Marine Policy 104 (2019) 19–28

Contents lists available at ScienceDirect

Marine Policy

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

Aquaculture subsidies in the European Union: Evolution, impact and future potential for growth

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ARTICLE INFO

Keywords:
Aquaculture
European maritime and fisheries fund
Structural funds
Subsidies
Economic impacts

ABSTRACT

Through its structural funds the European Union (EU) has invested €1.17 billion in the aquaculture sector over the period 2000–2014. In addition, the EU plans to spend a further €1.72 billion on the sector over the period 2014–2020 through the European Maritime and Fisheries Fund (EMFF). Despite this support, EU aquaculture production has not taken off. Indeed, EU production volume in 2016 was 8% less than in 2000, while global production increased by more than 150%. These investments aim to make the EU aquaculture sector more successful and competitive by focusing on quality, health and safety, as well as, eco-friendly production to provide consumers with high-quality, highly nutritional and trustworthy products. This study provides the first comprehensive overview on the allocation of the different structural funds in the aquaculture sector and across EU Member States from the year 2000–2020. The importance of these subsidies is put into perspective by comparing their evolution within and across the development of the different EU countries' aquaculture sectors.

1. Introduction

Globally, aquaculture has been the fastest growing animal food production sector in recent decades, a growth that is mainly attributed to a high degree of technological innovation going from relatively extensive to more intensive production systems [1–5]. The aquaculture sector is still relatively young, especially compared to agriculture, and consequently has a large potential for further growth and development [6]. The production process is determined by biological, technical, economic, institutional and environmental factors, which, to a large extent, are under human control [7]. Considering this rapid development and the high level of human interaction, public support may facilitate technological development and operation location, and accordingly could lead to higher production increases than in wild-capture fisheries. However, public support to the aquaculture sector can be considered good or bad depending on whether they exacerbate the activity's environmental impact [8,9]; even if the aquaculture industry and governance system have shown the capacity to address some of the negative effects [10,11] Yet, while fisheries subsidies have received substantial attention in recent years [12], less attention has been given to subsidies in aquaculture.

Global aquaculture production (including aquatic plants) in 2016 was 110.2 million tonnes, with the first-sale value estimated at USD 243.5 billion [13,14]. In addition to providing food, aquaculture obviously brings jobs, income and wealth to over 18.7 million people globally (the proportion of people employed in the sector increased from 17% in 1990 to 33%) [14]. However, the production increase is far from evenly distributed and most of the growth has been in Asian countries that produced 92% of the volume in 2014, although significantly less by value (77%).[1] In contrast, the European Union's (EU) aquaculture sector represented only about 1.7% of the world production in volume and 3.1% in value [13]. Moreover, EU production has

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[1] This discrepancy is interesting and can largely be explained by the increasing role of aquaculture in food security in several developing countries [55].

https://doi.org/10.1016/j.marpol.2019.02.045
Received 12 December 2018; Received in revised form 22 February 2019; Accepted 22 February 2019
Available online 07 March 2019

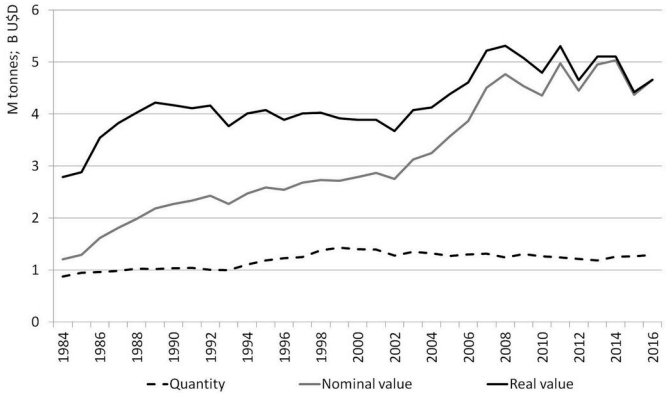

Fig. 1. Evolution of the EU aquaculture production in volume (million tonnes) and value (billion USD) in nominal and real terms (in 2016 USD)[a] (1990–2016). Source: own elaboration from Ref. [13].

gone from a moderate annual growth rate of 3.4% over the period 1980–2000, to a negative rate of −0.6% during the period 2000–2014, while the real value has increased slightly over the same period (Fig. 1). In 2014, the EU aquaculture sector provided 19% of its own supply of fish and shellfish production, substantially less than the global share.

This general lack of growth in the EU aquaculture sector has been explained, at least partially, by strict environmental regulations, a high bureaucracy burden that does not facilitate economic development (European Commission, 2009; [15–20] and the widespread use of command and control instruments to manage negative environmental externalities [21].[2] Management with command and control instruments (e.g. quotas on inputs and outputs) can lead to a sub-optimal level of aquaculture activity because they usually do not ensure conditions for the most efficient producers to increase production. These instruments are usually inflexible and do not incentivize producers to adapt and develop new technology [22].

