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Market incentives for shark fisheries

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ABSTRACT

Fishers tend to prioritize landings of the most valuable product to better utilize vessel capacity. This may lead to discards of catches that are economically undesirable or legally prohibited. The high-value of shark fins and the low-value of shark carcasses has traditionally led to an example of that practice, known as finning. Brazil is an important player in the trade for non-fin shark products. The recent increase in shark meat trade is associated with increased imports of shark meat in Brazil. This increase may be a consequence of stricter finning regulations that has created incentives for full utilization of sharks and exposed the resource to a new source of demand. Thus, sharks overexploitation may increase, even if demand for fins weakens over time. This paper investigates the shark meat market development in Brazil over the last decades using demand and cointegration analysis, with a focus on before and after implementation of finning restrictions in 1998. Results indicate that shark meat is not a new market in Brazil, but an old one driven by a particular interest from local consumers. The decline in domestic shark meat landings, increasing demand for seafood, and the commoditization of shark meat have facilitated import growth. Additionally, domestic prices seem to influence imports most likely because Brazil is an important player as a shark meat consumer. This means that even with the global shark fin market weakening, the Brazilian demand for shark meat is likely to contribute to the overexploitation of sharks in poorly managed fisheries.

1. Introduction

Fishers tend to prioritize landings of the most valuable products to maximize returns subject to constraints in vessel capacity. This may lead to discards of catches that are economically undesirable or unlawful. When catch is discarded, a portion of the discarded fish die, causing not only a loss of potential fishery yield and revenue, but also negative externalities.[1]

Shark fins and its high unit value in Asian markets have provided incentives for fishers to remove shark fins and discard shark carcasses [26,40,41]. This process, known as finning, aims to maximize fishers' production value given limited vessel capacity. However, during recent decades, global shark meat trade has increased significantly, nominally from 157 million dollars in early 2000 s to 283 million dollars in 2016 [36]. At the same time shark fin exports have been relatively stable at an average of nominally 160 million dollars per year [36]. This change in the shark market may suggest an increase in full utilization of sharks and a potentially new threat to shark populations driven by demand for shark meat.

Sharks have a life history, including a long lifespan and late sexual maturity, that make them particularly susceptible to overfishing. Global demand for shark products as well as high levels of bycatch have caused declines in many shark populations and have put many species at risk of extinction [32,45,51]. Pacoureau et al. [53] reported that three-quarters of the oceanic sharks are at risk of extinction. There have been numerous national and international efforts to improve shark conservation globally, but science-based limits on shark fishing mortality is lacking in most parts of the world. An international non-binding voluntary initiative by the United Nations "UN FAO International Plan of Action for the Conservation and Management of Sharks" was released in 1998. Since then, many countries have implemented finning restrictions, fishing bans, and to a lesser extent trade regulations. For instance, finning restrictions were implemented in Brazil in 1998 (and 2012), in Spain in 2002, in the European Union [Member Organization] in 2009 (and

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[1] In our context a negative externality can be defined as an unintended consequence of fishing on the environment, such as loss in biodiversity.

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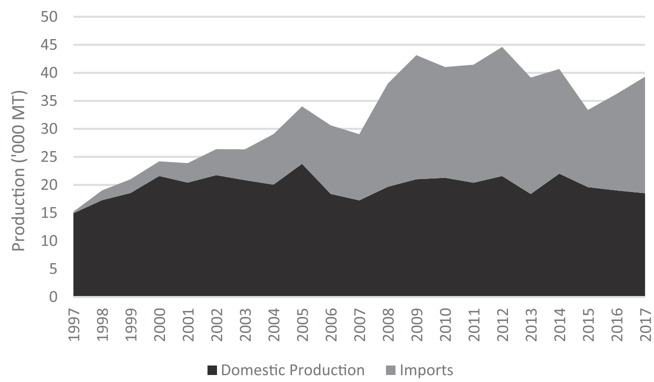

Fig. 1. Domestic production and imports of shark from 1997 to 2017. '000 MT. Source: [36,37].

2013), in Taiwan province of China (2012), and also, by the International Commission for the Conservation of Atlantic Tunas [ICAAT] in 2004, and various regional fisheries organizations in 2005 [30]. In the US, the Shark Finning Prohibition Act of 2000 made it unlawful for fishers to possess shark fins without the carcasses. In 2010, the US strengthened finning regulations with the Shark Conservation Act which has required US fishers to bring sharks ashore with fins attached. Still, the US trades shark fins with countries with no finning laws [38].

