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Harvesting costs and revenues: Implication of the performance of open-access industrial fishing fleets off Rio Grande, Brazil

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ABSTRACT

In order to assess the performance of major commercial fleets, key factors affecting fishing costs and revenues are provided along with a framework to standardize economic knowledge construction in data-poor fisheries, such as South Brazil's. Additionally, the effects of fuel subsidy policies on profitability were further evaluated among fleets. The unprecedented set of field survey data generated by this study revealed that fuel consumption, fish price, and catch volume were the main factors affecting profitability. Annual gross profit was positive for all fleets. Longliners showed the highest gross profit margin (29%), while single-bottom-trawlers, close to unviability, showed the lowest (0.9%). Overall, subsidies were ineffective in increasing Rio Grande fleet gross profits and may be masking poor economic performance, primarily for single-bottom-trawlers. Specific policy advice aiming to protect both economic performance and natural resources are discussed, including the importance of economic data collection and cost-benefit analysis.

1. Introduction

The contribution of economic analysis to the comparison of fishing fleet performance, together with environmental and social approaches, have been considered strategic to solving problems related to fishery mismanagement and unsustainable practices [1,2]. The burden of not having this perspective represented in both management and policy outcomes is widely recognized [3,4]. However, for several fishery systems, an economic performance analysis of the fleets has not been performed [5]. This lack of analysis is understandable because in practice, data and indicators of the socio-economic performance of commercial fleets have not been made publicly available, often not even to the scientific community [1,5]. Therefore, since the motivation for fishing is profit [6], knowledge of the economic dimension of fisheries can be particularly useful to address policy questions regarding fishery management.

In Brazil, economic data on fisheries are generally scarce. This is possibly because current fisheries' statistics systems do not include economic data (i.e., costs and profits) or evaluations of the economic performance and efficiency of fishing fleets in public reports. The systematic collection and updating of the information prioritizes data regarding the fishing effort and the landed production per species. Nevertheless, academic research papers have been reporting economic data on inland fisheries [7–9], marine small-scale fisheries, such as for lobster and shrimp [10–14], bioeconomic models and cost analysis for a few species [15–19]. According to [1], which was the first broad study describing comparative multi-fleet analysis of socio-economic performance indicators for fishing fleets in Brazil, there is a need to build on the suggested protocol for the standardized collection and analysis of economic data. Regarding the fishing industry in Brazil, data on the economic performance of fishing fleets, as explained by a detailed analysis of costs, benefits and profitability, have, in most cases, been difficult to access and measure and have been notably unavailable for multi-fleet comparison purposes [1].

In terms of subsidy policies for fisheries, there are at least 10 types in Brazil. Ranging from incentives for ports facilities, capacity enhancing, and closure compliance of small-scale fishers to marketing, credit access, social security, and operational ones (such as for fuel), it was estimated that approximately 25% of the subsidies show high risk potential for contributing to overcapacity or overfishing [20]. Nevertheless, a comprehensive subvention program to oil price [21] guarantees that the difference between national and international diesel prices be equalized for maintaining international trade. Thus, officially registered vessels (in Brazil's Fisheries Secretariat and port authority)

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have a fuel tax waiver at the state level, plus a federal pecuniary aid (cash transfer) for up to 25% of their fuel consumption per year [22] established as an individual quota in liters [23]. In practice, there are some vessels not eligible for receiving the subsidy.

According to [24], this policy contributes to an increase in catches without regard to knowledge on stock sizes, which tends to result in a decline in the fishery resources because catches are not regulated. Moreover, a central issue is that subsidizing fisheries without knowing their economic performance may underestimate the real benefits of the subvention. This issue becomes even more relevant, since the cost of fuel is significant in fisheries [5,19,25,26], and the appeal for its subsidy is constant in the fishing sector.

In addition, commercial fishing fleets in Brazil operate in an open-access regime, i.e., there are currently no constraints imposed by government besides fish and mesh size and closure seasons for a few resources (none in Rio Grande). For tuna fisheries, the country supports a quota established by the International Commission for the Conservation of Atlantic Tunas. However, it is well known that the eventual benefits of open-access regimes tend to weaken over time and can create economic inefficiencies as well as unsustainable yields [27].

From both the socio-economic and environmental perspectives, there are significant differences between the fishery fleets, emphasizing the need for specific studies to provide better knowledge, especially on financing and economics. Indeed, the lack of fleet studies limits the ability to understand and manage these fisheries. Another issue is the heterogeneity of the fleets in terms of vessel size and types of fishing gears, which leads to a variety of economic, social and environmental impacts that are rarely translated into financial terms or presented together in the form of a cost-benefit analysis [28]. Furthermore, before implementing costly management systems, it may be appropriate to investigate the economic efficiency of an open access fishery and how the cost-benefit relationship behaves [29].

Based on these assertions, the purpose of the present study was to evaluate the financial performance of the multi-fleet commercial fisheries of an open-access regime in South Brazil in terms of both budget (cost and revenues) and the impact of the government fuel subsidy policy on the profitability of these fleets.