The European Commission (EC), together with the EU countries, have invested significant funds in the aquaculture sector to boost food security and economic development. As of the year 2000, more than €1.17 billion of public money had been invested in the sector. Given the initial lack of production increases, the EC identified challenges facing aquaculture, including causes of stagnation and barriers to development, trying to give a new impetus to the sustainable development of aquaculture in the EU [23]. Moreover, through the Common Fisheries Policy (CFP) reform, the EC also intended to stimulate the aquaculture sector and in 2013 published the Strategic Guidelines presenting common priorities and general objectives at EU level. Four priority areas were identified in consultation with all relevant stakeholders: (i) reducing administrative burdens, (ii) improving access to space and water, (iii) increasing competitiveness, and (iv) exploiting competitive advantages due to high quality, health and environmental standards. In 2014–2015, EU countries developed Multiannual National Strategic Plans for the promotion of sustainable aquaculture, proposing concrete actions to address these strategic priorities.[3]

This study provides the first comprehensive overview on the allocation of the different structural funds (Financial Instrument for Fisheries Guidance – FIFG, European Fisheries Fund – EFF, and European Maritime and Fisheries Fund - EMFF) in the aquaculture sector and across EU countries from 2000 to 2014.[4] The importance of these subsidies is put into perspective by comparing the evolution of each, across and within the development of different EU countries' aquaculture sectors. Moreover, we analyse EU Member States' forecasted growth in the aquaculture sector based on the allocation of these funds and discuss future possibilities for development. The rest of the paper is structured as follows: Section 2 describes the different subsidy instruments developed by the European Commission to promote aquaculture development; Section 3 presents recent trends on key economic indicators for the EU aquaculture sector; Section 4 shows the main results of the public subsidies allocated to the aquaculture and their effects on the sector; Section 5 discusses the implications of the results obtained, and Section 6 concludes.

2. Subsidy schemes for the EU aquaculture sector

In this study, the current EMFF (2014–2020) is compared with the two previous EU fisheries funds, the FIFG and the EFF, for the programming periods 2000–2006 and 2007–2013, respectively. These are the main funds available to the EU fisheries and aquaculture sectors, however, additional support may have been granted through the European Regional Development Fund (ERDF), the European Agricultural Fund for Rural Development (EAFRD) or "*ad hoc*" Member States' aid provided directly. These are not considered in this study and therefore, the figures presented should be considered conservative values.

These EU funds are co-managed by DG MARE (EC) and EU countries over a seven-year programming period. Member States determine the priorities and the type of projects that can be funded in their country (from a predetermined list defined by DG MARE) and also provide additional national funding for these projects. In most cases the total public support is only a part of the funding with the rest being financed by the entrepreneurs themselves. In this study, both the EU and the national support consider the actual paid (and not committed) amounts for the FIFG and the EFF; while for the EMFF, the budgeted amounts are considered.

2.1. Financial Instrument for Fisheries Guidance

The FIFG was launched in 1994 to support the EU fisheries sector, yet support to aquaculture became more apparent as of the programming period 2000–2006 [24]. The FIFG (2000–2006) priority areas included the adjustment of fishing capacity and modernisation of fishing vessels, support to the processing and marketing sectors, and the development of aquaculture.

With a total budget of €5.715 billion (national 35.7% and EC 64.3%), almost 10% (€567 million) was spent on the aquaculture sector. The ex-post evaluation of the FIFG (2000–2006) concluded that the impact was [25]:

- negative in terms of increasing production weight because it did not prevent a global decrease in EU production and encouraged the overproduction of some species, mainly seabream and seabass;
- positive in terms of modernising the sector, with significant aids awarded to major innovating projects (e.g., cod, tilapia, barramundi) and investments consolidating EU leadership in turbot farming. FIFG also accelerated the establishment of production improvement systems;
- positive in terms of hygiene, favouring the improvement of sanitary and environmental conditions;
- positive in terms of profitability, companies receiving funds were

[a] Nominal prices measure the value of a product at the time it was produced. Real prices (or prices in real terms) are adjusted for inflation. So, real prices give a view of prices for various years based on one year. In our case, real prices are in 2016 dollars.

[3] Detailed information for each country is available at: https://ec.europa.eu/fisheries/cfp/aquaculture/multiannual-national-plans.

[4] This study analyses the aquaculture subsidies for the period 2000–2020 (*footnote continued*) because structured comparisons with funds from previous periods would be inconsistent due to a lower number of participating countries as well as the reduced number of financing areas.

better off than those not receiving funds. It strengthened the leading companies in seabass, seabream and turbot aquaculture, some of them merging or acquiring smaller companies.

2.2. European Fisheries Fund

Support to the EU aquaculture sector continued with the EFF for the programming period 2007 to 2013, with more emphasis placed on sustainability [26]. The EEF aimed to underpin the economic, environmental and social objectives of the CFP. In order to accomplish this objective, the EFF had a budget of €4.3 billion for the period 2007–2013.[5] The time period was extended to 2014, in part due to the delay of the EMFF implementation, as well as availability of funds from the EFF after 2013. Overall, total spending under the EFF between 2007 and 2014 amounted to €5.57 billion (49.2% of national contribution and 50.8% of EC contribution).

In May 2015, the EFF commitment to measure 2.1 "Support development of aquaculture" amounted to just under €600 million, equivalent to 14.2% of the total EFF committed. These funds were distributed between the actions: i) Increase in production capacity due to construction of new farms; ii) Variation (increase) in production due to the extension or modernisation of existing farms; iii) Increase in number of hatchery-produced fry; iv) Aqua-environmental measures; v) Public health measures; and vi) Animal health measures.

DG MARE's [27] ex-post evaluation of the EFF concluded that funds allocated to the aquaculture sector contributed to the: i) increase in production capacity and production of some farmed species; ii) increase of hatchery fry use; iii) improvement of health and animal welfare standards; iv) widespread view that EFF funding was essential during the financial crisis that reduced investment and borrowing activity. Yet, there were no clear linkages between the use of EFF and improvements in the economic performance or productivity.

