Marine Policy 110 (2019) 103561

Contents lists available at ScienceDirect

Marine Policy

journal homepage: www.elsevier.com/locate/marpol

The Norwegian seafood industry – Importance for the national economy

Ulf Johansen[a,*], Heidi Bull-Berg[a], Lars H. Vik[a], Arne M. Stokka[a], Roger Richardsen[b], Ulf Winther[b]

[a] SINTEF Community, 7465, Trondheim, Norway
[b] SINTEF Ocean, 7465, Trondheim, Norway

ARTICLE INFO

Keywords:
Input-output analysis
Seafood industry
Fisheries
Aquaculture
Policy makers

ABSTRACT

Harvesting, processing, and exporting of seafood are longheld traditions in Norway due to its vast marine resources. In the 1970s, Norway became an international leader in marine aquaculture. The seafood industry is of great importance to the Norwegian economy. This paper documents the seafood industry's direct and indirect effects on Norway's economy from 2004 to 2017. We use a national Input–Output model to quantify to what extent the Norwegian seafood industry has created appreciable effects both in the core industries of the value chain, as well as in the supplier industries and other industries through ripple effects. The total contribution is measured in terms of value added (contribution to GNP) and employment (FTE). We find particularly high growth in total value added generated by the seafood industry during the period. However, within the seafood industry, there are different trends associated with development for the value chain of fisheries and aquaculture. The value chain for aquaculture, which includes its impacts on other industries, is the fastest growing part of the seafood value chain, while fisheries show a more moderate growth. Hence, aquaculture became the dominant part of the Norwegian seafood value chain from 2010 to 2013 and onwards measured in value-added and employment, respectively.

1. Introduction

Norway's export revenue has always been dependent upon the marine resources that long coastline provides. According to a speech given by the governor of the central bank of Norway, Øystein Olsen [28], sale of fresh and processed fish constituted 39% of the export revenue in 1835, while 25% came from shipping services. More than a century later, in 1966, shipping represented roughly 40% of Norway's export revenues, but fisheries were still an important contributor to; almost 5% of the export revenue came from fish and processed fish. Later, the oil and gas industry became the most important sea-based exporter. Today, Norway is the world's second largest exporter of fish and seafood with an export value reaching NOK 94.5 billion in 2017. This is the highest export value ever seen within the industry and while petroleum revenue constitutes 38.5% of the export revenue, fish and seafood stand for 7.9% [26].

Both fisheries and aquaculture have been, and are, regulated by the government. The importance of fisheries for the Norwegian economy is emphasized by the fact that in 1946 Norway was the first country in the world to establish a separate Ministry of fisheries. The seafood industry is important for public authorities along two dimensions. First, it is important for generating export revenue. Second, it is important for value creation and employment in coastal areas, especially in the northernmost counties. Fig. 1(a)–1(b) show the spatial distribution of the fisheries fleet and accepted sites for aquaculture respectively in 2018. While our paper is focused on the importance of fisheries and aquaculture for the Norwegian economy as a whole, these maps show the importance of fisheries and aquaculture for employment and settlement along the Norwegian coast.

The Norwegian seafood industry is expected to further increase its contribution to the national economy. Several reports, public documents and strategies [1,15–17,24] suggest that there are high expectations and potential for the industry to increase in volume and better utilize residual raw materials (circular economy). The supplier industry associated with the aquaculture industry is also growing rapidly and, in the future, Norwegian aquaculture will likely also include more species than just salmon, including algae, such as seaweed. The farming of Atlantic Salmon (*Salmo salar*) has the potential to grow by a factor of five by 2050 [20], and the continued position of this industry, as a global leader in production and export, is defined as a political objective in the national marine strategy [15]. We assume that a prerequisite for this is that climate change does not become more dramatic than assumed and that today's challenges with respect to negative environmental impact and disease within the aquaculture industry have

* Corresponding author..
E-mail address: ulf.johansen@sintef.no (U. Johansen).

https://doi.org/10.1016/j.marpol.2019.103561
Received 21 December 2018; Received in revised form 13 May 2019; Accepted 21 May 2019
Available online 03 June 2019

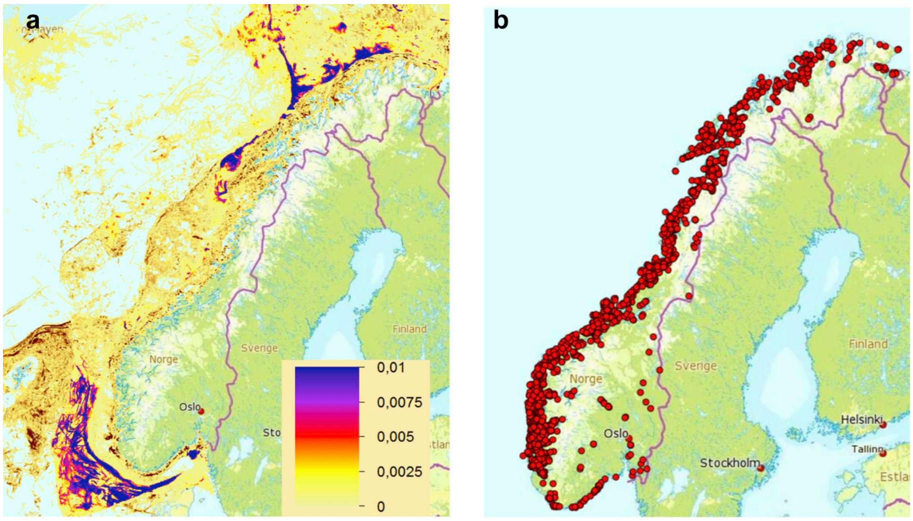

Fig. 1. Spatial representation of the seafood industry in Norway [2]. a: Fisheries activity level – fishery intensity is measured in length (m)/area (m2), 2018. b: Aquaculture sites in Norway – red dots show all accepted sites, 2018.(For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

been solved [7,20]. A predictable regulatory regime will also be crucial.

Given the expected future potential addressed in Olafsen et al. [20] for increased value creation and employment, a systematic measurement and quantification of the industry's economic impact is important for a variety of reasons. Empirical data, monitored annually over a long time span, serves as a knowledge-based decision support for sustainable and targeted policy-making. Further, this kind of key knowledge about the industry's performance (both in the core activity and supplier industry) is highly valued by the different actors in the value chain. It may also contribute positively to society‘s perception of the industry, which is an important element when arguing for the legitimacy of increased aquaculture production.