Thus, the objectives of the present study are to (1) provide economic indicators on the Rio Grande fishing fleets, including their cost structures and profits and (2) to present a methodology that may contribute to the organization (and collection) of economic data from Brazilian fisheries, which are currently non-existent. This knowledge was applied to analyze and compare the economic performance of the different fishing fleets and to estimate, compare and discuss the cost of fuel and the effect of the fuel subsidies policies on profitability, which might be useful for future regional management plans.

2. Background

Commercial fishing in Rio Grande is economically relevant because it is the main fishing center in the Brazilian state of Rio Grande do Sul. In addition, it is a traditional activity that involves many stakeholders. Evidence, however, indicates the decline of the industry, the number of active vessels, and the condition of overexploitation of certain stocks in the region [30–32]. In the 1970's, the Rio Grande fishing involved 23 large fishing companies, and the catch reached a maximum of 105,000 t. Currently, 16 companies are operating in the town [33] and, the catch has fallen sharply in recent decades and currently stands at approximately 35,000 t [34].

The causes of the declines may be related to outdated technology, organizational structure and outdated management methods [35]. Other important factors were fishing beyond the reproductive capacity of the species, blocks on the reproduction of marine species, pollution levels, and external predation in the economic zone of Brazilian territorial waters [36]. Between the years 1991 and 2001, 290 vessels were active and landed at Rio Grande, and approximately 10 years later, reduced to 266, while not all vessels operate every year [37]. The commercial fishing in Rio Grande has been carried out by different fleets using several gears (e.g., trawls, longlines, gillnets) and target primarily the argentine croaker (*Umbrina canosai*), white mouth croaker (*Micropogonias furnieri*), weakfish (*Cynoscion* spp), shortfin mako (*Isurus* spp), tuna (*Thunnus* spp), and swordfish (*Xiphias gladius*). The two croakers are the most important commercial species in the region, caught by gillnetters, bottom-trawlers and purse-seiners [34]. There are also some vessels for Mugilidae and skipjack tuna.

Finally, the masters and fishers value their autonomy, resisting both the wage labor system and long-term agreements with the industry, which predominantly involves the payment of shares that are now calculated on the overall value of production per fishing trip [38]. Thus, fishers are 'co-partners' together with the vessel owners and have no fixed salary. The individual salary is calculated by subtracting the operational cost (fuel, ice, repairs, etc.) and the owner's portion (profit) from the gross revenue, while division between the crew is made in parts and depends on their on-board functions [1]. Furthermore, obtaining information related to fishing activities in general, but particularly to economic data, is extremely difficult. First, due to the dynamics of the vessels, which spend the majority of their time at sea without a fixed date for their return to harbor, they often unload their merchandise at private locations where access to data is restricted. Second, the official data is incomplete, not collected regularly, and very often not made publicly available. Lastly, it seems that there is a 'secrecy pact', principally among the vessel owners and fishing companies, and there is a great deal of reluctance in making information available and a widespread belief that it will be used against the sector.

3. Methods

3.1. Data collection

The Rio Grande commercial fleet operating around Southern Brazil was analyzed. A survey was conducted during 2013–2014 among the primary landing points in the Rio Grande zone (Fig. 1). Key-informant, semi-structured personal interviews with vessel captains and owners were used [1,25] to gather data related to the technical and fishing effort details, costs, production data and ex-vessel price by species of the most recent fishing trip (Table 1) by vessel and from four different fleets (bottom-gillnetters, surface-longliners, pair-bottom-trawlers and single-bottom-trawlers). The questionnaire that was used had relatively little complex structure and required no more than half an hour to be completed. This approach was applied because it allows the economic situation of a fleet to be estimated when the official data is not complete or not collected regularly, as is the case in Brazil. The interviews were performed at three principal industries due to the significant numbers of vessels that landed at these sites and that are currently considered representative of the regional fisheries. Interviews were conducted between June 2013 and May 2014, completing a total of 106 questionnaires covering the four fleet categories. However, as some vessels were sampled more than once during the period, the interviews represent 22% of the active bottom-gillnetter vessels, 100% of the active longliner vessels, 39% of active single-bottom-trawler vessels, and 34% of active pair-bottom-trawler vessels. The number of potentially active vessels in the area was obtained from the CEPERG [34] and is shown in Table 2, as well as the basic technical characteristics of the commercial vessels analyzed.

