implementation of new technologies and the expansion of fish farming systems (Sandifer, 1979; Lehane, 2013).

Therefore, the objective of the present study was to investigate the development of aquaculture and fish farming production of major producers worldwide, and to conduct a performance assessment of research and innovation through an analysis of scientometric indicators, while examining the relationship of this development with the economic growth.

For the purpose of analysis, our scientometric indicators include the number of research publications and affiliations, and the number of patent documents, inventors, and applications for the period 2001–2016.

The evaluation in scientific research is essential in the foundation and development of knowledge worldwide. Knowledge accumulation influences a country’s productive capacity and international competitiveness, as well as the quality of human capital that can be enhanced through involvement in research activities and output (Raan, 2003; Pouris & Pouris, 2009; Inglesi-Lotz & Pouris, 2013). The academic system plays an essential role in the production of scientific research, while fostering the economic growth, as the lead supplier of scientific knowledge to the remainder of the economic system that nurtures the innovative process. Patents are widely accepted as a good indication or measurement of technological change and achievements of a country (Archibugi & Pianta, 1996; Pouris & Pouris, 2009; Antonelli & Fassio, 2016). Patents are the most widely used measure of innovation and potentially the most important index of intellectual property rights (IPRs) protection, in the measurement of economic growth; they are also the most preferred intellectual property (IP) rights regarding technological advances (Thompson & Rushing, 1996; Kalanje, 2006; Nelson, 2009). For a good reason, this system is the core of a nation’s policies toward technological innovation (Mansfield, 1986).

The gross domestic product (GDP) is the most used indicator for measuring economic growth. However, for the measuring a country, region, or institution’s research output and knowledge capacity, the scientometric analysis is regarded as one of the most objective, efficient and simple methods.

Researchers have shown interest in the relationship of a country's research output and economic growth measures in scientometric indicators (Inglesi-Lotz & Pouris, 2013).

Scientometrics − the quantitative analysis of science and technology as a discipline or economic activity − uses bibliometrics as a tool to measure a country's knowledge, based on research output as a research indicator, and patent indicators as technological activity (Hood & Wilson, 2001; Pouris & Pouris, 2009; Inglesi-Lotz & Pouris, 2013). Scientometrics involves using a collection of complex techniques, including the number of publications in a field and the number of patents of a country (Pouris & Pouris, 2009). As to the economic growth and publications, indicators should include the number of research publications of a country, and its research performance in relation to the rest of the world (Inglesi-Lotz & Pouris, 2013).

Methodological Approach

The primary data used in this study were retrieved from the State of World Fisheries and Aquaculture 2018 report, which was published by the Food and Agriculture Organization of the United Nations (FAO)[3]. The information listed from this report includes the major aquaculture producers in the world, along with the million tonnes of aquaculture production per country for the period 2001–2016.

To identify research publications and patents, we created a search strategy on two databases that include the keywords – "fish farming" OR "aquaculture" from 2001 to 2016. This selected-search span was correlated with the previous data of FAO (2018), which represented the aquaculture production data from the years 2001 to 2016. The database searches were conducted on January 27th, 2020.

In order to analyze publications, we systematically searched the *Scopus* (Elsevier, 2020)[4] database for abstracts and citations using search titles, abstracts, and keywords. There were 51,669 publications that met the selection criteria. The search was further limited to publications in their final stage, and the range of years 2001–2016 was selected; the final data resulted in a total of 28,012 document results. Then, we proceed to a patent search conducted on Espacenet, organization which is established by the European Patent Office (EPO). The Espacenet is the world's most extensive free assortment of patent publications. We chose this tool for our patent analysis, as it is a commonly used database containing over 100 million patent documents, and it has an extensive coverage on every technology of over 100 countries (European Patent Office, 2020). The search was carried out through advanced search, which allows of merging the data fields title and abstract of both keywords. The references from the basic search resulted in 19,244 publications. The search was further limited to records within 2001−2016, thus producing 9,692 publications which met the search and filter criteria with the final query: [(ta = "fish farming" OR ta all "aquaculture") AND pd within "2001 2016"].

For patents, it is important to note that the results provided two totals – one with duplicates (13,675) and one without them (9,692). The one with duplicates was slightly concealed, and was not considered in the final results; thus, the final results were listed as 9,692. The main reason for these two totals is that the system only shows "one document per patent family, and the document that is not shown is probably a duplicate ('equivalent')" (European Patent Office, 2020). Hence, the system considers it as such and eliminates its count from the final total. However, all documents (13,675) provided by the database are considered part of the countries publications. As such, the authors can only vaguely estimate the total, based on the figures provided. Nonetheless, due to this limitation, for the present study, the authors decided to present all data publications and documents retrieved from the database as depicted from the initial search performed for the period 2001−2016.

[3] The data used in this study can be found on page 28 of the published report of the FAO (2018).

[4] *Scopus* is the leading abstract and citation databank spanning more than 20,000 peer-reviewed journals in the several fields of social sciences, technology, science, medicine, humanities, and arts (Elsevier, 2020).