The European Court of Auditors [28], however, concluded that: i) the EFF did not offer effective support for the sustainable development of aquaculture; ii) at EU level, measures to support the sustainable development were not well designed and monitored; iii) at the level of the Member States, measures to support the sustainable development were not well designed and implemented; iv) the main objectives for growth were not met and the sector suffered from stagnation, even if the economic crisis contributed significantly to this, at least in the main producing Member States; v) some projects did not provide the expected results, or value for money, and contributed little to growth and employment; and vi), in conclusion, the framework at EU and Member State level was inadequate to translate the objectives for the sustainable development into reality and the measures taken did not provide sufficient results.

2.3. European Maritime and Fisheries Fund

The EMFF is the financial instrument to support the EU's maritime and fisheries policies for the period 2014–2020 [29]. It is one of the five European Structural and Investment Funds which complement each other and seek to promote a growth and job-based recovery in the EU.

The EMFF has an overall budget of €8.6 billion, with an EU contribution of €6.4 billion and the remaining €2.2 billion from the national contributions. Specifically, €1.725 billion, about 20% of the EMFF budget are destined to promoting sustainable aquaculture, which entails the following specific objectives[6]:

- strengthen technological development, innovation and knowledge transfer;
- enhance the competitiveness and viability of aquaculture enterprises, including the improvement of safety and working conditions, in particular of small and medium-sized enterprises (SMEs);
- protect and restore aquatic biodiversity and enhance ecosystems related to aquaculture and promote resource-efficient production systems;
- promote aquaculture with high levels of environmental protection, animal health and welfare, and of public health and safety;
- develop professional training, new professional skills and lifelong learning.

The total spending of the FIFG and the EFF by EU country, and total planned allocations of the EMFF funds by EU country is shown in Fig. 2 [20].[7]

The countries receiving the largest amount of subsidies for the aquaculture sector for the period 2014–20 are: Spain (€274.5 million), Poland (€269 million), Italy (€221.1 million), France (€118.4 million), and Romania (€112.3 million). These five countries account for more than 82% of the planned public investment but just 54% of the EU aquaculture production in 2014 (Spain 22%, Poland 3%, Italy 13%, France 16% and Romania 1%).

The overall level of the public spending in the two previous programming periods (2000–6, 2007–13) was quite similar (Fig. 2). For the period 2014–20, the national expenditure is expected to more than double while the EU expenditure increase more than 3-fold compared to the two previous programming periods. The relative share of public funding in the aquaculture sector relative to the total subsidies in each country is higher in landlocked countries (e.g. Czech Republic 67%, Hungary 66%, and Slovakia 60%), since funds to marine capture fisheries are not allocated. The aquaculture sector also receives particular attention in Romania (50% of the total funds), Poland (38%), Lithuania (35%) and Germany (30%). Allocation of funds between the different priorities is determined by the EU country administration.

In the Multiannual National Strategic Plans [30] for the promotion of sustainable aquaculture, EU countries quantify objectives (e.g. production growth) for their domestic aquaculture sector based on the strategic priorities and the EMFF funds received. According to the figures presented, the estimated projection for aquaculture production in 2020 is more than 1.7 million tonnes, an increase of over 300,000 tonnes (25%) from the 2013 level [31,32] (see Table 1).

3. EU aquaculture production data

The EU aquaculture sector is dominated by relatively few species. According to FAO data, the overall trend shows that the EU production volume declined by 8% from 2000 to 2016 (see Table 1).

In land-based freshwater production, trout and carp dominate covering 53% and 32% of the total volume produced. However, the production of trout has declined 22% whereas carp has remained at the same level from 2000 to 2016, resulting in a 18% decline in freshwater production in total.

In the marine finfish production "salmon and trout" and "seabass and seabream" cover 53% and 38%, of the total production respectively. "Salmon and trout" production increased by 23% and "seabass and seabream" by 62%, resulting in an overall increase of 38% in the

[5] The budget was distributed between five Priority Axis: 1) adapting the Community fleet (€1.2 billion), 2) aquaculture, inland fishing, processing and marketing of products (€1.2 billion), 3) measures of common interest (€1.1 billion), 4) sustainable development of fisheries areas (€0.6 billion), and 5) technical assistance (€0.2 billion).

[6] The relative share of the public funding in the aquaculture sector (compared to the overall funds) has also increased from the two previous programming periods (2000–6, 2007–15) were it was 10% and 11% to almost 22% for the period 2014–20.

(*footnote continued*)

[7] Bulgaria and Romania did not participate in the FIFG and Croatia did not participate in the FIFG and EFF because they joined the European Union in 2007 and 2013, respectively.

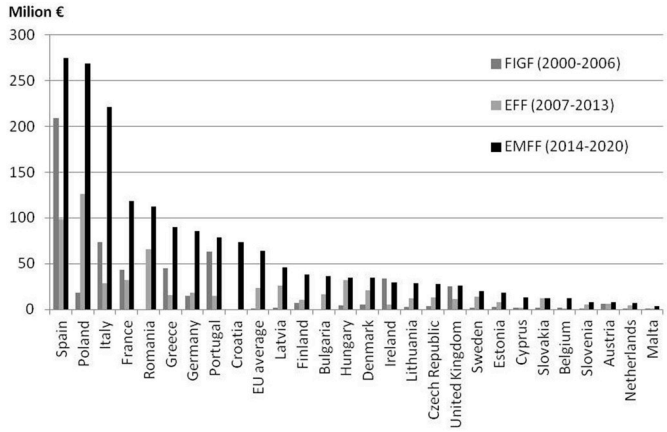

Fig. 2. Evolution of the EU structural funds devoted to aquaculture per country (in million €).
Source: [20].

production level and to the species composition that depends on the available natural resources and technological capacity within each Member State. Table 1 presents the total production volume for 2000 and 2016 of the 27 EU countries with reported FAO aquaculture statistics. Fourteen countries had a production of less than 10 thousand tonnes in 2000, of these only Belgium experienced a decrease in production whereas all the others were able to increase theirs, mostly driven freshwater trout and carp production. However, with a contribution of 6% of the total production volume in EU, these 14 countries can be considered as minor producers.