A fixed percentage of the gross revenue is taken from each fishing trip for vessels maintenance and repair. The results obtained on this from our surveys was considered for that estimate (varying by vessel and fleet, but about 20% for longliners, single-bottom-trawlers, and pair-bottom-trawlers and 16% for bottom-gillnetters). Despite the maintenance of the vessels varying between fixed and variable costs, this factor was only considered to be a variable cost within this study because, considering the fishing operation, the vessels repair costs can

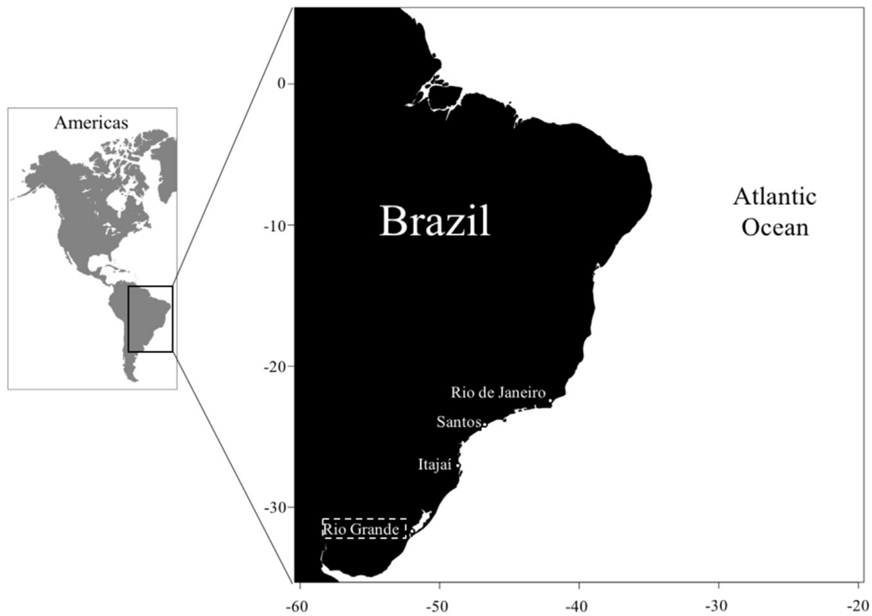

Fig. 1. Location of the fishing port of Rio Grande (in dots), in the coast of South Brazil, in South America.

Table 1
Attributes included in questionnaires for data-gathering interviews.

Attributes groups and collected data
Technical and effort – related data:
Vessel size (m)
Number of fishers
Number of fishing days by trip
Number of fishing trips by month
Fuel consumption (liters) per trip
Ice consumption (t) per trip
Yields:
Total catch per trip by species (in weight, t)
Ex-vessel price by species per trip (R$)
Costs (R$):
Fuel and lubricating oil (per trip)
Food (per trip)
Ice (per trip)
Landing (per trip)
Bait (per trip)
Vessel and gear maintenance (per trip)
Labor (per trip)
Fees and Taxes

be modified depending upon the catch produced per trip. Therefore, according to those interviewed, this amount is used to cover costs such as small repairs to the vessels, equipment and fishing apparatus, as well as the costs involved in larger maintenance work (the vessel itself and fishing equipment), the purchase of equipment and the required annual inspections by the Port Authority.

However, it is assumed that the fixed costs comprise all the costs established on land, since they remain unchanged independent of the catch volume.

Lastly, the annual diesel oil subsidy quotas were obtained based on official reports [39–41] for individual vessels.

3.2. Data analysis

Average values were used to describe the cost structure of each fleet, as well as the revenue per fishing trip, monthly and annually. To describe and evaluate the financial performance of the fleets, a set of indicators was calculated, as follows.

- The *average capital cost, also denoted as average capital investment (CI)* of the fishing vessels was estimated, including the initial cost of acquiring a fishing vessel and all the equipment necessary to perform the activities. To establish the CI, owners or captains were asked which the value of their vessel, gear and equipment under the assumption that they had to sell it in its current condition at that time.
- *Revenue (R)* is the total catch value [7,42]. To compute the value of catch per trip quantities are multiplied by the current price of fish (obtained from interviews to vessel owners and representatives of the industry) for the respective quantities. R was calculated monthly and yearly based on the original database (per fishing trip). The first represents the catch value per trip multiplied by the average number of trips per month. Annual data was calculated by multiplying the monthly values by the number of operating months (12 months).
- *Operational costs (OC)* include variable costs such as fuel, lubricating oil, ice, food, bait, landings and also repairs to the vessel and gear maintenance. Costs per month were based on the costs per trip multiplied by the average number of trips per month. Annual data was calculated by multiplying the average monthly values by the number of months that the fleet operated (12 months). To calculate the cost of fuel per trip each observed vessel were considered as non-subsidized, and the average market price of the diesel oil value was used for the city of Rio Grande and multiplied by the amount of fuel (in liters) on the trip per vessel. This involves speculation about how these vessels would have performed in the absence of the subsidies. The site of the National Agency of Petroleum, Natural Gas and Biofuels - ANP was consulted to establish the market price of diesel oil.
- *Fixed costs (FC)* included monthly and annual expenses for fees (social security contribution), vessel tracking service, insurances (vessel and crew), forwarding agents, and accountants. Data provided were per month and per year (not per fishing trip).
- *Labor costs (LC)* includes all payments to crew, and are calculated on the overall value of production per fishing trip. Thus, fishers are 'copartners' together with the vessel owners and the labor cost is calculated by subtracting the OC (fuel, ice, repairs, etc.) and the owner's portion (profit) from the TR.
- *Total costs (TC)* were calculated using the sum of operational costs and fixed costs.