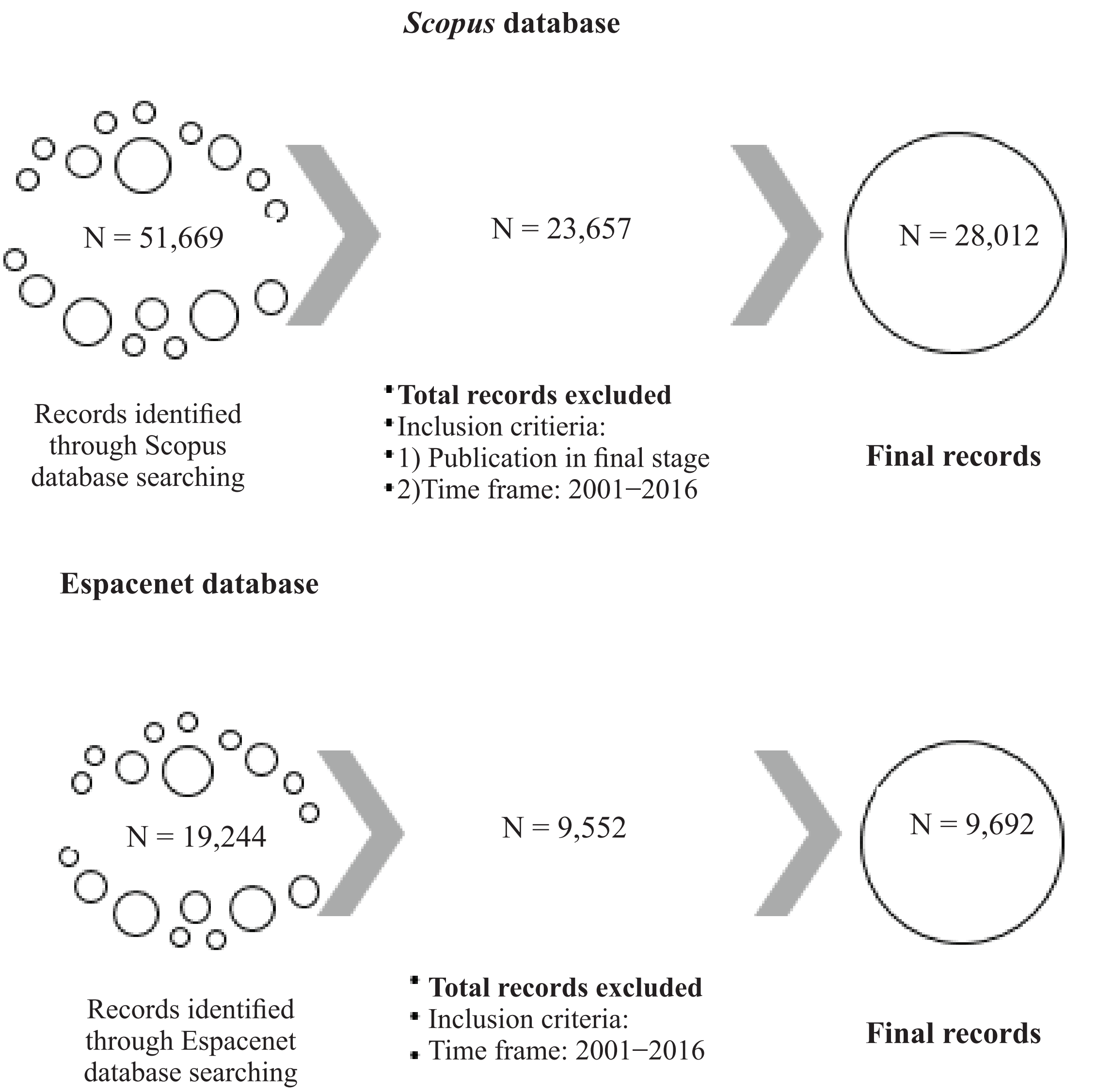

Figure 1. Data collection and inclusion process.

A scientometrics analysis was applied to investigate the abstracted research publications and patent data retrieved for this methodology process. The analysis and correlation from the scientometrics analysis were conducted in reference to the data retrieved from FAO (2018) (Table 1).

Table 1. Data retrieved fields, methods, and analysis.

Data category	Data fields	Scientometric analysis
Publications	Title, abstract, keywords, final publication stage, and publication year.	Publication performance including growth trend of publication documents, top 14 productive countries, and institutions of scientific publications.
Patents	Title, or abstract, and publication date.	Growth rate of published documents, number of documents published by the top 14 productive countries, country patent rank of inventors. and applicants.

Source: adapted from FAO (2018).

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RESULTS AND DISCUSSION

These data were retrieved from FAO (2018) and modified by the authors of the present study. As illustrated in Figure 2[5], out of the 194 active countries and territories with aquaculture production, there are only 14 major countries which are recorded by FAO in the global production of aquaculture; these countries are ranked as follows[6]: China, India, Indonesia, Vietnam, Bangladesh, Egypt, Norway, Chile, Myanmar, Philippines, Japan, Brazil, and the Republic of Korea. FAO has included other minor producers of various countries, taking into account the category labelled as "all others". As per the retrieved data, China is the leading and most significant country in aquaculture and fish farming production; they have surpassed the total amount of other major countries combined. It is apparent that most global aquaculture products are produced in China. China, by itself, showed 49.2 million tonnes of aquaculture products in 2016, while its competitors individually produced less than 6 million tonnes.

Amongst regions, the chief global producers of aquaculture products are Asia and Pacific, producing 62.9% in 2016, followed by South and Latin America (1.4 %), the Middle East (1.3 %) and Europe (1.2 %). Clearly, the other region's production is comparatively minor compared to the region of Asia and Pacific.