However, these regulations focus mainly on the ecological aspects of shark fishing and ignore economic, social, and cultural components. For instance, several fishing communities are highly dependent on sharks for food and income and this has prevented some governments from prioritizing conservation objectives [33]. Moreover, added costs and foregone profits associated with regulations on shark fisheries and trade are a disincentive to fishers to comply with management measures, and it increases the cost of monitoring and enforcement [19]. This highlights not only the economic and social importance of shark fishing, but also its complexity [18–20,46,60].

As a result of Illegal, Unreported, and Unregulated (IUU) shark fishing, many shark products reach the market unidentified or mislabeled [1]. This hinders informed decisions by consumers wanting to buy sustainable seafood. In fact, in the last decades, consumer's role in sustainable use of seafood has increased, and their awareness and buying decisions have impacted the seafood value chain [62]. For instance, consumer awareness campaigns in China designed to discourage consumption of shark fin may have some impact on the declining consumption of this product [35]. In general, stronger (reduced) demand and willingness-to-pay for products with (without) good environmental and societal production practices put pressure on producers to adopt sustainable production practices. This demand driven approach can also push other market actors in the value chain, such as buyers and retailers to source and supply seafood from more sustainable production systems [62]. In fact, as a result, there are premiums for certified products in several seafood markets [4,10,22,61,67].

Brazil is not only a big market for shark meat, but also an important player in the trade of non-fin shark commodities as one of the largest importers of shark meat. The recent increase in shark meat trade is directly and indirectly associated to the increase of imported shark meat in Brazil [30]. This leads to the question of whether this recent increase in shark meat trade may be a result of stricter shark finning regulations that have created incentives for full utilization of sharks and potentially exposed the resource to a new source of demand. If that is the case, the increase in demand for shark meat may increase, or at least maintain, sharks' vulnerability to overexploitation independently from the demand for shark fins.

Market analysis, such as demand and cointegration analysis, can offer important insights for answering this question. The prices and quantities relationships, i.e., market dynamics, can not only provide information on the drivers of exploitation, but also on responses to regulations. For instance, price elasticity (i.e., market's response to price changes) can reveal how an increase or decrease in prices will influence the quantity consumed. An increase in prices is expected to lead to a larger decrease in quantities consumed of elastic products than inelastic ones. Thus, this information can also contribute to the design of management policies which provide incentives to fishers to adopt better fishing practices.

There are very few studies analysing the seafood market dynamics in Brazil, and specially focusing on shark meat [39,56,57,68]. This paper contributes to fill this gap by investigating the shark meat market dynamics in Brazil over the last four decades using demand and cointegration analysis.[2] These analyses allow us to quantify prices and quantities relationships for the Brazilian shark meat market, focusing on two time periods: before finning restrictions were implemented in 1998, and after this period. In the latter, domestic production failed to meet increasing domestic demand for shark meat, and imports became an important supply source. Thus, using a cointegration analysis, we also test the influence of imports in the domestic market. Results indicate that shark meat is not a new market in Brazil, but an old one driven by a particular interest from domestic consumers. The decline in domestic shark meat landings, increasing demand for seafood, and the commoditization of shark meat have facilitated import growth. Additionally, domestic prices seem to influence imports most likely because Brazil is an important player as a shark meat consumer. This means that even with the global shark fin market weakening, the Brazilian demand for shark meat is likely to contribute to the overexploitation of sharks in poorly managed fisheries.

2. Supply of shark meat to the Brazilian market

The Brazilian shark meat market is supplied by both domestic production and imports (Fig. 1).[3] The relative importance of the domestic market has changed over time, with domestic fisheries decreasing to half of total supply in 2017. In the last two decades, an average of 19,818 MT of sharks were landed per year. However, this value is low compared to early 1980 s when its production reached 27,621 MT.

Sharks are an important fisheries resource in Brazil, comprising more than 120 species.[4] Historically, these resources were caught as bycatch by both small scale and industrial fisheries using longlines, gillnets and trawls [31]. However, the high value of shark products in Asian markets, such as fins, have provided incentives for the practice of finning [40,41].