This paper documents the Norwegian seafood industry's direct and indirect economic effects at a national level from 2004 to 2017. We use an Input–Output model to quantify to what extent the Norwegian seafood industry has created appreciable effects both in the core industries of the value chain, as well as in supplier industries through ripple effects. Although the I–O methodology dates back to the work of Leontief [9], our paper will contribute to the literature in two new ways. First, our work is based on results from a series of annual reports for the seafood industry that documented the ripple effects from 2004 to 2017 [21,22]. By explicitly measuring the size of the seafood industry and its estimated ripple effects in other industries over such a long time span, we provide insight that has not yet been addressed by other research. Second, we focus on the ripple effects in a value chain perspective by separating the seafood industry into an aquaculture and fisheries value chain. This distinction is highly relevant for Norway because aquaculture and a fisheries are quite different with respect to production technology, market price exposures, supplier industries, regional representation, environmental side effects, future growth potential, and relative importance for the Norwegian economy. Hence, we are able to construct production value chains for both the fishery and the aquaculture industries to adjust an initial I–O table and model simulations to fit into the Norwegian seafood value chain perspective. To the best of our knowledge, both the time series perspective and the split and estimation of the seafood industry into separate value chains is a new implementation, not investigated in the literature.

The rest of the paper has the following structure: In Section 2 we provide a summary of articles with analyses of marine industries using an I–O methodology. We then give an introduction of our I–O model and the data used in the analysis in Section 3. The results of the analysis are included in Section 4, while concluding remarks finalize the paper in Section 5.

2. Input–Output analyses of marine industries

The Input-Output (I–O) methodology originates from the work of Leontief [9].[1] This methodology is often used to assess ripple effects of exogenous changes in final demand, e.g., changes in exports or the ripple effects caused by establishing a new company within an existing industry. Several publications utilize this methodology to quantify the effects of various marine industries, while other studies use alternate methodologies for the same purpose [23]. We focus this review on relevant I–O analyses. A list of relevant analyses covering marine industries and how they relate to key aspects of the I–O model is presented in Table 1. We review papers concerned with concepts relevant to research questions addressed in this paper. The *Yes/No* distinction in Table 1 relates to whether this aspect is covered by the analysis performed in this paper or not. We include the *No* papers here because this provides a overview of analytical perspectives given by I–O analyses focusing on marine industries.

Analyses assessing ripple effects of the whole marine sector are discussed in Morrissey and O'Donoghue [12] and Huang et al. [6]. Whereas, Garza-Gil et al. [4], Lee and Yoo [8] and Grealis et al. [5] focus on the aquaculture industry. Garza-Gil et al. [4], Lee and Yoo [8], Norman-López and Pascoe [13] and Fuente et al. [3] are more concerned with the economic role of fisheries. In this paper, we focus on both aquaculture and fisheries.

The impact of these industries has been further analysed at various geographical levels. Some studies focus on regional effects of these industries for one specific region [3,4,6,13,23] within a country, while others have a national perspective, as we have in this paper [5,8,12].

The I–O methodology is based on a standardised framework with minor variations in implementation. Mostly, implementation variations are related to how data is used to cover relevant marine industries, whether it is a one-year analysis or an analysis with time series data tables, or which effects from an I–O model are included in the analysis – indirect effects or both indirect and induced effects. First, marine industries are not necessarily very detailed when represented in standard I–O tables. Both Morrissey and O'Donoghue [12] and García-de-la Fuente et al. [3] use additional survey data to supplement the standard official I–O tables in order to have a more detailed representation of marine sub-industries in their analyses. We also put effort into disaggregating I–O tables to improve the detail level of the seafood industry. Second, at the regional level, I–O tables do not necessarily have a yearly publication. Hence, most analyses covered by this review only

[1] See Miller and Blair [11] for a more comprehensive explanation of the methodology.

Table 1
Reviewed papers categorized by content and whether this is covered in our analysis.

		Paper	Covered by the analysis in this paper
Marine Industries	Aquaculture	[4,5,8]	Yes
	Fisheries	[3,4,8,10,13]	Yes
	Total Marine Sector	[6,12]	No
Geographical level	National	[5,8,12]	Yes
	Regional	[3,4,6,10,13,23]	No
Methodological	Data adjustments of I–O tables	[3,8,12]	Yes
	Times series of results	[8]	Yes
	Induced effects	[4]	No
Other effects	Environmental	[6]	No

present results for one year. One exception in the literature is Lee and Yoo [8]. They estimate multipliers for four selected years covering the period 1995–2010. Their results indicate quite stable multipliers over this time span. In our analysis, we try to cover each year between 2004 and 2017. Third, often an I–O model only incorporates inter-sectoral connection effects as the basic model, which are also characterized as the indirect effects. However, as presented in Garza-Gil et al. [4], in addition to the inter-sectoral effects, there are economic effects that materialise through changes in household expenditures, these are referred to as induced effects. At the regional level, as presented in for the Galicia region in Spain in Garza-Gil et al. [4], induced effects are important to give the total picture of the regional economic effects of aquaculture and fisheries. We do not incorporate these effects in our current analysis, but have included induced effects in some regional analyses since such effects are important at the regional level, and may vary between regions. One reason for not including induced household expenditure effects in the national analysis, is that such effects per employee are similar across industries. One important purpose of the national analysis has been to create comparisons with other industries. Adding nearly the same amount of induced consumption effects does not add much in terms of describing inequalities between industries. However, as a measure of the overall importance of the industry, the induced effects could have been included. Our analysis of the fisheries industry can therefore be characterized as conservative with a minimum level of ripple effects.

The activity level of marine industries generally affects the environment negatively. As a consequence, policymakers are interested in balancing positive economic effects to negative environmental effects [15,18]. Huang et al. [6] connects I–O methodology with environmental effects. By introducing an environmental Input–Output (EIO) model, they estimate economic multipliers of marine transportation and water-front tourism and estimate environmental footprints per unit of gross output for these industries. Hence the EIO model is a step forward from the traditional I–O model because it provides a more holistic picture of the economic and other side effects of marine industry activities. These aspects are highly relevant for Norway. Although they are not included in our analysis, we highlight them as potential future research in the Conclusion section of the paper.

Each of the reviewed papers in Table 1 are relevant as a reference when we present our methodology, data, and results for the Norwegian seafood industry.

3. Methodology and data sources

3.1. Methodology - a national I–O model of the Norwegian economy

The term *ripple effects*, for the purposes of this investigation, needs a comment. In general one may distinguish between two main types of economic ripple effects; supply side effects and demand side effects. Supply side effects belong to the category external economic effects and are difficult both to identify and quantify. Demand side effects, on the other hand, are usually possible to both observe and trace. In many cases an I–O model is used to measure the economic contributions from a given sector in the national or regional economy. The I–O model is in its origin demand-driven, and changes in the economy has changes in final demand as a point of departure. As a consequence, economic ripple effects calculated in an I–O model will most often be considered as synonymous with demand-driven or backward effects, related to final demand changes. Hence most reviewed literature presents only demand-driven ripple effects of marine industries. However, when using an I–O model it is possible to calculate supply-driven effects in the meaning forward-linked effects by transforming it to a so-called Gosh model. A thorough discussion of demand- and supply-driven I–O methods and the so-called hypothetical extraction method is given in Miller and Blair [11], and a presentation of applications of the different methods related to the marine sector is to given in Leung and Pooley [10]. Also Morrissey and O'Donoghue [12] and Lee and Yoo [8] use the I–O model to present results of both the demand- and supply-driven effects (forward and backward linkages) related to the marine sector. In our analysis we are calculating total effects by using a counter factual technique based on the hypothetical extraction approach in the I–O model and leave forward-linked effects for the current analysis.