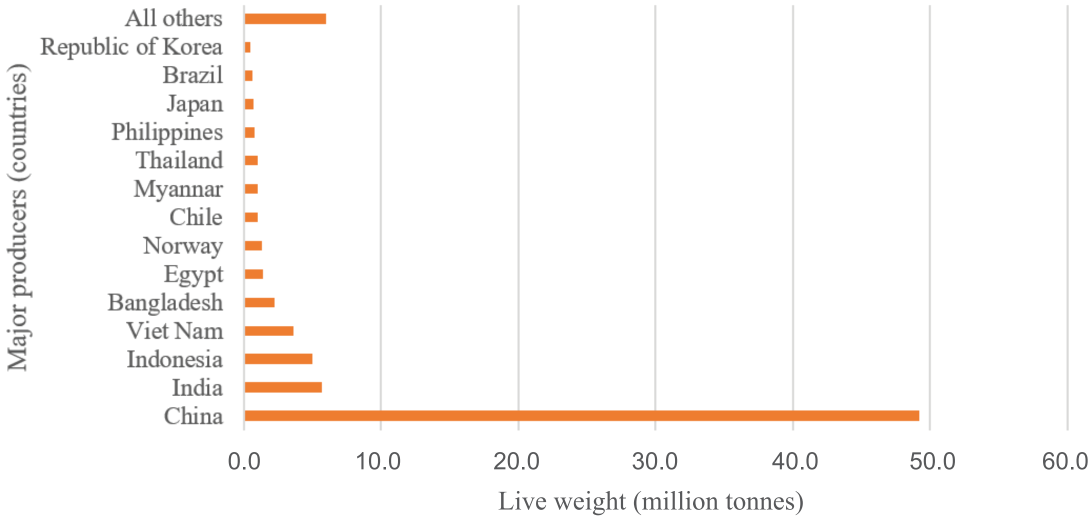

Figure 2. Production of major aquaculture producers, 2016.

Source: adapted from FAO (2018).

Analysis of research publications

Out of the 28,021 publications identified, the top 14 countries/territories represent 88% of all documents retrieved during 2001−2016 (Table 2). The United States published 17.14%, or 4,801 documents on aquaculture or fish farming, which makes it the most significant contributor

[5] Note: The entry of each country represents the production of the final year, 2016. However, the original production representation displayed each country's data for the years from 2001 to 2016.

[6] These countries are ranked based on those producing the excess of 500,000 tonnes in 2016, excluding aquatic plants.

(Table 3)[7]. The other countries that have published the most on this subject consist of China (3,795), United Kingdom (1,806), Spain (1,740), Australia (1, 674), Norway (1,623), Canada (1,576), India (1,410), Brazil (1,312), France (1,173), Japan (1,108), Italy (988), Germany (821), and Mexico (748). As per regions in the ranks, six European countries, four countries/territories from Asia & Pacific, two North American countries, and two South/Latin American countries. Overall, the United States and China are the dominant players and collectively produced about 31% of all publications for that period, in comparison with the remaining 12 countries producing 57.04% jointly. The contribution of documents published obtained from different countries/territories and regions around the world is compelling. However, the bulk of publications and institutions in this field originate from only a handful of countries.

In total, there are 160 affiliated organizations of authors; and the top 14 organizations contributed 19% of the publications derived from 8 major countries (China, Norway, UK, France, Canada, the Netherlands, Brazil and the United States). The top four most productive institutes are all based in China. As the most prolific countries in affiliation, China stands out for the 3,047 publications (10%) yielded by its researchers, in comparison with 9% by researchers of the additional seven countries combined. Overall, the Chinese Academy of Sciences is the leading institute that produced 811 documents, which suggests that China is a significant contributor of research publications on aquaculture or fish farming, by both country and affiliation.

In general, both China and the United States have played a strong and major role in aquaculture scientific research development and fish farming production. As for the United States, ranked number one as the leading country by documents published, it is ranked poorly (#14) in its organizations with which the authors were affiliated. Nevertheless, it is important to recognize that author collaborations are prevalent with such affiliations and play an increasing role in modern research.

Table 2. Top 14 most productive countries of scientific publications and institutes, 2001–2016.

Documents by country				Documents by affiliation			
Rank	Country	Count	N (%)	Affiliation	Count	N (%)	Country
1	United States	4801	17.14	Chinese Academy of Sciences	811	3	China
2	China	3795	13.55	Chinese Academy of Fishery Sciences	512	2	China
3	United Kingdom	1806	6.45	Ministry of Agriculture of the People's Republic of China	401	1	China
4	Spain	1740	6.21	Ocean University of China	395	1	China
5	Australia	1674	5.98	Havforskningsinstituttet	382	1	Norway
6	Norway	1623	5.79	Ministry of Education China	374	1	China
7	Canada	1576	5.63	University of Stirling	369	1	UK
8	India	1410	5.03	IFREMER - Institut Français de Recherche pour l'Exploitation de la Mer	368	1	France
9	Brazil	1312	4.68	Fisheries and Oceans Canada	355	1	Canada
10	France	1173	4.19	Wageningen University and Research Centre	345	1	Netherlands
11	Japan	1108	3.96	Shanghai Ocean University	280	1	China
12	Italy	988	3.53	Institute of Oceanology - Chinese Academy of Sciences	274	1	China
13	Germany	821	2.93	UNESP - Universidade Estadual Paulista	269	1	Brazil
14	Mexico	748	2.67	Auburn University	267	1	USA

Source: adapted from Elsevier (2020).