An international non-binding voluntary initiative by the United Nations "UN FAO International Plan of Action for the Conservation and Management of Sharks" was released in 1998. In the same year, finning restrictions were implemented in Brazil requiring that fin landings and shark meat landings be proportional (fins should make 5% of shark landings). This regulation changed in 2012 requiring that the whole shark be landed. These regulations to limit finning domestically, together with the decline of some tuna and swordfish stocks exploited by fleets in Brazil, and the increase in domestic demand have provided incentives for fishers to target and land sharks. Assessments during the

[2] In fact, to the authors knowledge this paper is the first to estimate a demand system for shark meat products in Brazil, along with estimating the price relationships between import and domestic products.

[3] This figure can also be considered as the total apparent consumption of sharks in Brazil, given that exports of shark meat from Brazil is around approximately 1000 MT in total considering all the years since 1976.

[4] The term "sharks" refers in this paper to all species of sharks, skates, rays and chimaeras (Elasmobranchii subclass). Sharks comprise species from the families *Lamnidae, Carcharhinidae, Triakidae, Odontaspididae, Sphyrnidae, Alopiidae, Squalidae. Rajidae, Rhinobatidae, Myliobatidae, Gymnuridae, Narcinidae* and *Dasyatidae*.

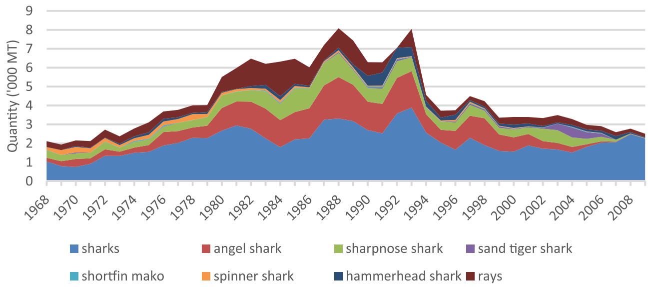

Fig. 2. Shark groups quantities commercialized at the São Paulo wholesale market in Brazil, from 1968 to 2009.
Source: CEAGESP.

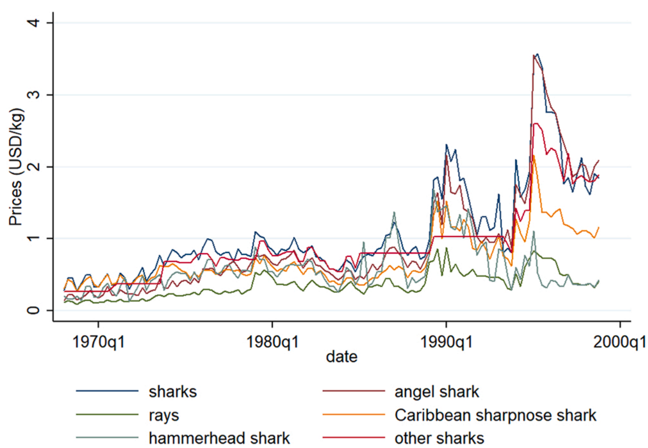

Fig. 3. Deflated prices (USD/kg) of the different shark groups commercialized at the São Paulo wholesale market in Brazil, from 1968 to 1998.
Source: CEAGESP.

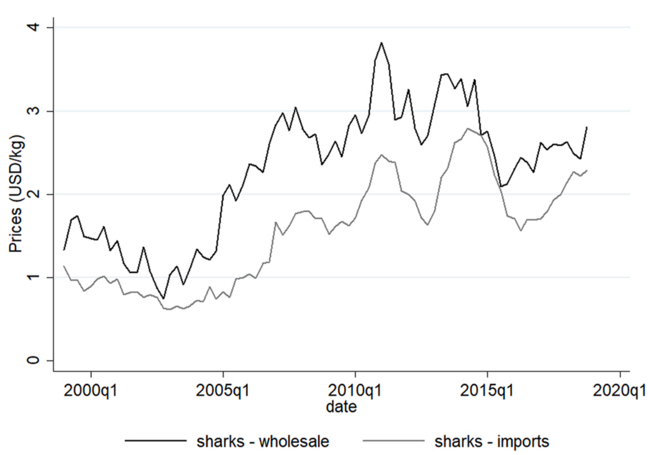

Fig. 4. Generic shark wholesale and import prices from 1999 to 2018 (USD/kg).
Source: CEAGESP and MDIC ([52]).