The I–O model relates the gross output $\mathbf{X}$ of the sectors in an economy to the technical coefficient (input) matrix $\mathbf{A}$ and the final demands $\mathbf{y}$ for the output from each sector,

$$\mathbf{X} = \mathbf{Ax} + \mathbf{y} \tag{1}$$

where the $\mathbf{A}$ matrix $= \ a_{i,j} \ = \ z_{i,j}/X_j$ is a matrix of input coefficients indicating how many units of inputs from sector i to j are required to produce one additional unit of output for sector X_j, thus reflecting the economy's production structure. $z_{i,j}$ is the intermediate demand of inputs from supplying sector i to receiving sector j.

A matrix operation transforms Eq. (1) to

$$\mathbf{X} = (\mathbf{I} - \mathbf{A})^{-1}\mathbf{y} = \mathbf{Ly}, \tag{2}$$

where $\mathbf{I}$ is the identity matrix. Eq. (2) expresses total output solely as a function of the final demands and the sectors' production functions, also known as Leontief inverse (or multiplier) matrix $\mathbf{L}$, which can be derived from statistical data. These backward linkages in the form of multipliers help to determine how a change in final demand ($\Delta\mathbf{y}$) affects total output ($\mathbf{X}$) in the economy. Our model is an open I–O model where both foreign exports and imports are treated exogenously, and the ripple effects calculated are thus restricted to reflect domestic or national effects.

In our case, we are calculating the effects on the national economy by eliminating the aquaculture and fishery industries entirely from the I–O table. These value chains consist of several detailed industries (cf. Table 2), and the multipliers related to single industries from the inverse table cannot be used directly to calculate the multiplier or ripple effects related to an assembly of detailed industries. Instead we have chosen to calculate ripple effects related to these value chains by using a counter-factual or a so-called hypothetical extraction method [11]. This is done by constructing a situation where all industries in the value chain are removed from the initial coefficient table $\mathbf{A}$, the output vector $\mathbf{X}$, and the final demand vector $\mathbf{y}$. By resolving the model with these changes, we simulate the production in an economy without the actual value chain. The differences between output values from the two model solutions give the total effect of the value chain and is further split into direct and indirect effects. We are eliminating both the line and column elements belonging to the value chain industries, which gives the total effects.

To quantify the output effects of the activity of an industry (s), we adjust the initial I–O matrix $\mathbf{A}$ to a new matrix $\mathbf{A}^*$ with input coefficients

$a_{i,j}^{*} = \frac{z_{i,j}^{*}}{x_i^{*}}$. Here, $z_{i,j}^{*}$ are the elements of a new intermediate demand matrix, derived by eliminating both industry s's amount of intermediate demand from industry i and eliminating industry s's amount of intermediate deliveries to industry j the original $z_{i,j}$. Finally, $\mathbf{y}^{*}$ is the final demand vector with eliminated final demand in the industry s that we analysed.

$$\Delta\mathbf{X} = (\mathbf{I} - \mathbf{A})^{-1}\mathbf{y} - (\mathbf{I} - \mathbf{A}^{*})^{-1}\mathbf{y}^{*} \tag{3}$$

Eq. (3) shows how we measure the total effect on outputs in a counter factual scenario. In addition to output effects, two other important measures of impact are employment and value-added effects. We have chosen to present ripple effect results related to the two last-mentioned effects, because employment is always an important characteristic of industrial activity, and value added is an important measure of contribution to GNP. To further go from output effects ($\Delta\mathbf{X}$) to value added and employment effects, we multiply the output effects with the value added and employment shares of output in each industry respectively.

In the current analysis, we simulate the effects of more than one industry s in the I–O table, $\mathbf{A}^{*}$ and $\mathbf{y}^{*}$ are adjusted similarly for all s.

2.2. Times series of national account data and survey data from the seafood industry

The data we use to measure the effects in Eq. (3) are collected from a variety of sources. First, we use key figures from the national account allocated to 50 different industries[2] [25]. These data have been consistently delivered to our I–O model by Statistics Norway according to industry aggregation methods used since 2004.

In order to describe complete value chains for fisheries and aquaculture separated, we split three of the official national account industries as described in Table 2. These industries are *Fish processing* and *Wholesale trade*, which are disaggregated into fish and aquaculture specifics. We also split the *Manufacture of food* into fish feed production and a catch-all food industry category. This is done because fish feed production is the most important input in aquaculture production and this industry is quite different with respect to production technology compared to the rest of the food industry.

The disaggregation method we use is based on a method described in Wolsky [27]. We compile survey data for each year on outputs of the sub-industries in the last column of Table 2. To collect these data, we used accessible open sources, the Norwegian Directorate of Fisheries, the different sales organisations, and the Norwegian Seafood Council. We also used Statistics Norway for wholesale data. For each of the three industries, we have parameters w_1 and w_2 (in the last case we also have w_3), which in sum represent the gross output share of the initial aggregated sector. These parameters are further used to extend the initial I–O table in line with the method of Wolsky [27].

As a first step, this method is sufficient to give a consistent extended I–O table extended from 50 to 54 industries. However, the I–O table at the current stage does not have the correct relationship between fisheries and aquaculture and the respective fish processing industries. Hence, we adjust the technological coefficients of the new industries based on industry relation-knowledge (e.g., intermediate deliveries (z) from aquaculture to wild fish processing ($z_{4,8.2} = 0$) is set to zero whereas the initial value is added to $z_{4,8.1}$. We perform a similar adjustment to deliveries from fisheries to aquaculture processing $z_{3,8.1} = 0$. Moreover, to eliminate the relationship between farming and fish feed production, which we know does not exist, we reset the technological

Table 2
Expansion of industries in the data from the National Account.

Industries as registered in the National Account (see Appendix Table 15)	Constructed sub-industry categories for the purposes of value chain analysis of the seafood industry
8. Fish Processing	8.1 Aquaculture processing
	8.2 Wild fish processing
9. Manufacture of food	9.1 Fish feed production
	9.2 Rest of manufacturing of food
27. Wholesale trade	27.1 Aquaculture wholesale
	27.2 Wild fish wholesale
	27.3 Wholesale rest

coefficients of farming deliveries to fish feed production ($z_{1,9.1} = 0$), whereas these deliveries are added to an intermediate relationship from farming to the rest of food production ($z_{1,9.2}$).