[7] The table is ranked according to the number of publications that each country produced.

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Analysis of patents

As expected, among the reviewed patents in this study, China's contribution outnumbered all other countries collectively in this category, making it the leading country for patent document publications for aquaculture and fish farming. China has published almost 80% of all documents during 2001−2016, while the remaining countries are approximately 20% combined. China is followed by the United States (4.7%) and South Korea (4.7%). These are the top three countries in this category; the other countries and organizations individually published less than 4% of patent documents.

On the subject of inventors, thirty inventors were retrieved for the period limited to 2001–2016. However, the top 14 inventors in this line of work were identified as China (27.9%), United States (18.7%), South Korea (15.7%), Norway (4.9%), Taiwan (4.1%), Canada (3.5%), Germany (3.1%), Chile (2.5%), Russia (2.3%), United Kingdom (2.2%) Australia (2.0%), Japan (2.0%), Israel (1.8%), and France (1.5%). In this category, China is also the leading country, as per the number of documents by inventors, followed by the United States and South Korea. Amongst applicants, the rankings by documents per country are very close to that of inventors. China, the United States, and South Korea filed the majority of patent applications with 28.1%, 18.0%, and 15.9%, respectively. The patent output of aquaculture and fish farming during 2001−20016 is summarized in Table 3.

As to regions, the most common ones for all categories included Asia & Pacific, North America, Europe, and South/Latin America. From the four regions, the most outstanding in this patent analysis are Asia & Pacific, North America, and Europe. From the allocation of countries/regions, it can be seen that China, the United States, and South Korea ranked the top three leading countries in all patent categories, in the field of aquaculture and fish farming. As a matter of fact, China, unquestionable, is the most competitive and dominant country on the topic of patents in this field compared to the other countries and/or organizations, and to some degree, the region of Asia & Pacific.

Table 3. The fourteen most productive countries, according to the number of patent documents published, inventors, and applicants of patents by country, in the period 2001–2016.

	Number of documents published per country / Organization		Number of documents per inventors by country		Number of documents per applicants by country	
Rank	Country	Count N (%)	Country	Count N (%)	Country	Count N (%)
1	China	77.9	China	27.9	China	28.1
2	United States	4.7	United States	18.7	United States	18.0
3	South Korea	4.5	South Korean	15.7	South Korea	15.9
4	WIPO(1)	3.6	Norway	4.9	Taiwan	4.2
5	Japan	1.6	Taiwan	4.1	Norway	4.2
6	Canada	1.6	Canada	3.5	Germany	3.9
7	Australia	1.3	Germany	3.1	Canada	3.4
8	EPO(2)	1.2	Chile	2.5	Belgium	2.5
9	Taiwan	1.2	Russia	2.3	Japan	2.2
10	Russian	0.7	United Kingdom	2.2	Australia	2.1
11	Mexico	0.4	Australia	2.0	Russia	2.0
12	United Kingdom	0.2	Japan	2.0	United Kingdom	1.9
13	Germany	0.2	Israel	1.8	Chile	1.8
14	New Zealand	0.2	France	1.4	Israel	1.7

(1)World Intellectual Property Organization. (2) European Patent Office.

Source: adapted from European Patent Office (2020).

Growth trends of publications and patent output

There has been a steady increase of both research publications and patent documents over the period 2001−2016 (Figure 3). The growth of scientific documents published between 2002 and 2004 was zero; however, from 2005, the number of research publications has rapidly increased, with 9.24% average growth rate of scientific research publications per year. The number of patents also grew; however, the growth remained constant throughout the period, with 20.75% annual growth. For patents, the European patent applications are typically published 18 months following the date of filing or earliest priority date (European Patent Office, 2020), which has resulted in zero publication number of patent entries in 2016. Overall, based on these current growth trends, we can assume that the future potential and productivity of patent and research publications in aquaculture and fish farming will experience even greater peaks on a global spectrum.