late 1990 s indicated that some fisheries resources in Brazil had reached critical levels, such as angel shark, Brazilian guitarfish, hammerhead shark, sand tiger shark, school shark, narrownose smooth-hound and sawfish [14,31]. Currently, according to CITES [24], there are 39 sharks threatened or overexploited in Brazil. Landings of some species of rays and other more oceanic species have increased, such as requiem and blue sharks (e.g., the oceanic whitetip shark, *Carcharinus longimanus*, is a requiem shark), which are harvested for their fins [71]. This increase is associated with the expansion of the domestic fleet to offshore waters, and the concession programs granting fishing privileges to the foreign fleet [58,59].

Table 1
Shark groups scale flexibilities for the 1968–1998 period.

product	Coef. (St. Error)
sharks	-0.995 * **
	(0.020)
angel shark	-1.075 * **
	(0.044)
caribbean sharpnose shark	-1.090 * **
	(0.040)
rays	-0.731 * **
	(0.090)
hammerhead shark	-0.424
	(0.215)
other	-1.117 * **
	(0.154)
N	123

* * p < 0.01, * ** p < 0.001

On the other hand, the share of imports in Brazilian shark consumption has increased from less than 10% in late 1990 s to 50% in 2017 (Fig. 1). Most of imported sharks are blue sharks, and come from Uruguay, Taiwan, and Spain. Taiwan (China) and Spain (EU) implemented restrictions on finning in 2011 and 2013, respectively. In Uruguay finning has not been restricted. A considerable share of the fishing in the South Atlantic has occurred in international waters since the 2000 s [55]. The International Commission for the Conservation of Atlantic Tunas (IICAT) is responsible for international waters in South Atlantic and established restrictions on finning in 2004 [14]. However, relatively low enforcement and potential loopholes in the regulations may limit their effectiveness [42].

The increase in shark meat consumption is part of a general trend in Brazil in which seafood consumption has increased due to population increase, changes in diet preferences, access, convenience, and availability [16]. In particular, imports and aquaculture have provided most of the seafood available, given the limited domestic supply [56,57].

3. Data and Empirical Analysis

The analysis in this paper is based on monthly time-series data of prices and quantities from the Brazilian wholesale market and imports for the available shark categories. [5] The wholesale market prices for Brazilian sharks are available by CEAGESP (São Paulo wholesale market), from 1968 to 2018, while quantities are available from 1968 to 2009. However, the series, in particular for the disaggregated shark groups, have increasingly missing periods from 1998.[6] The price series for imported shark meat were compiled from Aliceweb [52], a database of the Ministry of Development, Industry and Foreign Trade, from 1999 to 2018.

The quantities (in '000 MT) and prices (in USD/kg) for the different groups of sharks commercialized at the São Paulo wholesale market, regionally known as CEAGESP, are presented in Figs. 2 and 3, respectively. This market, located in São Paulo city, is among the biggest wholesale markets in South America, supplying all Brazil but mostly the 40 million people living in the São Paulo state. Most of the seafood sold in CEAGESP come from regional fisheries landings, and their trends follow similar paths [58,59].

Most shark species are registered as "sharks", a generic group comprising sharks and rays. This generalisation comes from the fact that most sharks have been landed without its fins and heads, making visual

[5] Prices used in the demand analysis were deflated using the Consumer Price Index (2018 as base year), while prices used in the cointegration analysis were converted to USD/kg.

[6] This precludes the demand analysis to the period from 1999.

Table 2
Shark groups scale flexibilities for the 1968–1998 period.

	With respect to quantities of					
Price	generic sharks	angel shark	Caribbean sharpnose shark	rays	hammerhead shark	other
	Coeff (St. Err.)	Coeff (St. Err.)	Coeff (St. Err.)	Coeff (St. Err.)	Coeff (St. Err.)	Coeff (St. Err.)
generic sharks	-0.584 *** (0.019)	-0.163 *** (0.009)	-0.111 *** (0.005)	-0.076 *** (0.006)	-0.013 *** (0.004)	-0.049 *** (0.008)
angel shark	-0.506 *** (0.039)	-0.379 *** (0.028)	-0.078 *** (0.019)	-0.069 *** (0.018)	-0.028 *** (0.008)	-0.015 (0.018)
Caribbean sharpnose shark	-0.620 *** (0.037)	-0.145 *** (0.025)	-0.169 *** (0.029)	-0.101 *** (0.020)	0.006 (0.009)	-0.061 *** (0.019)
rays	-0.525 *** (0.081)	-0.148 *** (0.049)	-0.135 *** (0.037)	0.084 (0.052)	0.036 (0.019)	-0.043 (0.039)
hammerhead shark	-0.044 (0.163)	-0.152 (0.087)	0.105 (0.055)	0.138 (0.062)	-0.360 *** (0.055)	-0.011 (0.080)
other	-0.573 *** (0.110)	-0.062 (0.059)	-0.126 ** (0.038)	-0.075 (0.043)	-0.054 ** (0.027)	-0.223 *** (0.075)