These manual adjustments, included as a second stage to the disaggregation method, are, to some degree, arbitrary, because we do not inspect and adjust all intermediate-delivery relationships (based on *a priori* industry-relation knowledge) in the same manner. However, working with these analyses over several years made us observant of critical relationships to note for the final results. In particular, when analysing the aquaculture value chain, we noticed that farming deliveries to fish feed production generated large ripple effects as this is an important supplier to the aquaculture industry. For this reason remaining intermediate deliveries from farming to fish feed production are moved to the rest food production industry ($z_{1,9.2}$). Including this adjustment in the disaggregating routine, we only see minor ripple effects from aquaculture to farming industry, which seems as a more realistic result.

This restructuring of the I–O table data enables us to model and measure core parts of the Norwegian seafood industry value chains in total or grouped. These industries are(see Table 3):

If we organize the core part of the value chain grouped by fish raw material, we can divide these two value chains by sub-seafood industries as presented in Fig. 2.

The total seafood industry including the fisheries, aquaculture, fish processing, and wholesale trade is the sum of the two sub-value chains. Where the aquaculture value chain consists of the aquaculture industry, including breeding, smolt production in hatcheries, on-growth production in net pens, slaughtering, processing, and wholesale trade. The fisheries value chain consists of the fisheries, processing, and wholesale trade.

With the I–O data, we can compare a status analysis of the Norwegian economy with the seafood industry as it is today (the left side part of Eq. (3)), with a scenario where the seafood industry is not a part of the Norwegian economy (a counter factual scenario, right side part of Eq. (3)). In the latter case, we solve the model with new parameter values reflecting the absence of the seafood industry. We argue that the differences between the scenarios illustrate the contribution of the seafood industry in the Norwegian economy, comprising both direct and in-direct effects of both sub-value chains or the sum of these as described in Fig. 2. These ripple effects are calculated first in terms of gross production derived from Eq. (3) and are further re-calculated to yield value added and employment effects. These results are further presented in the next section.

4. Results

In terms of contribution to economic growth in the Norwegian gross national product (GNP), the seafood industry is one of the most successful starting as far back as 1970. At a macro level, this is shown in Fig. 3. Since 1970, the average increase in contribution to GNP per year from fisheries and aquaculture is 19%, in current prices, with particularly strong growth from 1990 onward. In comparison, the average

[2] The names of the 50 industries are presented in the Appendix, Table 8. All industries are classified according to the NACE code system. This is a system that groups enterprises according to their business activity. We took this five digit code and aggregated industries at different digit-levels. In some cases, we use code at the five digit level, for others we only use the first digit of the code.

Table 3

Fisheries value chain	Aquaculture value chain
3. Fisheries 8.2 Wild fish processing 27.2 Wild fish wholesale	4. Aquaculture 8.1 Aquaculture processing 27.1 Aquaculture wholesale

increase in GNP for Norway is 8% and for the manufacturing industry only 3% in the same period [25]. Both fisheries and aquaculture have had substantial growth in productivity per employee (GNP/FTEs). Aquaculture is ranked number four, well above the average for Norway, while fisheries is ranked at number twelve. Nevertheless, both industries are among the most productive in the Norwegian economy.

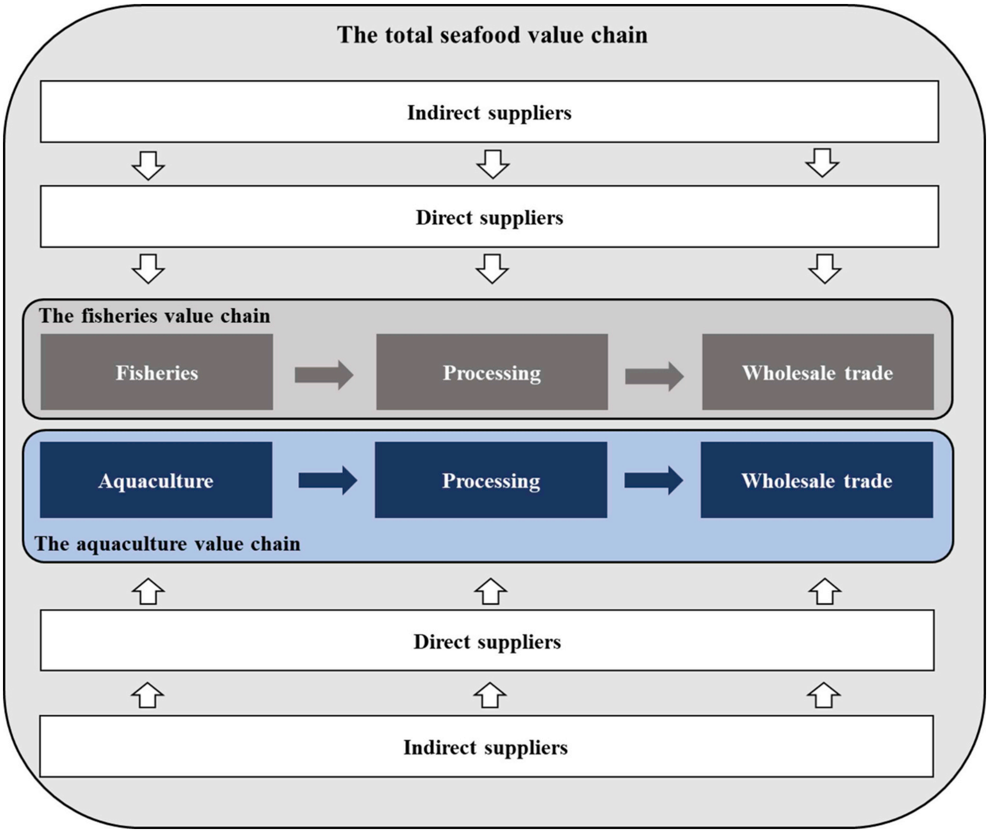

Fig. 2. Norwegian Seafood industry value chains and its supplier industries.

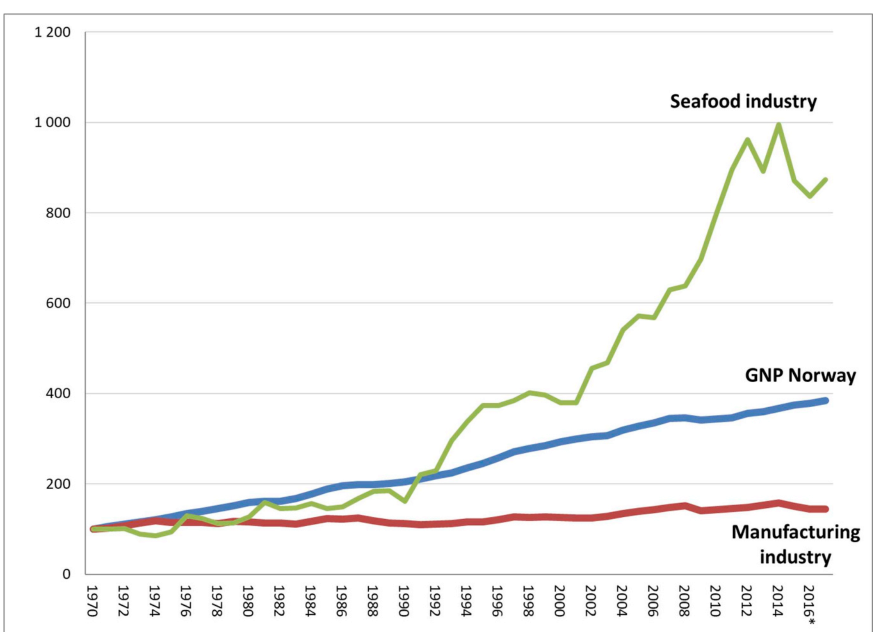

Fig. 3. Growth in value added, fixed 2005-prices, 1970 = 100.