In 2000, eight countries were producing between 10 and 75 thousand tonnes. Of these only Hungary, the Czech Republic and Poland were able to increase their production in 2016, mainly freshwater trout and carp. Conversely, production of trout fell in Finland and Denmark. The decline in Ireland, Germany and the Netherlands was primarily a result of decreased harvest of mussels, as with Spain, France and Italy, which are the largest aquaculture producers in EU. Freshwater trout production also declined in these three countries. For the five largest producers, Spain and Greece managed to increase the production of

Table 1
EU aquaculture production volume, nominal value and percentage of change for 2000 and 2016, and EU Member States projections for 2020.
Source: [13,32]. Exchange rates from the European Central Bank.

Country	Weight (tonne) 2000	Weight (tonne) 2016	Projected Weight (tonne) 2020	2000–16 % change	2016–20 % change	Value ('000€) 2000	Value ('000€) 2016	2000–16 % change
Spain	309,229	283,828	320,000	−8%	13%	359,678	506,392	41%
France	266,770	166,140	265,000	−38%	60%	460,213	621,934	35%
Italy	213,525	157,109	206,854	−26%	32%	483,380	409,391	−15%
United Kingdom	152,485	194,492	254,000	28%	31%	499,274	1,022,376	105%
Greece	95,418	123,314	170,000	29%	38%	315,416	524,784	66%
Netherlands	75,231	62,940	n/a	−16%	n/a	115,761	96,527	−17%
Germany	65,891	41,721	52,000	−37%	25%	137,113	97,707	−29%
Ireland	51,247	40,190	81,700	−22%	103%	106,508	154,208	45%
Denmark	43,609	36,237	55,000	−17%	52%	159,020	123,212	−23%
Poland	35,795	38,300	61,000	7%	59%	72,463	109,555	51%
Czech Republic	19,475	20,952	20,000	8%	−5%	52,914	39,398	−26%
Finland	15,400	14,412	20,000	−6%	39%	62,687	62,633	0%
Hungary	12,886	16,248	27,000	26%	66%	23,638	31,521	33%
Romania	9727	12,574	36,000	29%	186%	16,930	27,679	63%
Portugal	7537	9785	35,000	30%	258%	54,683	60,375	10%
Croatia	6876	15,805	24,050	130%	52%	30,428	89,963	196%
Sweden	4834	15,747	25,000	226%	59%	16,136	51,270	218%
Bulgaria	3654	15,754	20,000	331%	27%	7942	32,668	311%
Austria	2847	3483	5500	22%	58%	12,950	22,457	73%
Lithuania	1996	4393	6400	120%	46%	2613	12,241	368%
Cyprus	1878	6625	6332	253%	−4%	11,157	36,268	225%
Belgium	1871	44	1032	−98%	2245%	6648	440	−93%
Malta	1746	6073	10,500	248%	73%	5426	60,431	1014%
Slovenia	1181	1844	2420	56%	31%	3916	4996	28%
Slovakia	887	2169	n/a	144%	n/a	2038	5035	147%
Latvia	325	788	2256	142%	186%	448	2083	365%
Estonia	225	868	n/a	286%	n/a	567	3877	583%
Totals	**1,402,545**	**1,291,834**	**1,707,044**	**−8%**	**32%**	**3,019,947**	**4,209,422**	**39%**

marine finfish production. The shellfish production is more diverse but the main bulk of production is covered by blue mussels, Mediterranean mussels and oysters. Combined, mussel production fell by 26%, and oysters by 46%, leading to an overall 28% decline in volume. On the other hand, production value increased 39% between 2000 and 2016, while remaining stable in real terms. Prices of main farmed species in the EU have been stable or even declined in real terms. Hence, the improved performance in value compared to the volume is due to a decrease in the production of lower value species (e.g. mussels) and an increase in the production of higher value species (e.g. salmon, seabass and seabream).

At country level there is a large variation in the achieved growth, which is partly due to some countries starting off from a very low seabream and seabass, whereas the UK increased the production of marine produced salmon. Spain also increased production of turbot.

On the whole, the decline in EU aquaculture production appears to be primarily related to a fall in mussel harvest within the larger EU producing countries, whereas the success stories seem to be the marine aquaculture producing salmon and seabass/seabream.

This general decrease in the EU aquaculture production is in contrast with the EU Member States' forecasted production for 2020. In order to achieve 2020 goals, EU aquaculture production will have to increase by almost 1/3 compared to the 2016 production level. Thus, it seems a real challenge reaching the national goals of the strategic plans, if mussel production does not recover during the next 5-year period.

Table 2 shows the evolution of the number of enterprises, Gross

Table 2
Evolution of aquaculture enterprises, employment and FTE, and Gross Value Added (in million €) (2000–16).
Source: [20,32].