Table 2
Major characteristics of the four studied fishing fleets based at three principal industries of the Rio Grande region, in the South Brazil Bight.

Fleet	Gear	Target-species	Bycatch	Range length of vessel sampled(m)	Average number of crew	Average duration of fishing (days)	Number of active vessels (CEPERG, 2012)	Number of sampled vessels and percentage in relation to the number of active vessels
Bottom-gillnetters	Bottom-gillnet	*Micropogonias furnieri, Umbrina canosai, Cynoscion striatus*	*Cynoscion* spp, *Urophycis* spp, *Carcharhinus* spp, *Pomatomus saltatrix*	15–26	8.9	15.1	46	10 (22%)
Surface-longliners	Surface longlines	*Thunnus* spp, *Xiphias gladius, Isurus* spp	*Auxis thazard, Carcharhinus* spp, *Squalus* spp, and another 20 species.	22–28	9.3	10.0	5	5 (100%)
Pair-bottom-trawlers	Bottom-pair trawls	*Umbrina canosai, Micropogonias furnieri, Cynoscion striatus*	Over 77 species from 25 families.	17–25	13.4	16.9	50	17 (34%)
Single-bottom-trawlers	Otters trawls	*Umbrina canosai, Cynoscion striatus*	*Macrodon ancylodon, Prionotus punctatus,* and another 40 species	20–27	6.1	16.7	31	12 (39%)

$$\text{Total Costs (TC)} = \text{OC} + \text{FC} + \text{LC} \quad (1)$$

- *Gross profit* (before interest and taxes) is simply calculated as the total revenue minus all expenses considered in this study (specifically operating, fixed and labor costs).

$$\text{Gross Profit} = \text{R} - \text{TC} \quad (2)$$

- *Economic efficiency (EE)* [7] was estimated by dividing the mean of the annual total revenue (total catch value) by the mean of the annual total costs.
- *Gross profit margin* (%) [12] was calculated by finding the mean of the annual profit as a percentage of the mean of the annual total revenue. The profit margin represents what is left to the vessel owner as compensation for the capital as a percentage of sales, *i.e.*, the total revenue.

$$\text{Gross profit margin (\%)} = (\text{Gross profit/R})*100 \quad (3)$$

The profitability of the fleets was measure by gross profit margin (%) and gross profit indicators, and the monthly gross profit and annual gross profit margin (%) were used to compare the profitability of fleets.

Depreciation and the opportunity cost of labor and capital were not included in the analyses because this study was not designed to be a full economic analysis of the profitability of the fleets but rather a financial cost-benefit analysis of current operational sector. Financial performance is the measure of most interest to fishers, as it represents how much income they are left with at the end of the year [43,44].

Note that all costs and values are in Brazilian currency (Real, R$; conversion rate of US$1.00 = R$2.23 on May 30, 2014).

The effect of fuel subsidies on profitability for each fleet was evaluated by (1) separating subsidized and the non-subsidized vessels, and (2) calculating annual fuel cost per vessel (diesel consumption from the database multiplied by liter price minus tax waiver for subsidized vessels). However, in some cases, the fuel consumption exceeds the subsidized quota (the percentage approved by law based on a fixed consumption per vessel) and that surplus was multiplied by diesel market price. Then, gross profit was estimated for both non-subsidized and subsidized vessels, adding the federal pecuniary aid in the second case. The difference in annual gross profit was tested using a two-sample (independent) *t*-test.

Significant differences between the monthly profitability and costs related to the fishing operation per fleet were tested using the Kruskal–Wallis Test. If the Kruskal-Wallis Test revealed significant differences, then a posteriori pairwise comparisons were conducted using a nonparametric multiple comparison procedure.

4. Results

A summary of major characteristics of the four studied fishing fleets is shown in Table 2. Longliners ranged from 22 to 28 m length (Table 2), with average catches of 7.1 t of fish per trip (Table 3), and with the highest target-stocks ex-vessel prices/kg (i.e., tuna ranging from R$ 22 to R$ 40). The other three fleets (bottom-gillnetters, single-bottom-trawlers and pair-bottom-trawlers) target croaker and weakfish, ranking the lowest ex-vessel prices (i.e., from R$ 1.81–2.20/kg). However, bottom-gillnetters, single-bottom-trawlers and pair-bottom-trawlers show differences on their average catch, with 26.2 t/trip, 44.5 t/trip and 74.6 t/trip of fish, respectively (Table 3).

4.1. Cost structure

The average capital cost of the four different fishing fleets is shown in Table 3. Longliners showed the lowest total average investment (approximately R$ 1,153,000) in contrast to the pair-bottom-trawlers whose initial investments required approximately R$ 1,764,000. Pair-

Table 3
Performance indicators per fishing trip, as monthly and annual mean values, by fleets in R$ (Brazilian Real) and excluding the subsidies. (S.D.: Standard deviation; EE: Economic efficiency).