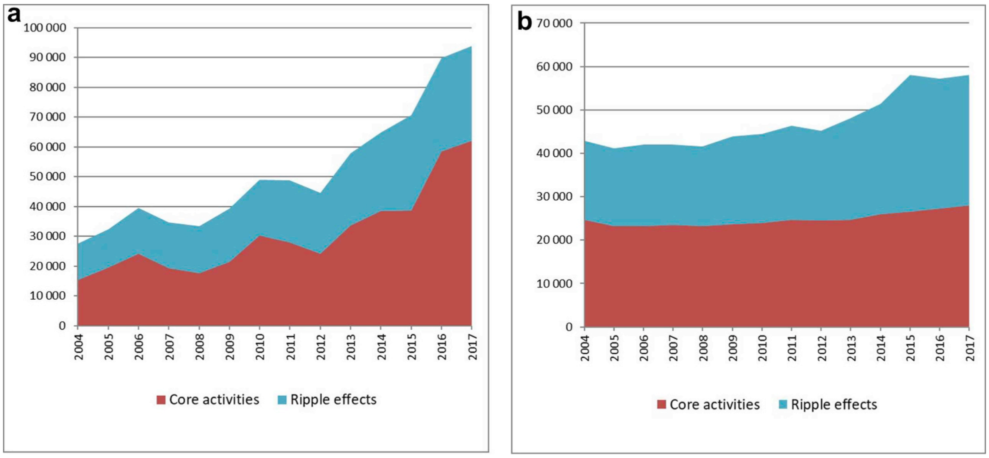

Fig. 4. Value added and number of employees (FTEs) in the seafood value chain. Core activities and ripple effects, 2004–2017. a: Total seafood value chain: Value Added (1000 NOK). b: Total seafood value chain: Employees (thousand employees, FTE's).

In the following chapters, we will present results from Input–Output analyses showing direct and indirect economic effects of the seafood value chain in Norway for the period 2004–2017. All effects are domestic effects at a national level. We start by presenting results for the total seafood value chain. We then describe results for the aquaculture and fisheries value chain, respectively. Effects are measured in contribution to GNP and number of employees. All employee data are expressed in FTEs.

4.1. The total seafood value chain in Norway

As described previously the Norwegian seafood value chain consists of fisheries, aquaculture, fish processing (both fisheries and aquaculture) and whole sale trade (both fisheries and aquaculture) as core activities. In addition ripple effects in other industries, supplying the core activities with goods and services, are also included. Fig. 4(a)–4(b) show development in the Norwegian seafood value chain from 2004 to 2017 in terms of value added (current prices) and number (current prices) of employees.[3]

Value creation in the total seafood value chain has had substantial growth during the entire period (2004–2017) due to good market prices and good margins. The chain is estimated with a contribution to GNP of NOK 94 billion in 2017, starting at NOK 28 billion in 2004. This represents an impressive growth during the period in nominal values. Fig. 3 illustrates the relative growth of total seafood industry compared to growth index of GNP Norway. Seafood industry has grown 8.7 times from 1970, while GNP Norway has grown 3.8 times.

The contribution from core activities amounts to 58% of the total value. All of the core activities have had growth in this period, but aquaculture is clearly the most dominant. Turning to the ripple effects, in 2004, these amount to an estimated value of NOK billion 12 and for 2017 are estimated to be NOK 32 billion. We see more stable ripple effect growth up to 2015. From 2015 to 2017, ripple effects show stabilization around NOK 30 billion. By measuring ripple effects relative to the total level of value added in the seafood value chain, we can determine the size of the effects in terms of multipliers.

Although the value added ripple effects show continuous growth, the value added multiplier fluctuates during the same period starting at 1.8 in 2004 and ending at 1.5 in 2017. This is caused by the fact that the total seafood value chain's contribution to GNP is sensitive to the aquaculture industry and to the market price for salmon, which fluctuates. As seen from Fig. 4(a) the GNP contribution from core activities has increased substantially the most recent years, mainly due to increased margins for primary producers in the aquaculture sector. This naturally makes the multiplier (fraction) of the ripple effect decrease somewhat – although absolute value of the ripple effects has grown steadily up to now.

The total seafood value chain's contribution to employment is illustrated in Fig. 4(b). In total, the number of employees is estimated to be 43,000 in 2004 and 58,000 in 2017, which represents a growth of about 36% during this period. The number of employees in core activities has been rather stable from 2004, with some increased growth since 2014, mainly caused by employment growth in fisheries and aquaculture. The employment ripple effects are also quite stable from 2004 to 2012. In this period, the ripple effects amount to about 45% of the total employment effects. However, from 2012 to 2014 the number of employees in the supplier industries has had strong growth, mainly driven by employment growth in aquaculture and fish processing supplier industries. Hence, these results show an increasing employment multiplier of 1.7 in 2004 to 2.1 in 2017.

The total seafood industry gives rise to ripple effects across a wide spectrum of supplier industries. Table 4 shows the 10 largest supplier industries in 2017, in percentage of total ripple effects. We present the figures for value added and employment, respectively. For value added, none of the industries have a share larger than 10%. Service industries are dominant indicating that the seafood value chain is quite mature and developed. One exception is production of fish feed, one of the main suppliers in aquaculture. The composition of employment ripple effects is also dominated by services. The largest supplier, Retail trade, exceeds 10% and is estimated with a share of 14%. Our results show that the composition is quite stable over time.

4.2. The aquaculture value chain

In this section, we present the results for the aquaculture value chain and its development for the period 2004–2017, including estimated ripple effects for this chain. Fig. 5(a)–5(b) show similar results as those presented in the previous section, but we also show results for the different core activities.[4] The aquaculture value chain share of the total seafood value chain in terms of direct effects on value added increased from approximately 30%–60% during the period 2004–2017. While its share of direct employment is relatively smaller, starting from around 30–40%. A similar pattern is observable for the estimated ripple effects, going from approximately 55% in 2004 to 75% in 2017 in terms of both value added and employment. These numbers show that this part of the

[3] Corresponding numbers to the figures are given in the Appendix, Table 5 From these results we also present the estimated multipliers.