	Number of enterprises		Total employees		FTE		Gross Value Added	
	2008	2016	2008	2016	2008	2016	2008	2016
Bulgaria	274	588	1110	1046	1110	923	−10.7	23.1
Croatia		187		2192		1625		49.5
Cyprus	12	16	319	522	247	459	18.5	
Denmark	162	107	606	549	349	366	30.6	44.9
Estonia	8	10	24	41	15	34	0.7	
Finland	180	173	387	495	300	341	16	39.4
France	3171[b]	2700	18,519[b]	15,074	10,139[b]	8837	446.1[b]	421.1
Germany[8]	10	293	60	1638	60	983	6.6	
Greece		328		3986		3482		209.9
Ireland	304	289	1972	1948	1287	1027	27.7	71
Italy	696	711	4357	5460	3428	3289	107.4	185
Malta	6	6	221	301	169	256	19.8	37
Netherlands	130	70		189	218	206	69.3	35.4
Poland		1242		8759		5256		
Portugal	1463	1402	2347	2650	1227[a]	829	16.3[a]	83.6
Romania	315[a]	430	2669[a]	3699	2542[a]	2912	25.1[a]	
Slovenia[8]	11	7	29	20	26	20	2.3	0.8
Spain	3101	2990	26,322	17,811	6612	6534	100.8	238.9
Sweden	155	136	379	489	223	295	10.9	43.3
United Kingdom	531	473	3050	3285	2660	2802	216.4	573.3
Total	**10,529**	**12,158**	**62,371**	**70,154**	**30,612**	**40,476**	**1104**	**2056**

[a] Refers to 2009 data because of missing 2008 data.
[b] Refers to 2010 data because of missing 2008 and 2009 data.

Value Added (GVA) and employment (in total and by Full Time Equivalent (FTE)) by EU country collected through the EU Data Collection Framework (DCF) [20,32]. These data only include countries participating in the EU DCF.[8]

The total number of aquaculture companies in these Member States was estimated at 12.5 thousand, with a reported €2.1 billion in GVA and an EBIT of €1.2 billion in 2016 [32]. The enterprises directly generate more than 75 thousand jobs, employing on average about 5.9 persons per enterprise. Almost 90% of the firms are micro-enterprises, employing less than 10 employees in coastal and rural areas. The number of companies, total employment per country and overall economic performance has improved from 2008 to 2016 (see Table 2).

The average values obtained from the years the DCF data are available (mostly 2008–13) were used to compute the various indicators for the EFF (2007–2013) period. Where needed, data were raised for the total period from the available years (e.g. for 7 years from 6 years available - 7/6) and then compared to the total public spending for the period. In the case of the EMFF, where only 2014 to 2016 data are available for the programming period (2014–2020), these data were used as the average value for that period and raised accordingly. In addition, for the public funding per kg of farmed fish indicator, average production was estimated considering the average values for the 2014–16 period, as well as with a proportional increase to reach the 2020 forecasted value.

4. Results

The public funding per enterprise, employee, FTE and GVA are reported in Table 3.

When considering the DCF data [20] and the funds allocated by country, an average of almost €41 thousand per enterprise were spent over the period 2007–13, and funding will increase to €123 thousand per enterprise for the period 2014–20. Similarly, the public funding spent corresponds to almost €7 thousand per employee during the period 2007–13, to more than €21 thousand for the period 2014–20 (€11.6 thousand and €39 thousand when measured in FTE). However, results vary significantly by country, with Estonia showing the highest ratios and France and the United Kingdom the lowest.

Overall, public funds corresponded to 4% of the GVA produced by the EU aquaculture sector during the period 2007–13, and will increase to 9.3% during the period 2014–20.

Table 4 presents the public funding measured in EUR per kg of farmed fish produced (i.e., extra price paid by tax payers) and Table 5 shows the average aquaculture production price and the public funding measured in EUR per value (i.e., price increase percentage).

On average, during the 2000–6 period, public funding represented 6 cents for each kg of farmed production (corresponding to 2.8% of its value or price). During the 2007–13 period, public funding represented 7 cents for each kg of farmed production (2.5% of its value); while for the 2014–20 period (if 2014–16 production levels are maintained), public funding would represent 19 cents for each kg of farmed production (6.2% of its value) or 17 cents if the projected production is reached by 2020. This is equivalent to say that taxpayers paid 6 cents more per kg for their farmed fish (not imported) between 2000 and 2006, 7 cents more from 2007 to 2013, and will pay 17 to 19 cents more from 2014 to 2020.

However, the situation across EU countries is quite diverse. For example, for the period 2007–13, Romania received public funds equivalent to €0.89 per kg of farmed fish (≈51.4% of the total Romanian production value), Estonia €1.66 per kg (≈43.7% of the total production value), Latvia €6.18 per kg (≈271.2% of the total production value) and Slovakia €17.2 per kg (≈69.5% of the Slovakian production value).

When considering EU aquaculture production stable at 2014-16 levels until 2020, for the period 2014–20, Latvia would receive public funds equivalent to Belgium €15.78 per kg, €8.48 per kg, Estonia €3.02 per kg, Romania €1.40 per kg, Slovakia €1.14 per kg and Portugal €1.10 per kg. Then this public funding received would be equivalent to 314.3% of the value of aquaculture production for that period in Latvia, 268.8% of the value of the Belgian aquaculture production, 70.9% of

[8] The collection of freshwater aquaculture is on a voluntary basis. Belgium, Latvia and Lithuania have only freshwater aquaculture and decided not to collect these data. Germany and Slovenia only reported marine aquaculture data, and Poland in addition to marine aquaculture reported some data at the total national level.

Table 3
Public funding per enterprise, public funding per employee, public funding per FTE and public funding per GVA indicators during the EFF (2007–2013) and EMFF (2014–2020) periods.