	Bottom-gillnetters		Longliners		Pair-bottom-trawlers		Single-bottom-trawlers	
	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
Capital investment	1,400,000	144,584	1,153,333	147,935	1,764,342	750,877	1,606,250	982,831
Per fishing trip:								
Catch (t)	26.2	11.7	7.1	3.3	74.6	37.7	44.5	27.1
Revenue	56,215	20,906	109,783	51,684	166,977	71,493	80,641	42,495
Operational Cost	27,266	7104	40,415	12,550	93,846	34,265	68,886	14,905
Labor Cost	14,475	8032	34,684	27,253	36,565	26,558	5,877	19,950
Fixed Cost	0		0		0		0	
Gross profit	14,475	8,032	34,684	27,253	36,565	26,558	5,877	19,950
Monthly:								
Trips per month	1.48	0.34	2.27	0.72	1.56	0.38	1.70	0.69
Revenue	84,080	38,170	255,678	150,383	257,463	121,881	133,957	110,530
Operational Cost	39,731	12,832	86,711	30,722	142,153	45,828	114,727	58,641
Labor Cost	22,174	13,489	84,483	71,255	57,654	46,431	9,615	38,626
Fixed Cost	5,509	626.63	9,002	0	10,123	848.58	5,748	1,923
Gross profit	15,608	14,068	75,481	71,255	44,795	46,376	3,866	37,487
Annual:								
Revenue	1,008,965	458,042	3,068,140	1,804,600	3,089,557	1,462,579	1,607,486	1,326,368
Operational Cost	476,780	153,983	1,040,532	368,673	1,705,839	549,939	1,376,726	703,702
Labor Cost	266,092	161,869	1,013,804	855,069	691,858	537,542	115,380	463,517
Fixed Cost	116,212	7,519	108,030	0	164,203	11,651	101,581	24,583
Gross profit	137,208	168,821	905,774	855,069	527,655	536,019	13,799	450,004
Gross profit margin (%)	13.6		29.5		17.1		0.9	
EE (R$)	1.22		1.42		1.21		1.01	

bottom-trawlers showed the greatest value of capital cost due to the need of operating two vessels.

For the four fleet segments, the operational, labor and fixed costs varied in nature and importance (Table 3). The operational costs were directly related to the types of gears used, where pair-bottom-trawlers and single-bottom-trawlers showed the highest operating costs, respectively (Fig. 2). Significant differences in operational costs were found between fleets (χ^2 = 58.592, df = 3, $p < 0.001$) and *a posteriori* pairwise comparisons showed that pair-bottom-trawlers had significantly higher operational costs compared with other fleets, except single-bottom-trawlers.

Fig. 3 shows the relative importance of each type of operational cost within each fleet per fishing trip. Fuel was the primary cost for all the fleets, accounting for 60%, 48%, 36% and 35% of the total operational costs, excluding the subsidies, for single-bottom-trawlers, pair-bottom-trawlers, bottom-gillnetters and longliners, respectively. There are significant differences in fuel costs between the fleets (χ^2 = 70.37, df = 3, $p < 0.0001$), however no significant differences were found between pair-bottom-trawlers and single-bottom-trawlers. The second largest operational cost was vessel maintenance for all fleets.

An inter-fleet comparison of all monthly costs and gross profit is shown in Fig. 2. Relatively higher operational and fixed costs were estimated for pair-bottom-trawlers; however, this was not the fleet with highest profitability since relatively higher gross profits were recorded for the longliners. Labor costs ranged from 6% to 49% and were lowest for single-bottom-trawlers. Labor costs were significantly different between fleets (χ^2 = 24.926, df = 3, $p < 0.0001$) and pairwise comparisons found significant differences for the following groups: longliners vs. bottom-gillnetters, longliners vs. single-bottom-trawlers, pair-bottom-trawlers vs. single-bottom-trawlers.

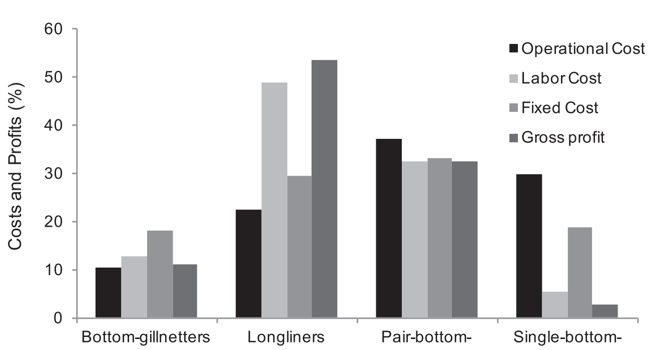

Fig. 2. Inter-fleet comparison of the relative importance of costs and gross profits, as estimated by month, excluding the subsidies.