[4] Corresponding numbers for the figures are given in Appendix, Table 6.

Table 4
Ripple effects are shown by industry: ten largest in percentage of total ripple effects, value added, and number of employees (FTEs).

Industry (Value added)	Percent
1. Wholesale trade (Excl. seafood)	9%
2. Production of fish feed	9%
3. Professional, scientific and technical services	8%
4. Retail trade (Excl. repair of motor vehicles)	7%
5. Construction	7%
6. Financial and insurance activities	6%
7. Real estate activities	5%
8. Electricity, gas, steam and air conditioning supply	4%
9. Manufacturing of food products, beverages and tobacco products (Excl. seafood)	4%
10. Telecommunications and information services	3%

Industry (Number of employees)	Percent
1. Retail trade (Excl. repair of motor vehicles)	14%
2. Wholesale trade (Excl. seafood)	10%
3. Construction	8%
4. Professional, scientific and technical services	8%
5. Crop and animal production, hunting and related service activities	7%
6. Manufacturing of food products, beverages and tobacco products (Excl. seafood)	5%
7. Security and other business services	5%
8. Land- and air transport	4%
9. Rental and leasing activities	3%
10. Repair and installation of machinery and equipment	3%

during the period (56–69%). The contribution from the aquaculture industry as a core activity is quite stable with a share of around 20%. We also see that for employment, the share of fish processing is declining (20–6%). The Norwegian fish processing industry has improved performance and competitive strength by investing in automation and new technology. However, this leads to a reduction in employee numbers (improved productivity).

The respective multipliers for this part of the seafood value chain is estimated to 2.4–1.7 for value added and 2.2–3.2 for employees. Hence, the trend in the two multipliers over these years is quite different over the time span analysed. This is due to the comprehensive structural changes in the aquaculture sector. Originally, back in the 70s, aquaculture was a small-scale industry, where most activities were organized within each company. After 1973, the government required a permit for establishing a fish farm. A national breeding program was established, and fish farming expanded to such an extent that by the late 1980s there was an oversupply in the market. Thus, early in the 1990s, a lot of the smaller aquaculture producers went bankrupt starting the process of consolidation and industrialization of the aquaculture industry. Today, the industry is highly industrialized and dominated by large companies. This has given ground for highly specialized suppliers delivering products and services to the farming companies. Hence, the ripple effects, i.e., the employment multiplier, have increased substantially. In addition to this explanation, both the aquaculture sector and fisheries have had good growth in volume produced, which influence the employment ripple effects.

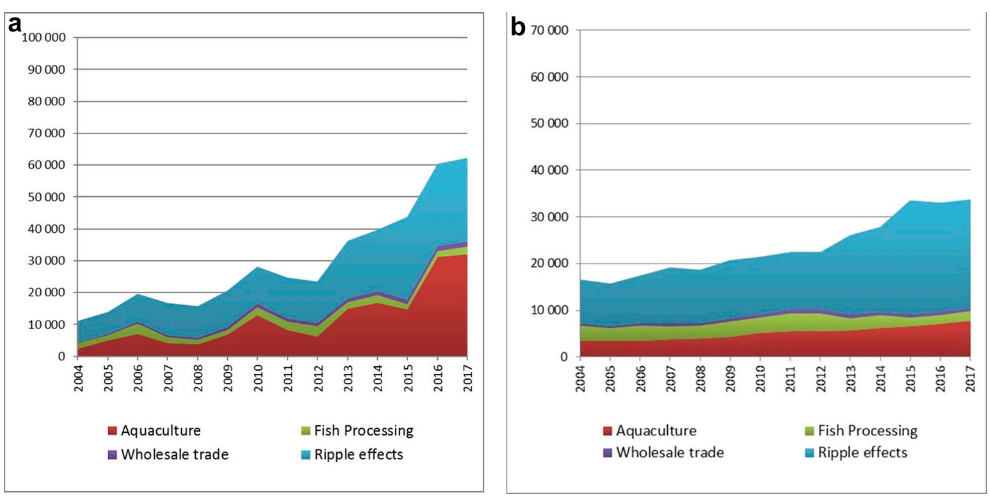

Fig. 5. a: Aquaculture value chain: Value Added (1000 NOK). b: Aquaculture value chain: Employees (thousand employees, FTEs). Value added and number of employees in different parts of the aquaculture value chain industries including ripple effects in other industries covering the period 2004–2017.

Norwegian seafood industry is dominant in all measures except for direct employees, which is still dominated by fisheries.

The aquaculture value chain is the expanding portion of the Norwegian seafood industry, starting at 11 billion NOK in 2004 and ending at 62 billion NOK in 2017. During the period, the ripple effects were the main contributor, but their importance has been reduced from a share of 59% in 2004 to 42% in 2017. Accordingly the contribution from the aquaculture industry as a core activity (direct effect) has increased over the period (22–51%). Fish processing and wholesale trade experience rather modest shares during the period (fish processing 16–4%, wholesale trade 4–2%), while fish processing shows a rather substantial decline. In terms of employment, the development is more modest. Total number of employees for 2004 was estimated to be 16,500. Experiencing a 1% average yearly growth, the number of employees in 2017 was estimated to be 33,700. Again, we see that the ripple effects are the main contributor and we observe increased shares

4.3. The fisheries value chain

The corresponding results for the fisheries value chain are presented in Fig. 6(a)–6(b).[5] The value chain has had a more stable development over time than the aquaculture value chain, with only minor fluctuations during the period 2004–2017. Its relative importance to the total seafood value chain in terms of direct effects on value added has decreased during the period from 70 to 40%, mainly because aquaculture has become more dominant. The value chain's share of direct employment has accordingly gone from a share of 70% in 2004 to 60% in 2017. For the estimated ripple effects, the share for both value added and employees declines from 45% in 2004 to 25% in 2017. The fisheries value chain has an estimated contribution to the Norwegian economy

[5] Corresponding numbers for the figures are given in the Appendix, Table 7.