	Funds/enterprise Thousand €		Funds/employee Thousand €		Funds/FTE Thousand €		Funds/GVA (%)	
	EFF	EMFF	EFF	EMFF	EFF	EMFF	EFF	EMFF
Bulgaria	54.3	71.6	21.5	36.4	21.5	43.3	210.2	26.0
Croatia		402.6		33.4		48.2		50.4
Cyprus	180.6	787.5	6.8	27.6	7.5	32.2	2.2	15.3
Denmark	141.2	310.3	40.4	66.3	66.5	99.7	8.4	12.1
Estonia	956.2	1848.6	309.9	475.5	416.1	589.4	415.8	3237.9
Finland	61.0	218.0	22.1	74.1	28.9	106.1	8.7	17.9
France	10.5	42.0	1.8	7.6	3.4	13.3	1.0	3.9
Greece		311.6		20.8		28.1		7.9
Ireland	18.9	105.8	3.0	16.0	5.5	30.1	1.9	7.0
Italy	44.2	330.2	5.4	42.8	10.5	78.4	2.2	14.1
Malta	67.5	551.1	2.1	13.9	2.5	15.7	0.8	1.7
Netherlands	38.7	78.7		34.7	14.4	31.4	1.3	2.4
Poland	149.6	216.6	22.9	32.8		53.2		
Portugal	10.4	56.0	6.4	32.2	11.2	99.5	9.8	22.1
Romania	170.0	261.3	22.5	36.8	24.9	48.9	50.4	37.2
Spain	32.2	90.6	4.0	14.8	15.9	43.2	10.5	19.2
Sweden	83.7	146.9	33.9	45.3	53.7	70.7	14.9	10.9
United Kingdom	21.9	50.0	3.7	7.8	4.3	9.4	0.8	0.9
Average EU	**40.9**	**122.8**	**6.9**	**21.4**	**11.6**	**39.1**	**4.0**	**9.3**

Table 4
Public funding (EUR) per weight (kg) of farmed fish produced.

	Public funding per kg of farmed fish (€/kg)			
	FIGF (2000–2006)	EFF (2007–2013)	EMFF (2014–2020) (average 2014–16)	EMFF (2014–2020) including 2020 projections
Austria	0.36	0.32	0.33	0.26
Belgium	0.18	0.28	15.78	4.65
Bulgaria		0.35	0.38	0.34
Croatia			0.71	0.58
Cyprus	0.11	0.07	0.32	0.30
Czech Republic	0.03	0.09	0.19	0.19
Denmark	0.02	0.08	0.14	0.12
Estonia	1.01	1.66	3.02	n/a
Finland	0.07	0.11	0.38	0.33
France	0.02	0.02	0.10	0.09
Germany	0.04	0.07	0.38	0.30
Greece	0.06	0.02	0.11	0.10
Hungary	0.04	0.30	0.30	0.27
Ireland	0.08	0.02	0.12	0.08
Italy	0.06	0.02	0.21	0.18
Latvia	0.51	6.18	8.48	4.99
Lithuania	0.16	0.50	0.96	0.80
Malta	0.01	0.02	0.08	0.08
Netherlands	0.00	0.01	0.01	n/a
Poland	0.07	0.53	1.00	0.83
Portugal	1.18	0.25	1.10	0.58
Romania		0.89	1.40	0.77
Slovakia	0.22	1.72	1.14	0.93
Slovenia	0.04	0.58	0.71	0.56
Spain	0.11	0.05	0.14	0.13
Sweden	0.05	0.19	0.21	0.15
United Kingdom	0.02	0.01	0.02	0.02
Average EU	**0.06**	**0.07**	**0.19**	**0.17**

the value of the Estonian aquaculture production, 70% of the Romanian aquaculture production, 38.2% of the Lithuanian production, and 44.2% of the Slovakian aquaculture production value.

The public funding for the EMFF period divided by the EU Member States projected production increase (EUR/kg) for the period 2014–20 is reported in Fig. 3.

On average, €3.6 of public funding will be used to increase aquaculture production by one kg in 2020, and it is expected that this production increase will be maintained over time. Public funding, measured by expected production increase in weight, varies significantly by country, with Latvia requesting €28.7 per kg of farmed production increase, Belgium €17.9 per kg, Poland €12.8 per kg, and Cyprus €12.7 per kg, while United Kingdom and Ireland requested €0.5 per kg and €0.7 per kg, respectively.

5. Discussion

The €1.17 billion spent on increasing the EU aquaculture production over the FIGF and EFF programs did not lead to an overall increase in production volume. Funds supported growth by increasing

Table 5
Average aquaculture production price (€/kg) and public funding per value of farmed fish produced (%) for the periods analysed.