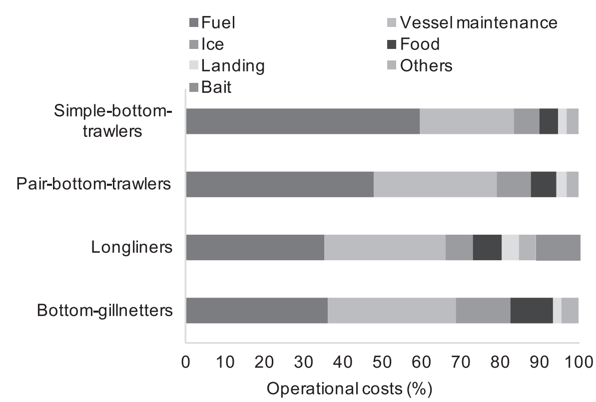

Fig. 3. Relative importance of operational costs within each fishing fleet as estimated per fishing trip, excluding the subsidies.

4.2. Financial performance

The profitability indicators (gross profit margin and EE) are shown in Table 3. On average, the fleet that had the greatest gross profit margin, excluding the subsidies, was the longliners followed by the pair-bottom-trawlers. However, significant differences were found in the monthly gross profits for all fleets (χ^2 = 22.3, df = 3, p = $<$ 0.05), where longliners were significantly more profitable than the bottom-gillnetters and single-bottom-trawlers, but not for the pair-bottom-trawlers fleet, which is more profitable than the bottom-gillnetters (Table 4). The longline fleet showed a high gross profit margin (29.5%) and the opposite occurred with the single-bottom-trawlers, which

Table 4
A posteriori multiple comparison test of monthly gross profit by fleet. Number of observed differences. Asterisks indicate statistical significance.

Fleet	Bottom-gillnetters	Longliners	Pair-bottom-trawlers	Simple-bottom-trawlers
Bottom-gillnetters	–	29.185*	19.029	9.776
Longliners	29.185*	–	10.156	38.962*
Pair-bottom-trawlers	19.029	10.156	–	28.806*
Simple-bottom-trawlers	9.776	38.962*	28.806*	–

Kruskal-Wallis test $\chi^2 = 22.3$, df = 3, p = < 0.05.

showed a very low gross profit margin (0.9%).

In terms of economic efficiency (EE), for every R$1 invested, longliners had an income of R$1.40, and pair-bottom-trawlers and bottom-gillnetters had an income of R$1.20 (Table 3). On the other hand, single-bottom- trawlers showed zero income on relation to expenses (EE = R$1.00).

The results show that, in average, the annual gross profit for subsidized and non-subsidized vessels was positive for all fleets (Table 5). However, when each trip was analyzed separately, of the 106 fishing trips, 13% had negative returns. The most negative return trips were carried out by non-subsidized vessels, mainly for the single-bottom trawlers, where 44% of fishing trips have had negative returns. The subsidized vessels were more profitable than the non-subsidized for pair-bottom-trawlers and single-bottom-trawlers, and the difference in profitability was 8%, and 44%, respectively. The case of the bottom-gillnetter and longliner fleets were reversed, non-subsidized vessels were 23% and 53% more profitable than subsidized. However, annual gross profits were significantly different between subsidized and non-subsidized vessels only for longliners (p-value = .003).

5. Discussion

The present study highlighted the importance of a standardized framework to establish the economic knowledge construction for the fisheries of Brazil. In this sense, the methodology and the list of basic data provided by this contribution (Table 1) can be considered representative of the general economic trend of regional fleets and may also be used as a reference for the development of strategies for collecting, organizing, and analyzing fisheries economic data in Brazil. The recording of the data of each fishing trip proved to be very illuminating by way of providing evidence relating to the yielding of negative returns during some sampled fishing trips, where the operational costs turn out to be higher than the total revenue.

Differences among the fleets were found in respect to the composition of costs and revenues, as well as to financial profitability and efficiency. Negative returns per trip had already been evidenced in previous studies for some pair-bottom-trawlers from a nearby region [16]. However, this issue has never been evidenced for bottom-gillnetters, longliners, single-bottom-trawlers, and pair-bottom-trawlers off South Brazil before.

Nevertheless, on average, profitability was positive for all the fleets in 2013–2014, even in the open access fisheries regime and when the fuel subsidies were excluded. The annual gross profit margin (%) for the Rio Grande fishing fleet presented here varied widely and may be considered high for longliners (29.5%) fleets when compared with fleets of other regions of the world. Therefore, for the national, large-scale fleets in France, Portugal and Spain, the average gross profit margin was 14.1%, 22.5% and 9.5% [45], respectively. On the other hand, pair-bottom-trawlers showed the second best financial performance because they have higher revenue (higher fishing efficiency and higher catches), despite their high operating costs. However, catch volume seems to be the main factor influencing the profitability of the trawlers studied, since even targeting the same species with approximately the same ex-vessel price, they do not differ in operating costs. In addition, overall, the best financial performance of longliners can be related to their higher fishing efficiency with target species showing high ex-vessel prices/kg.