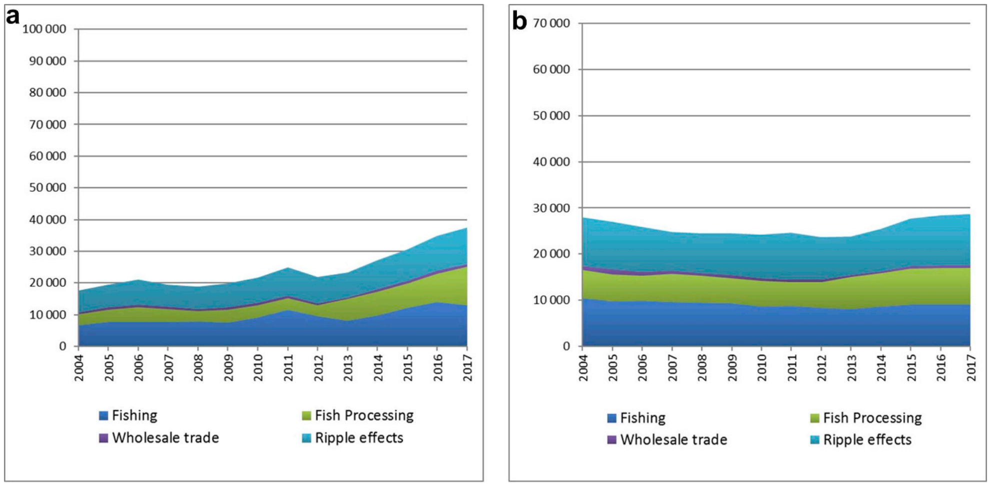

Fig. 6. a: Fisheries value chain: Value Added (1000 NOK). b: Fisheries value chain: Employees (thousand employees, FTEs). Value added and number of employees in different parts of the fisheries value chain industries including ripple effects in other industries covering the period 2004–2017.

starting at a total value in terms of value added of NOK 18 billion in 2004 and ending at NOK 38 billion in 2017. During the period, the fisheries as a core activity have been the main contributor. Accordingly, the contribution from fish processing and wholesale trade has also been stable. Compared to the aquaculture value chain, fish processing has a substantial share that has also increased during the period (20–32%). In terms of employment, the development is more modest. The total number of employees for 2004 is estimated to be 28,000. That number then declines during the subsequent years when it hits its lowest level of 23,000. In 2014, it turns around and in 2017 the level is back up to approximately 28,000. The ripple effects are the main contributor, with a stable share around 38%. The contribution from the other core activities (fisheries, fish processing, and wholesale trade) is also quite stable, with fisheries having the largest share. This implies a stable relationship between the different players in the fisheries value chain. Both the fishing fleet and the processing industry have experienced major structural changes since the 70's, which reduced the number of smaller fishing boats and processing plants. This was due to political decisions intended to reduce overcapacity in fishing, depleting stocks of vital species, and poor economic performance. First, most national subsidies were removed from the value chain. Second, a comprehensive revision of the fishing quota scheme was introduced to allow for quota sales directly to other units, which then made the resource base per unit much stronger. Since 1975, a total quota (TAC) was introduced for the capture of Atlantic cod and, during the 90s, the price regulations and governmental financial support were gradually reduced. Third, the fishing management scheme, i.e., stock assessment including control mechanism, have been strengthened substantially with strict regulations by Individual Transferable Quotas (ITQ's), restrictions on ownership of fishing vessels (barrier of entry) and regulatory schemes for first hand prices. These caused an improved balance between fleet capacity to available TAC's and improved catch per unit effort. The effect can be seen in 6(a), which shows a steady growth in value added from the fisheries value chain. Regulations have been vital to securing good value creation in Norwegian fisheries by reducing the number of fishing ships. A minor increase in employment in recent years is due to a good resource base for volumes in the processing industry and also due to good demand for seafood in major markets.

5. Conclusion

Our empirical analyses of the Norwegian seafood value chain show that this industry is of great importance to the Norwegian economy. With a good resource base, high level of expertise, and rigorous management, the industry has enjoyed adventurous growth over our analysis period, 2004 to 2017. In particular, we see large growth for the aquaculture part of the seafood industry in Norway.

The role of the seafood industry as an important food supplier in the future is unquestionable. As the world's population grows, it grows older, richer and more people live in urban areas. Over the past 50 years, the world's population, and the world economy, has doubled. It is expected that the middle class in emerging economies will triple by 2050 [14]. The United Nations Food Organization (FAO) and the Organization for Economic Cooperation and Development (OECD) point to the importance of the ocean to solve many of our future global challenges [19]. OECD states that economic activity in the ocean space is growing strongly and estimates that the ocean economy will provide 40 million jobs and double its contribution to global value creation by 2030 [19].

Much of the growth is expected to occur in industries where Norway already has important advantages such as value chains of the petroleum industry, the marine industry, and the seafood industry. Norwegian marine resources are among the world's richest. Our long coastline is well suited for the production of living marine resources. The marine strategy published by the government in 2017 points out that one of Norway's foremost competitive advantages is competence by oil engineers, process operators, seamen, fishermen, and farmers with high operational expertise in exploiting the ocean resources [15]. The decline in petroleum prices in 2014 has, to some extent, shifted attention from the petroleum industry and toward other marine industries, particularly aquaculture. Engineering companies that were previously focused on petroleum alone, now also develop innovations for offshore fish farming. Hence, the increased demand from seafood industry towards ocean-based supplier industry is a part of the solution for the Norwegian economy, as Norway moves towards a post-oil industry era.

Future research may take a wider perspective than the pure economics focus in this analysis. The cost, environmentally and otherwise, of further growth and future expansion of ocean use, must be weighed against the benefits. Sustainable growth (economic, social, and environmental) is a prerequisite. This calls for sustainable long-term management, policy-making, and measures. Hence, implementing environmental perspectives in the I–O modelling framework, as presented in our literature review of I–O analyses of marine industries, is highly relevant in the future as we move forward in the research. We also know that the seafood industry is crucial to settlement and development of rural areas along the Norwegian coast. Thus, a methodological extension of the analysis in the future, could be to explore the regional economic importance of the Norwegian seafood industry.

Acknowledgements

This research was funded by the FHF (the Norwegian Seafood Research Fund). We are grateful for the long period of funding which has enabled us to obtain the time series results.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.marpol.2019.103561.

Conflicts of interest

The authors declare no conflict of interest.

Table 5
Results for the seafood value chain.

Value added	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Core activities	15 250	19 506	24 184	19 362	17 590	21 465	30 326	27 913	24 057	33 574	38 513	38 638	58 434	61 924
Ripple effects	12 336	12 870	15 242	15 354	15 761	17 876	18 658	20 905	20 449	24 159	26 188	32 069	31 366	31 896
Total	27 586	32 376	39 426	34 717	33 351	39 342	48 984	48 818	44 506	57 733	64 701	70 707	89 800	93 820
Multiplier	1.81	1.66	1.63	1.79	1.90	1.83	1.62	1.75	1.85	1.72	1.68	1.83	1.54	1.52
FTEs	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Core activities	24 656	23 275	23 279	23 542	23 206	23 628	24 006	24 635	24 571	24 688	25 907	26 525	27 226	28 024
Ripple effects	18 210	17 881	18 692	18 469	18 397	20 298	20 409	21 646	20 576	23 444	25 518	31 523	29 979	30 099
Total	42 866	41 156	41 971	42 011	41 604	43 925	44 415	46 280	45 147	48 132	51 426	58 047	57 204	58 123
Multiplier	1.74	1.77	1.80	1.78	1.79	1.86	1.85	1.88	1.84	1.95	1.98	2.19	2.10	2.07

Notes: Value added in the table is measured in Mill. NOK, FTEs is measured in thousands, while multipliers are a relative measure between total numbers and number in core activities for Value added and FTEs, respectively.