	Average price (€/Kg)			Public funding per value of farmed fish (%)		
	FIGF (2000–2006)	EFF (2007–2013)	EMFF (2014–2020)	FIGF (2000–2006)	EFF (2007–2013)	EMFF (2014–2020)
Austria	4.43	6.15	6.05	8.0	5.2	5.4
Belgium	3.20	5.36	5.87	5.7	5.2	268.8
Bulgaria	2.27	2.49	2.16		14.0	17.8
Croatia	3.59	3.85	5.46			13.0
Cyprus	6.00	5.49	5.69	1.8	1.2	5.6
Czech Republic	2.03	1.97	1.87	1.4	4.7	10.3
Denmark	3.08	2.69	3.24	0.7	3.1	4.3
Estonia	3.37	3.79	4.26	30.0	43.7	70.9
Finland	3.12	3.22	3.78	2.4	3.5	10.0
France	2.07	3.00	3.66	1.2	0.7	2.7
Germany	2.71	2.54	2.69	1.4	2.8	14.0
Greece	3.20	3.66	4.31	2.0	0.5	2.7
Hungary	2.00	1.91	1.87	2.2	15.8	16.1
Ireland	1.83	2.55	3.73	4.4	0.7	3.1
Italy	2.37	2.59	2.51	2.4	1.0	8.3
Latvia	1.36	2.28	2.70	37.8	271.2	314.3
Lithuania	1.61	2.11	2.50	10.0	23.7	38.2
Malta	4.89	8.22	9.65	0.3	0.2	0.9
Netherlands	1.65	1.86	1.54	0.2	0.7	1.0
Poland	1.97	2.15	2.66	3.7	24.8	37.6
Portugal	5.72	5.55	5.41	20.6	4.6	20.3
Romania	1.64	1.72	2.00		51.4	70.0
Slovakia	2.01	2.48	2.58	10.8	69.5	44.2
Slovenia	2.71	2.55	2.66	1.5	22.9	26.6
Spain	1.09	1.44	1.62	9.8	3.8	8.5
Sweden	2.81	3.07	3.43	1.8	6.0	6.1
United Kingdom	2.99	3.61	4.85	0.7	0.2	0.4
Average EU	**2.19**	**2.69**	**3.13**	**2.8**	**2.5**	**6.2**

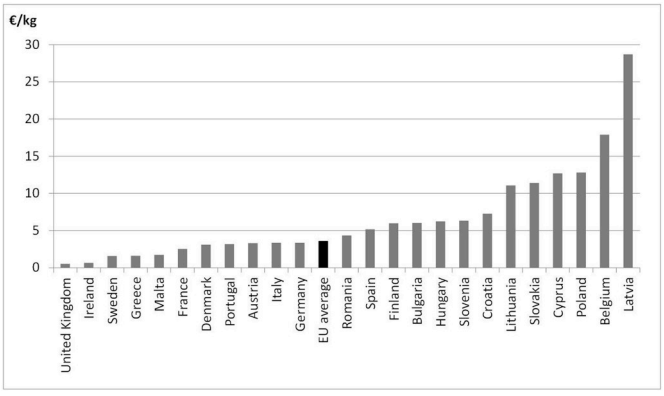

Fig. 3. Public funding per projected production increase (EUR/kg).

production capacity through financing the construction of new farms and hatcheries while investing in environmentally friendly technology and species diversification. Aquaculture experts, researchers and producers have often pointed out (e.g. Refs. [18,20,23,32–34], that the lack of growth in the EU aquaculture sector can be mainly explained by the difficulties of integrating EU and national environmental policy concerns (e.g. the water framework directive) and at the same time sustain growth in an environmental and economically sustainable way to satisfy an increasing demand of seafood consumption [35].

Yet, these overall figures do not fully show the evolution of the EU aquaculture sector. Between 2008 and 2016, the EU aquaculture production increased by 39% in value terms, despite the decrease in the production volume (−8%). Most of the key EU producers, with the exception of Italy, increased their value production. Behind these numbers, the production of seabass, seabream and salmon has increased by almost 40%, while the production of mussels, the main aquaculture production in volume, has declined by 15% during this period. Mussel production has declined in the EU due to spreading of diseases and low earnings, which may be due to local limitations in EU countries such as the high atomization of mussel enterprises in Spain [34] or the impacts of climate change on the mussel aquaculture sector [36], among others. Thus, the overall production evolution hides a decrease of species with low economic value (e.g. mussels) only partly due to poor economic performance, and production increases of higher valued species (e.g. seabass and seabream). Moreover, average GVA increased by 71% during this period.

However, the EU may have failed in directing the funds where it could have made a more significant impact [28]. The payments of funds are handled nationally and with a very wide range of possibilities to support different types of projects under the overall EU strategy for developing the aquaculture sector. As a result, the subsidies are distributed among many small-scale projects, in most cases, and it has proven very difficult to measure and obtain knowledge on the effects of support given to these small individual producers/projects. The structure of the EU aquaculture sector is mostly small-scale family owned businesses [20,32,37], which have limited interest in sharing knowledge and new technology advances due to high competition in the sector.[9] On the other hand, the small-scale farmers also have limited ability to adopt and apply new technology and knowledge even when available. Looking at the few successes in the EU, it is mostly large-scale producers with high expertise and economic means producing well established species (salmon, seabream and seabass) in large scale that have been successful. Furthermore, it seems that the environmental constraints on sea cage farming, so far, is less than the land-based alternatives, even though there is less control with the nutrient load and potential disease spreading. Thus, the potential in sea cage farming of already produced species seems promising.

Land based producers compete with other inland producers on emissions to the surrounding environment. Even though there has been

[9] This contrast strongly with the large firms that dominate the most successful European aquaculture sector, salmon, within EU (primarily Scotland) and outside of EU (Norway and the Faroe Islands) [59].

an intensive technology development reducing the nutrient loads from aquaculture farm, the stage where fish farming can be decoupled from the environment is still not an economically viable business. The problem here seems again to be the economic structure of the sector and the focus of the funding. If the demand for the new technology increased, their prices would decrease [2,38] and make it more profitable to introduce the new technology, and this also carries into the supply chain [39]. However, the small-scale producers and limited volume of production in each country combined with the unfocused spending of public means on small-scale projects do not support further technical development and do not give input providers an incentive to further develop and invest in the aquaculture sector.