The gross profit margin reflects the percentage of revenue that a sector retains as profit; the single-bottom-trawler fleet had the lowest efficiency (0.9%) and can be compared with the demersal trawler fleets of France, Belgium and the UK, generating a gross profit margin of 0.9%, 1.2% and 1%, respectively [45]. In this sense, this study suggests that the single-bottom-trawlers are not economically profitable, primarily due to high costs, low fish price (average R$ 1.81/kg), and the decline of the fleet's target-species, the argentine croaker stock (*Umbrina canosai*) and whitemouth croaker (*Micropogonias furnieri*), which already are considered overexploited in this region [31,46]. Accordingly [32], the intense exploitation of the argentine croaker stock over the last 40 years should serve as a warning for the high risk of collapse of the second most important species to the demersal fisheries in the region. One particularly important point is that the primary targets of 95% of the active vessels in the region are the croaker and weakfish species [34]. Because it is a resource exploited by various vessels belonging to different fleets (Table 2), there is no self-regulation of expectations, thus requiring state action (the right of the public to participate in fishing).

Overall, a good economic performance can encourage investment in fishing [25]. In fact, the number of longliner vessels in the region has increased in recent years [47], reflecting an investment in this fishery primarily driven by the high international market price of swordfish (*Xiphias gladius*), which is the target species of this fleet [48]. Indeed, the International Commission for the Conservation of Atlantic Tunas (ICCAT) is concerned about the considerable increase in swordfish catches in the South Atlantic [49], although the Brazilian government has implemented rules aimed at regulating tuna and tuna-like fish [50].

Monitoring should be an important management action necessary for the conservation of profitable fleets. Nevertheless, all other

Table 5
Annual gross profit, fuel cost and diesel oil subsidy quotas (in R$) by fleet and by subsidized and non-subsidized vessels.

	Bottom-gillnetters	Longliners	Pair-bottom-trawlers	Simple-bottom-trawlers
Subsidies case				
Maximum gross profit (R$)	416,073	1,657,459	2,086,987	1,151,517
Minimum gross profit (R$)	− 151,707	12,172	− 51,717	− 780,283
Avarege gross profit (R$)	154,208	615,254	709,423	117,755
Average fuel cost (R$)	136,139	317,111	588,771	795,033
Average subsidy quota (R$)	36,059	62,561	139,070	101,171
Non-subsidies case				
Maximum gross profit (R$)	389,593	2,521,635	1,510,911	788,955
Minimum gross profit (R$)	− 132,460	− 275,461	− 209,300	− 302,714
Avarege gross profit (R$)	201,412	1480,767	543,543	65,462
Average fuel cost (R$)	154,890	294,330	887,218	720,469

demersal resources caught by other fleets studied here are poorly managed because the regulations, when they exist, seem inadequate for the current status of the stocks [32,37,46]. The problems associated with unregulated or pure open-access fisheries have generally been recognized and relatively few fisheries around the world are subject to no management at all [51]. In fact, in an open-access regime, excess capacity may drive difficulties in achieving long-term fishery sustainability [25].

In this study, fuel was the principal cost component for all four fleet segments. This is consistent with results from many fisheries around the world [2,6,25,52–54]. Fuel use varies considerably depending on the fishery [55], but in most cases, the passive gear segments suggested consistently lower consumption, whereas mobile gear showed consistently higher fuel consumption [56,57]. This pattern was the case for the fleets analyzed here, where pair-bottom-trawlers and single-bottom-trawlers that use mobile gear had the highest fuel costs when compared to those of the fleets using passive gear, such as bottom-gillnetters and longliners.

Indeed, with the rising cost of fuel, the decade between 2003 and 2013 saw oil commodity prices climb by over 300% [58], with the most important discussion being about the profitability of fishing. However, oil prices tend to show great fluctuations, and perhaps the implication of falling oil prices on natural resources involves the likely increase in fishing pressure. Likewise, fuel subsidies deflate costs, making more fishing possible unless the number of fishing trips or the catch is restricted. In the case of the studied fleets, this restriction does not occur because of the current unmanaged regime, without any reference point of allowable catch and effort.

Surprisingly, no consistent evidence was found that the fuel subsidy policy resulted in a significant increase in gross profits in Rio Grande's fleets, either when comparing subsidized or non-subsidized vessels. In this case, the fuel subsidy may be masking some low gross profits, mainly for the single-bottom-trawlers, which may aggravate the future economic performance of that fleet. Moreover, besides resulting in an innocuous increase to fleet profitability, the subvention policy seems to give an unfair advantage to more profitable vessels (e.g., longliners and pair-bottom-trawlers), which do not show real difficulties in maintaining a profit margin even when not receiving the benefit (Tables 3 and 5).