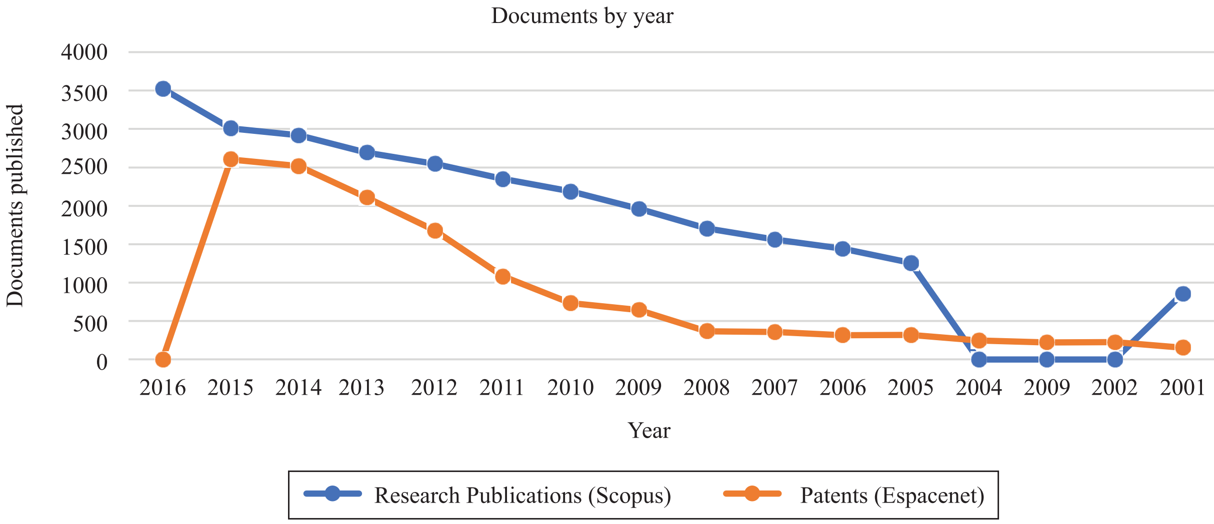

Figure 3. Growth rates of research publications and patents from 2001 to 2016.

Source: adapted from Elsevier (2020).

Next, we present an analysis of all the logical relations between the top fourteen significant aquaculture-producing countries and the spread of research and innovation from the various countries, during the specified period. The visualization of the top countries originating from each classification in the domain identifies that China and Japan clearly dominate all fields, including aquaculture fish farming production, research, and innovation output (Figure 4). Brazil, India, and Norway are the main prevalent countries contributing to both production and scientific research developments, but they are absent in patent outputs. The same way, South Korea is a key contributor to both aquaculture production and patent development, but it is deficient in scientific research. Furthermore, it can be observed that the most common countries for contribution to only scientific and patent outputs for this period originated from the United States, the United Kingdom, Australia, Germany, Canada, and Mexico. Spain, Italy, France, and Malaysia share in the development of scientific publications solely, whereas; Taiwan, Russia, New Zealand, WIPO, and EPO are common for their contribution to only patent publications.

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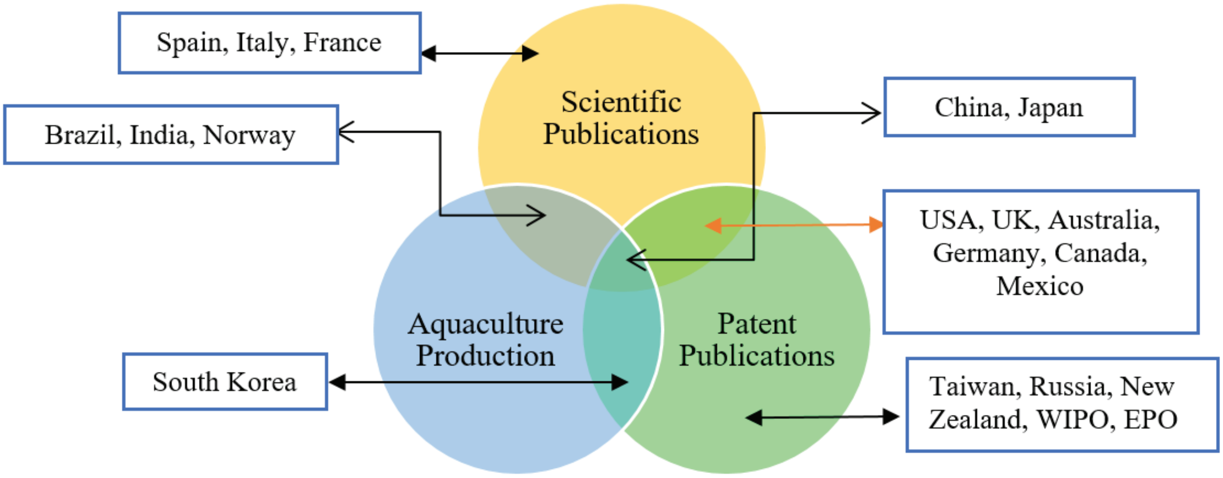

Figure 4. Major productive countries of aquaculture production, scientific and innovative outputs, 2016.

Source: FAO (2018); Elsevier (2020); European Patent Office (2020).

Publications

To examine the growth rate of science, publications are known to be a relevant source of data; it is also generally acknowledged that academic research through a mixture of new knowledge production, research and development, and enhanced human capital contributes to the culture of economic growth (Bornmann & Mutz, 2015; Kim & Lee, 2015). However, it is important to consider that the nature of economic and research performance varies from country to country (Kim & Lee, 2015). As reported by Inglesi-Lotz & Pouris (2013), this relationship is dependent on the country's stage of development, along with distinct scientific disciplines. The author further explained that the correlation or impact for developing countries is less significant than that for developed countries.

Nonetheless, several studies have fully established that there is definitely some type of association with research output as a measure of accumulated knowledge that fosters economic growth and *vice versa* (Inglesi-Lotz & Pouris, 2013). For instance, economies that place greater importance on the role of knowledge are considered, based on their construct, as knowledge-driven economies or knowledge-based economies. These economies are technologically competitive and are driven by scientific research and science, which plays a vital role in economic growth (Nguyen & Pham, 2011; Rosenbloom et al., 2014). The accumulation of knowledge is significant in the international competitiveness and productive capacity of a country (Inglesi-Lotz & Pouris, 2013).