Overall, funding for research with a more overall aim of supporting development of technology, vaccines, breeding and feeding for well-established species already produced and sold on the EU market could be a way forward to get a more significant effect in terms of production volume under the given environmental constraints. Furthermore, most EU countries base their existing regulation on command and control. This kind of regulation can secure a certain level of environmental impact from a sector, such as the level of nitrogen, phosphorus and organic material from the aquaculture sector. However, command and control regulations usually do not ensure that the most efficient producers are the ones producing, they are inflexible and do not provide producers with an incentive to adapt and develop new technology [10,22,40]. Implementing incentive-based regulation, such as individual transferable quotas or taxes on their environmental impact, can induce economically optimal management, which could support further growth in the EU aquaculture sector.

6. Conclusions

While there is an ongoing global aquaculture revolution, the EU is to a large extent not participating on the producer side, as production growth in volume was weak until the turn of the century and has stagnated since then. This decrease in the EU aquaculture production is mainly due to the decrease in the mussel production; while production of more expensive species (e.g. salmon, seabass and seabream) with a higher degree of control by the farmer of the production cycle (e.g. feeding, medicines, juveniles, broodstock, etc.) has increased.

Still, the EU is set on promoting growth in the EU aquaculture sector, having invested €1.17 billion from the structural funds over the period 2000–2014 and plans to spend a further €1.72 billion over the period 2014–2020 through the EMFF. These significant levels of public funding can be difficult to justify[10], especially when experts indicate strict environmental regulations and administrative burden for the overall lack of growth rather than the need of public funding [20]. These funds represented on average 4% of the GVA produced by the EU aquaculture sector during the period 2007–13, and will increase to 9.3% for the period 2014–20. On average, each enterprise received almost €41 thousand in public funding (2007–13), and will increase up to almost €123 thousand per enterprise (2014–20). Likewise, this corresponds on average to almost €7 thousand per employee during the period 2007–13 (i.e., about €1000 per year), and more than €21 thousand in the period 2014–20 (i.e., about €3000 per year). However, given the small size of the EU aquaculture sector, the public funding destined to the sector represents a small expense for the EU taxpayers.

This support aims to improve food security and economic development in line with the EU's Blue Growth Strategy and the potential of creating sustainable growth and jobs from marine sectors [41,42]. However, the projected 25% growth in the EU aquaculture production may be too optimistic considering the overall zero growth in the sector during this whole millennium, especially if mussel production does not recover.

Seafood markets are becoming more competitive, and subsidies allocated to improve productive efficiency, reduce production costs and increase productivity are key to increasing the competitiveness of aquaculture in the EU, as for many species there is a strong competition from imports [34,43–46]. Ideally, subsidies should target improvements on the production efficiency through technical, operational and management innovations that lead to a reduction of the average cost of production. By improving the economic margins, profitability would be less dependent on the volume of production and the level of imports, thus making the sector more resilient [47]. Past experiences have shown that while the overall objective of these programs has been to increase the production of the sector in general, not all productions types should be promoted equally. Subsidy policies must promote high-quality, high-nutritional products and eco-friendly production, but also consider consumer preferences and market demand. Quality or other product attributes can be used as a differentiation factor under certain circumstances by the EU producers [48,49]. Therefore, we recommend focusing on improving the value of the EU aquaculture production than just increasing production (i.e., food security) per se. We believe this approach helps to explain the successful increase in the salmon, seabass and seabream productions in the EU.

Unfortunately, we do not have data to compare the subsidy levels with other non-EU countries, but it is worthwhile to note that subsidies have been a factor in many of the numerous anti-dumping cases for seafood such as salmon to the US [50–52], salmon to Europe [53] and shrimp to the US [54]. However, as for fisheries subsidies [12], subsidies for aquaculture are likely to be present primarily in developed countries and primarily for net importers of seafood. Thus, despite the subsidies devoted to its aquaculture sector, the EU should not receive anti-dumping complaints, as a net importer of seafood and hardly exporting any farmed products.

Declarations of interest

Sebastian Villasante acknowledges financial support from the European COST Action “Ocean Governance for Sustainability - challenges, options and the role of science” and by the ICES Science Fund Project “Social Transformations of Marine Social-Ecological Systems”.

The other authors declare no conflict of interest.

Acknowledgements

The authors wish to thank two anonymous referees for all their constructive comments. Any errors or views expressed in this paper are solely the responsibility of the authors. The opinions expressed in this paper are those of the authors and do not necessarily reflect their institutions's positions or policy.

[10] Public funding to the aquaculture may be justified by producing positive externalities, such as improving environmental conditions, for example mussel farming can be used for water purification to reduce eutrophication [60,61], and public health, as seafood consumption can have a positive effect on particularly with respect to cardiac diseases [62].

Annex: Reference box for acronyms

Table 6
Reference box for acronyms

Acronym	Definition
DCF	Data Collection Framework
DG MARE	The European Commission's Directorate-General for Maritime Affairs and Fisheries
EAFRD	European Agricultural Fund for Rural Development
EBIT	Earnings Before Interests and Taxes
EC	European Commission
EFF	European Fisheries Fund
EMFF	European Maritime and Fisheries Fund
ERDF	European Regional Development Fund
EU	European Union
EUR	Euro currency
FAO	Food and Agriculture Organization of the United Nations
FIFG	Financial Instrument for Fisheries Guidance
FTE	Full Time Equivalent employment
GVA	Gross Value Added
kg	kilogram
OECD	Organization for Economic Cooperation and Development
STECF	Scientific, Technical and Economic Committee for Fisheries
USD	United States of America dollar

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