Table 6
Results for aquaculture value chain.

Value added	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Aquaculture	2383	4955	7000	4171	3758	6841	12869	8333	6176	14869	16833	14822	31268	31976
Fish Processing	1730	1662	3327	1790	1417	1469	2496	2586	3267	2150	2420	1564	1849	2476
Wholesale trade	390	518	668	759	601	878	1125	1046	1018	1128	1228	1499	1494	1537
Ripple effects	6535	6835	8554	10001	9922	11425	11767	12815	13056	18065	19325	25884	25895	26303
Total	11038	13970	19549	16720	15698	20613	28258	24780	23517	36212	39806	43769	60506	62293
Multiplier	2.45	1.96	1.78	2.49	2.72	2.24	1.71	2.07	2.25	2.00	1.94	2.45	1.75	1.73
FTEs	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Aquaculture	3400	3350	3480	3700	3990	4250	5212	5546	5493	5700	6200	6500	7000	7800
Fish Processing	3281	2754	3170	2873	2707	3302	3154	3795	3815	2637	2692	1911	1950	1950
Wholesale trade	546	504	547	573	575	686	823	811	851	861	751	746	747	745
Ripple effects	9294	9105	10298	11959	11404	12581	12180	12361	12341	16871	18296	24481	23440	23263
Total	16520	15714	17494	19105	18676	20820	21369	22512	22499	26068	27938	33638	33137	33759
Multiplier	2.29	2.38	2.43	2.67	2.57	2.53	2.33	2.22	2.21	2.83	2.90	3.67	3.42	3.22

Notes: Value added in the table is measured in Mill. NOK, FTEs is measured in thousands, while multipliers are a relative measure between total numbers and number in core activities for value added and FTEs, respectively.

Table 7
Results for fisheries value chain.

Value added	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Fishing	6616	7638	7761	7788	7970	7550	9159	11462	9446	8196	9734	12225	13904	12920
Fish Processing	3481	3994	4689	3969	3142	3946	3825	3778	3533	6707	7548	7657	9052	12122
Wholesale trade	650	739	738	886	702	782	851	708	617	524	750	870	867	892
Ripple effects	6837	7134	7826	6763	7052	7526	7887	8993	8381	7785	9085	9861	10964	11449
Total	17584	19505	21015	19406	18866	19803	21722	24941	21977	23212	27118	30613	34786	37383
Multiplier	1.64	1.58	1.59	1.53	1.60	1.61	1.57	1.56	1.62	1.50	1.50	1.48	1.46	1.44
FTEs	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017

(continued on next page)

Table 7 (*continued*)

Fishing	10500	9710	9830	9600	9490	9300	8635	8745	8364	8100	8700	9100	9100	9100
Fish Processing	6019	5946	5490	6127	5773	5478	5559	5189	5534	6963	7108	7789	7950	7950
Wholesale trade	910	1011	762	669	671	611	623	549	514	427	457	479	479	478
Ripple effects	10579	10307	9787	8349	8564	9056	9339	10169	9305	8306	9249	10363	10793	11117
Total	28008	26974	25869	24746	24499	24445	24156	24653	23718	23797	25514	27731	28322	28645
Multiplier	1.61	1.62	1.61	1.51	1.54	1.59	1.63	1.70	1.65	1.54	1.57	1.60	1.62	1,63

Notes: Value added in the table is measured in Mill. NOK, FTEs is measured in thousands, while multipliers are relative measure between total numbers and number in core activities for value added and FTEs, respectively.

Table 8
Industries in the national account I–O table (bold indicates that they are a part of the seafood value chain.)

Industry	NACE code (25 digit of the code)
1 Crop and animal production, hunting and related service activities	1
2 Forestry and logging	2
3 Fisheries	03.103
4 Aquaculture	03.134
5 Oil and gas extraction, transport via pipelines	06, 49.5
6 Services related to oil and gas	09.101, 09.109
7 Mining and quarrying	05, 07, 08, 09.900
8 Manufacture of fish products	10.feb
9 Manufacture of food products, beverages and tobacco products (except manufacture of fish products)	10 rest, 11, 12
10 Manufacture of textiles, wearing apparel and leather products	13, 14, 15
11 Manufacture of wood and wood products, except furniture	16
12 Manufacture of paper and paper products	17
13 Printing and reproduction of recorded media	18
14 Refined petroleum, chemical and pharmaceutical products	19, 20, 21
15 Manufacture of rubber and plastic products	22
16 Manufacture of other non-metallic mineral product	23
17 Manufacture of basic metals	24
18 Fabricated metal products, except machinery and equipment	25
19 Manufacture of computer, electronic and optical products and electrical equipment	26, 27
20 Building of ships, oil platforms and modul	43.130
21 Manufacture of motor vehicles, machinery and equipment n.e.c	28, 29, 30 rest
22 Manufacture of furniture	31, 32
23 Repair and installation of machinery and equipment	33
24 Electricity, gas, steam and air conditioning supply	35
25 Water collection, treatment and supply	36, 37, 38, 39
26 Construction	41, 42, 43
27 Wholesale and retail trade and repair of motor vehicles	45
28 Wholesale trade, except of motor vehicles	46
29 Retail trade, except of motor vehicles	47
30 Freight and passenger ocean transport, supply and other sea transport offshore services	50.101, 50.201, 50.204
31 Freight and passenger coastal transport	50 rest
32 Land transport, except transport via pipelines, air transport	49.1–49.4, 51
33 Warehousing and support activities for transportation	52
34 Postal and courier activities	53
35 Accommodation and food service activities	55, 56
36 Publishing activities, motion picture and video programme production, broadcasting	58, 59, 60
37 Telecommunications, computer programming and related activities	61, 62, 63
38 Financial service and insurance activities	64, 65, 66
39 Real estate activities	68
40 Legal and accounting activities, architectural and engineering consultancy activities, advertising and market research	69, 70, 71, 73, 74, 75
41 Scientific research and development	72
42 Rental and leasing activities, employment activities	77, 78
43 Travel agency and tour operator reservation service	79
44 Security and investigation activities	80, 81, 82
45 Repair of computers and personal and household goods	95, 96, 97
46 Private sector education	Part of 85
47 Private sector human health activities and social work activities	Part of 86, 87, 88
48 Creative arts and entertainment activities, sports and amusement ation activities,	Part of 90, 91, 92, 93, 94, 99
activities of membership organisations	Part of 84, 85, 86, 87, 88, 90,91,92,93
49 Local public administration, education, human health care and social work activities	
50 Central public administration education, human health care, social work activities, and defence	Part of 84, 85, 86, 87, 88, 90,91,92,93

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