It is recognized that one critical method used to discover a country's scientific activity, research performance, and even scientific innovation is to measure the number or quantity of scientific research output publications in peer-reviewed academic journals, against the rest of the world (Nguyen & Pham, 2011; Inglesi-Lotz & Pouris, 2013; Kim & Lee, 2015). Hence, it is recognized from the scientific publication analysis of the present study that China and the United States were the driving forces in scientific research and development of aquaculture and fish farming. These economies are considered more technologically competitive, as their global share in scientific research output and their emphasis on scientific knowledge development in this industry has surpassed all other nations in these fields. The other countries, albeit producing significantly less than China and the United States, are also impactful players in this specific domain, in that they are representations of scientific manpower through the value and quantity of research publications (Pouris & Pouris, 2009).

Moreover, it is widely acknowledged that, behind high-technology and economic growth, the major generator is public science that is conducted in public research institutes, including universities, academic and governmental research organizations and is backed by governmental and charitable institutions (Narin et al., 1997; Kim & Lee, 2015). According to Antonelli & Fassio (2016, p.538) "[…] the economic performances of countries have been strongly linked to the quality and efficiency of their academic system". Along these lines, we can conclude that the major most productive (fourteen) universities or affiliations for the research output of aquaculture and fish farming originated from China, Norway, the United Kingdom, France, Canada, the Netherlands, Brazil, and the United States, which are heavily supported and most likely highly funded, or which have received large public investments in research and development in this specific domain, in comparison to other countries and affiliations around the world. Therefore it is clearly understood that developments in scientific knowledge promote the nation's economic growth, creating an incentive for governmental support of academic research (Rosenbloom et al., 2014).

To increase research production also suggests the increase of the quality of human capital, which is an important facet of economic life, as it deals with the accumulation of new knowledge (Inglesi-Lotz & Pouris, 2013). The high quality of human capital is related to factors such as higher education, training, and research activities, size of research output and community (Inglesi-Lotz & Pouris, 2013). Therefore, we can assume that the fourteen most productive countries contributing to research production in this field displayed a higher-quality human capital which is above average compared to the rest of the world. However, the quality of human capital is even greater in China and the United States, from the perspective of publications, thus fostering changes of economic performance. For instance, these countries would have exhibited improved involvement and production in research activities such as literature, methodology, and research output, and included a greater number of scholars, scientists, and graduate students in these fields.

Furthermore, as specific to the field, the role of scientific knowledge as a sole direct determinant of economic growth originating from countries such as France, Italy, and Spain may not be as great or influential to economic growth as the previously mentioned countries. To put it differently, inputs of both technological knowledge and scientific knowledge together with the industrial sector are shown to be more influential in the aspect of fostering economic growth (Kim & Lee, 2015).

It is important to keep in mind that the index generally used for measuring economic growth is the gross domestic product (GDP). Although the scientometric analysis is considered an alternative objective approach, it is still difficult from an empirical perspective to clearly identify the impact of each academic field on the economic performances of a country. To put it another way, whether aquaculture or fish farming impacts economic performance or not is difficult to determine. This is due to the fact that several other variables − institutions, culture, the industrialization of a country, and the relationships − are interconnected mainly with the quantity and availability of knowledge, its use in the business sector, and the exploitation of innovations. Considering all aspects, the academic system is thought to play an essential role in the fostering of economic growth; however, in doing so, it is important to understand which specific academic fields are in a better position to promote economic growth (Inglesi-Lotz & Pouris, 2013; Antonelli & Fassio, 2016).

Patents

The role of intellectual property protection, specially the patent system, promotes innovation, product development, and technical change through new knowledge, which is a key factor in the fostering of international trade, economic growth, technology and industrial development of a country, as well as regional development (Basberg, 1987; Maskus, 2000; Acs et al., 2002; Kumar, 2003).

There is evidence that the measuring of these knowledge inputs and outputs is important to understand both roles of knowledge and innovation at the industry, state, and economy levels (Acs et al., 2002). Although the effectiveness of patent protection differs from industry to industry (Kumar, 2003), based on empirical evidence, patents are suggested as a tool to provide a dependable measure of

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innovative activity (Acs et al., 2002). According to Kalanje (2006, p.6), “Patent documents continue to be a relevant source of information that is often grossly underutilized”. Patent documents offer a wealth of information with over 800,000 annual patent grants confirmed worldwide (Kalanje, 2006). Moreover, patent data are generally used to gauge the movements of patents amongst countries, in order to evaluate the dissemination of technology (Basberg, 1987).

The research of patent analysis for field and practicality has been regarded as a helpful macro-analysis amongst several agents, including academicians and policymakers. There is also evidence to back a positive causal connection between the strength of patent rights and innovation (Yoon & Park, 2004; Williams, 2017). Technological knowledge on economic growth is mainly measured by the number of patents (Kim & Lee, 2015). In the present study, we used the number of patent documents in our analysis.

The manner by which the IPRs effort foster economic growth and development is a complex process centered on several variables. Nevertheless, a strong innovative activity of IPR system shows the value for creating economic growth, and it could indirectly contribute to growth through the improvements of productivity, international trade, FDI (Foreign Direct Investment) inputs, and technology transfer, including country and community income relocations (Maskus, 2000; Kumar, 2003; Atun et al., 2007). Likewise, intellectual property policies foster poverty reduction (Fink & Maskus, 2005). As reported by The Organization for Economic Cooperation and Development (OECD), to encourage a long-term economic growth, an innovative environment is essential (Atun et al., 2007), also in the view of economic globalization, which is becoming ever more vital for economic growth and competition (Fink & Maskus, 2005). Overall, intellectual property rights and protection are essential growth elements (Gould & Gruben, 1996).