This issue also raises the question on the social dimension of policy effects, since economic analysis may also consider rent distribution aspects associated with subventions. For example, in order to eventually solve equity issues when reviewing the subvention criteria in place, policy could rather be directed to the least profitable vessels, aiming to guarantee more secure financial levels to those most vulnerable ones. Additionally, it is clear that the fuel subsidy program generates more benefits to vessel owners than to crew members, as the crew rent in those fleets is a result of a share that is based on fishing trip revenues minus operational costs, and the subsidy cash transfer is not shared with the crew.

Some authors argue that the discount of taxes on fuel for fisheries should not be considered as a subsidy e.g., [59,60] since in some countries those taxes are allocated for the maintenance of terrestrial highways and thus would not apply for non-highway users such as for fishing fleets. However, in Brazil, this discount should also be considered as a subsidy because all taxes collected by the government are summed and treated together as a whole (before distribution among the Federal State, the states, and the municipalities) to be allocated to meet public services and broader social demands. Subsidies are often intended to aid and support vulnerable sectors of the economy during periods of economic problems, such as for the fishing sector. In addition, subsidy holders may pressure governments to maintain or increase subsidies, arguing that the catching cost is high. However, in South Brazil, in addition to the fuel subvention, other types of capacity-enhancing subsidies are applied, resulting in effort increases through artificially increased profits and obviously exacerbating resource overexploitation [20,61]. In this case, an effective control of fishing effort [59] and re-directing the “harmful subsidies” to “beneficial subsidies” could be strategies to promote a reduction in the negative effects of subsidies and the long-term sustainability. Sumaila et al. [62], for example, propose the idea of programs towards improving methods for fish catching and processing, as well as management organizations as beneficial subsidies.

Considering the condition of overexploitation of stocks in the studied region, the sharp fall in the volume of the catch, and the closure of industrial plants, the adoption of the fuel subsidy policy can stimulate a fisheries sector that has already been under pressure because of its performance over the years. The subsidies remove the costs from the market reality and create prices that are not in line with the scarcity of the products. However, very often, an increase in the operational costs of vessels cannot be compensated by an increase in the fishing price [63], and as such, many countries have already recognized that their fisheries, besides being ecologically unsustainable, are heading towards a lack of social and economic sustainability [1,64].

Relating to the fleets surveyed, the labor cost is not linked to the number of crew in each vessel but rather to the value of the catch. The more profitable the fleet's catch is, the greater the percentage of the net revenue that will be distributed among the crew. Therefore, given the "share" system, the crews of the less profitable fleets share the risks of unprofitable fishing trips with vessel owners, leaving them equally vulnerable to debt.

Lastly, while it is noted that economic data on Brazilian fisheries are scarce and difficult to collect, some steps could be taken to improve this gap. These steps include the implementation of appropriate training to conduct the collection of cost data with or by industry members and fishermen's associations as well as the insertion of these data in the current fisheries statistics systems and management. Such data should be updated regularly and processed in a complete and reliable way, which could encourage fisheries research organizations to use the economic performance measures presented here.

6. Conclusions

Longliners and pair-bottom-trawlers were the most economically profitable commercial fishing fleets in Rio Grande, while single-bottom-trawlers, operating in an economically wasteful manner, were less profitable and close to being unviable. The main factors affecting costs and gross profit were the following: fuel consumption, fish price, and volume of catch. However, fishing effort (number of active vessels), the exploitation status of target stocks, and the lack of management are also indirect factors. Fuel was the primary cost, and as expected, the costs were directly related to the types of gear used, as fleets using active catch methods showed higher operating costs than the ones using passive methods.

This study revealed, for the first time in the region, that some fishing trips are yielding negative economic returns. Nevertheless, on average, profitability was positive for all fleets even when subsidies were not computed in the analysis. Moreover, the effects of fuel subsidy policies have not shown statistically significant differences on gross profits when these are compared between subsidized and nonsubsidized vessels, such as single-bottom-trawlers, pair-bottom-trawlers, and bottom-gillnetters. However, negative returns were more frequently seen in nonsubsidized single-bottom-trawlers.

In terms of a standardized framework to ground the construction of economic knowledge in Brazilian fisheries, lessons learned included two facts: a) collecting and analyzing attributes “by fishing trip” instead of using monthly or annual data is more sensitive to evidence of negative economic returns; and b) the analysis of the average values of profits and costs lacking proper statistical tests may result in errors without clarifying the actual situation of vessel's economic performance.

Finally, these findings should guide decisions and resolutions aimed to redress the economic situation of vulnerable single-bottom-trawl vessels and the needs of fishery management measures (e.g., input controls/fishing effort reduction, recovery plans for overfished stocks). The results also suggest the benefits of revising the fuel subsidy program in place in South Brazil. In this regard, the study showed that the subsidy masks the profitability of the poorly performing fleets since it has been applied to vessels that would already be profitable without the subsidy, particularly when compared to fleets in poor economic conditions. The current program also seems to promote an artificial increase in revenues, and when applied to highly profitable fleets that may be operating in an overcapacity scenario, on overfished stocks, and under open-access conditions, it may damage the overall fishery system.

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