Similarly, patent analysis is often used to assess multiple factors, including the competitiveness, market share, and technological change of [countries], investment focus on research and development, or decisions to invest in innovation, flows of technological knowledge and its impact on the productivity and innovative performance in the international environment (Yoon & Park, 2004; Atun et al., 2007). It is important to note that the positive effects on the economic growth and development are thus greatly dependent on the competitiveness of each specific country, based on their circumstances and economy (Maskus, 2000; Atun et al., 2007). Nonetheless, we will use the above mentioned indicators in our analysis for the present study.

In accordance with the data retrieved from the EPO, in 2001–2016, China was the most prolific or innovative country for both the number of patent documents published, inventors, and applicants of patents of aquaculture and fish farming production. In general, the Intellectual Property (IP) system in China was progressively well-developed. China is a major technology and IP generator and, in the next decade, its patents creation will the country to dominate significant technology areas, thanks to the fact that China emphasis and recognizes the importance of IP to economic growth (Atun et al., 2007). Moreover, the second and third places are held by the United States and South Korea, respectively. The US has strategically created an IP infrastructure at a country level, thanks in part to policymakers (Atun et al., 2007). And, South Korea has been adopting stronger patent regimes, in general (Kumar, 2003).

In our patent analysis of aquaculture and fish farming, these prolific countries are highly concentrated and represent a minority of countries. Globally, these countries are viewed to have more robust patent regimes in this domain. We can assume, as per industry, that these countries are more competitive and have stronger market power and share; they are highly efficient in aquaculture and fish farming, regarding FDI inflows, increased investments in knowledge creation, and greater research and development, as well as openness to trade (Maskus, 1998, 2000; Fink & Maskus, 2005). According to Maskus (2000) inventive countries are inclined to steer their research programs in the direction of technology and products for which they anticipate a substantial global demand. As such, we can safely assume that these countries have taken the incentive to direct their research programs for aquaculture and fish farming production to a greater extent than other nations. Besides, we can infer that these countries hold stronger foreign investment, foreign trade, and a flow of new technology [in this area] than their competitors (Thompson & Rushing, 1996). Overall, these patent analysis indicators measure the connection between technology development and economic growth (Yoon & Park, 2004).

Conversely, the other countries in this analysis are considered to hold weaker patent rights in aquaculture and fish farming production. In economic terms, those weak in patents are assumed to have lower research and development, reduced innovation, suppressed technical change, inadequate patent industry policies, and are less competitive in the industry globally (Maskus, 1998, 2000).

There can be several reasons why countries have no, or weak patent enforcement, concerning high aquaculture fish farming production. These countries with weak or no patent enforcement may also indicate the country's unwillingness to cover administration costs and the inability to fully manage the demands of such a system (Mansfield, 1986; Maskus, 2000). Comparatively, we can also presume that these countries experienced weak inward trade and flow in FDI in aquaculture due to the lack of innovative inputs and technology, resulting in low domestic patent productivity in aquaculture (Maskus, 2000).

We should point out another fact worth noting, in general, trade protection is a significant factor in weak patent systems across many countries. As a matter of fact, it was shown from a survey conducted of over 3,000 Brazilian companies, that confirmed that the degree of trade protection was negatively impacting their own technological developments (Fink & Maskus, 2005). As illustrated in the present study, Brazil is highly active in both aquaculture fish farming production and scientific publications, but it is extremely weak in patent enforcement. Brazilian's weak protection for innovation discourages technological advances, since the venture is a disadvantage (Gould & Gruben, 1996). As such, the lack of patent protection may also be a major element to other absent or low-performing patent countries in this study. Thompson & Rushing (1996) stated that the results of weak [patent] enforcement might, to a certain degree, result in economic stagnation or slow growth rate by various less-developed countries.

The number of patented inventions is considered a major aspect of the innovative process and is a good indicator of measuring technological change and creation (Maskus, 1998; Acs et al., 2002). Thus, an environment that protects [patents] boosts inventions (Atun et al., 2007). Countries in our data set, their rank in patent inventions, and applications across countries and the number of patent documents per country are pointed out (Table 3). Without controlling for other key determinates of growth and in comparison, to other countries, China, the United States, and South Korea held the highest rank of patent inventions and applications; hence, we can assume that these countries have an advanced environment that protects patent inventions, and they have also greater technological changes and creations, representing a stronger innovative activity in aquaculture and fish farming technology. However, those countries with a lower ranking of patent inventions are less innovative, but they still contribute to aquaculture technological development, albeit to a lesser extent. Nevertheless, it is important to realize that although inventions are good indicators of economic growth, several other factors should be considered before any conclusion can accurately be affected (Gould & Gruben, 1996).

In practice, each patent office is different in its processing and services, which in turn influences inventors' interest in the application process (Archibugi & Pianta, 1996); there are several general factors at stake for weak patent inventors. These include the high cost or capacity to finance the patenting, undesirable projected income, the ease and ability for a competitor to copy the patent, the projected economic life of the invention, patent processing and, notwithstanding, the factor of uncertainty (Basberg, 1987). The data from the present study indicated that although the major countries dominate the top three positions, other less significant countries are involved in the active patenting development of aquaculture and fish farming production. As per these indicators, we can assume to some degree that these countries may share one or more of these factors in the considering of patenting.

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Several points are often overlooked regarding patents. Thus, it is important to mention that not all new inventions are patented, and alternative methods are often used (Archibugi & Pianta, 1996; Acs et al., 2002). Similarly, inventions patentability has very little connection to its economic importance (Basberg, 1987); also, patent data is not a sound reflection of the innovation and can be overstated (Nelson, 2009). Empirical evidence showed that to stay competitive many companies have a higher preference for trade secrets, as opposite to patents, or patent documents, due to their costs and system complexity (Kalanje, 2006).

Another key point to remember is that one size does not fit all, which means that the economic growth is dependent on specific circumstances in each country and varies widely across countries, for which various macroeconomic elements should be considered, such as the liberalization of trade regimes and trade policies, the openness of the economy, market structure, competition policies, a substantial level of GDP per capita, technology infrastructure, and the accumulation and stock of human capital and knowledge. Nevertheless, evidence is emerging that stronger [patent] systems could foster technical change and economic growth, while encouraging effective and dynamic competition (Gould & Gruben, 1996; Maskus, 2000; Atun et al., 2007).

Implications

The findings of this study confirmed that most of the top fourteen major aquaculture-producing countries, listed by FAO in 2016, held weaker patent regimes within the industry than scientific publications (FAO, 2018). An important aspect of this article is to provide insight into these major aquaculture and fish farming producers, especially those weaker in technology production, as a means to increase overall productivity and competitiveness. As we have observed, China's fish farming production, research, and innovation performance in this field is unparallel, in comparison with the rest of the world. China´s status and contribution to aquaculture is not a surprise and may lead to the economic growth of this nations (Inglesi-Lotz & Pouris, 2013). Japan has also shown strong evidence of the sector development concentration efforts, thus indicating a strong capacity in boosting economic growth. One reason for this is that Japan has become a world leader in technology creation, its patent regime objective is to gear toward safeguarding essential technologies (Maskus, 2000).

To become more competitive, these aquaculture-producing countries need to adopt new systems and techniques that can significantly increase productivity, specially countries that retain weaker standards and productivity of both technology and science. These countries could increase their efficiency with the required investments, which are crucial for increasing productivity toward the aquaculture and fish farming industry. The collective impacts of these investments can be critical for growth of industry productivity and knowledge. Technological development varies considerably between nations within the aquaculture industry; this is presented in this study's patent statistics, which displayed a difference in the number of patent documents. As established, even among countries, there might be significant differences for patent policies and legislations. As recognized in the present study, one of the major probable reasons for this fact is that a major or even the most influential factor in patent regimes is policy and trade protection.

Nonetheless, on the path of strengthening patent systems and laws for producing countries of aquaculture and fish farming, it is recommended that governments (most importantly) should create technological policies that motivate innovation and encourage patent inventions. It is also necessary to provide technical training in the development of new technologies, and to create a supportive environment that promotes foreign investment, specially for countries with weak patent protection. Likewise, the encouragement is essential for the expansions of research and development through technological programs, to foster information sharing, research partnerships, support, and development contracts between private and public research organizations (Gould & Gruben, 1996; Maskus, 2000; Atun et al., 2007; Moser, 2013). In a nutshell, intellectual property is a potent advantage and good strategy for economic growth, and patent rights matter significantly for the development of this industry, which is also conducive to growth (Gould & Gruben, 1996; Maskus, 2000; Atun et al., 2007).

Limitations

This study has several limitations that should be clarified. Firstly, we already discussed the limitations in the data screening process for patents using the EPO database. Secondly, the three types of data were retrieved and investigated independently and were not directly mapped, or integrated between each country's GDP, or other macroeconomic factors. Thus, although there is a linkage between science, technology, and economic growth with several correlations within this study, the authors could not interpret a direct relationship with each country's level of research publications, patents, and production of aquaculture and fish farming to economic growth. We observed that numerous country-level and sectoral factors influence the development of science and technology in aquaculture and fish farming. Nevertheless, our findings provided a synopsis of the countries, regions, and organizations of research publications and patents, in addition to major aquaculture producers. Overall, this formation has shown a complementary insight into the development of research and science of major aquaculture producers in 2016.

CONCLUSIONS

In the final analysis, our results indicate that there is a lack of science and technology integration amongst the major aquaculture producers. Besides, this study suggests that the majority of the producers have dominated its integration in science or research with a very limited number of producers accounting for the significant proportion of patent publications in this field. The study further indicates that the growing concentration of both patenting and publications collectively is derived from countries that are not major aquaculture producers in this sector. Integrations of this sector are among limited countries and institutions, but the development of science, technology and fish farming production is dominant amongst a limited number of bigger players in this sector.

All things considered, technological and scientific inputs together with the industrial sector are shown to be more powerful in the aspect of economic growth culture; in this case; this study confirms that China and Japan are the most prominent countries in this sector, with an emphasis on their higher productivity of academic research and patent technology development, along with the industrial sector, for aquaculture production development, thus stimulating industry development, plus growth and performance at country level.

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