* * $p < 0.01$, * ** $p < 0.001$

Table 3
Johansen cointegration and hypothesis test results, considering import and wholesale market shark prices, from 1999 to 2018.

		Null Hypotheses (Trace test)		Constant Relative Prices	Exogeneity
		Rank (r) = 0	Rank (r) = 1	(β = 1, −1)	(α = 0)
import	wholesale	27.081	5.742 * *	1, −1.304(0.133)	0.307(0.073)* ** 0.157(0.110)

identification impossible. Meat consumption for itemized species at the wholesale market level increased, such as for angel sharks and sharpnose at least up until the early 2000 s. After this period, "sharks" is the main group commercialized in the wholesale market. This may be related to the higher number of similar species, and to the removal of the head and fins which make species morphological identification difficult, and thus, mislabeling may occur accidentally [23]. However, this can also be intentional to conceal catches of overexploited and prohibited species.

The prices for the shark groups were similar up to late 1980 s at which point the prices have diverged from each other. In general, rays and hammerhead have the lowest prices, while angel shark, sharpnose shark and generic sharks presented higher prices and a relatively steeper downward trend from the mid-1990 s

From 1999, generic shark wholesale prices are higher than import prices, but wholesale prices also appear to be more volatile (Fig. 4). Although there are short-run deviations, the prices appear to follow a similar increasing trend for most of the period, which provides some evidence that they are considered substitutes in the Brazilian market. This is not surprising given the overexploitation of most domestic shark fisheries, the increasing demand for seafood in Brazil, and the preferences of Brazilian consumers (e. g., low price and boneless).

Imported sharks are also mostly marketed as generic "sharks" instead of a specific species (Fig. 2). Blue sharks may benefit from selling under a generic name as it is one of the main imported shark species, but is not considered the best for consumption due to its soft and strong flavoured meat [30,71].

Based on these available data, the market analysis was divided into two periods, from 1968 to 1998 and from 1999 to 2018. Also, two different methods were used to investigate the shark market in Brazil. The availability of wholesale prices and quantities for the first period allowed a demand analysis to be performed, while due to the lack of quantities for the second period, a market integration analysis was applied using the wholesale and import prices. Next, we describe both methods.

3.1. Demand analysis

Demand analysis focuses on the relationship between product quantities and price. A common approach to model this relationship is to use the almost ideal demand system (AIDS) suggested by Deaton and Muellbauer [27]. This model is formulated in terms of budget shares and has the advantage of being expressed in levels and being linear when using a price index that satisfies the parameter consistency. However, for certain goods, such as seafood and other perishable goods, producers may act as price takers, and supply may be inelastic in the short term [15]. In addition, especially in fisheries, management policies may set limits on landings, so that the quantities supplied are fixed in the short term.[7] In these cases, the quantities supplied may be considered exogenous, and the model expressed by the prices as a function of expenditures, i.e., an inverse almost ideal demand system (IAIDS). This approach has been used for several seafood markets ([28,44,54]; Thong et al., 2012; [12,13,50,63,65,66]).[8] Considering the São Paulo wholesale market before 1998, it is also reasonable to assume shark supply fixed in the short term, since most of their products would come from the domestic fisheries that used this market as main outlet. In order to confirm whether the IAIDS model is appropriate, it is recommended to perform the Durbin-Wu-Hausman test [34,72], which tests endogeneity.[9]

The IAIDS model can be specified as:

$$w_{it} = \alpha_i + \sum_j \gamma_{ijt} \ln q_{jt} + \beta_i \ln Q_t \tag{1}$$

[7] Yet, supply needs to have some response to prices, so that consumer's preferences can induce different fishing behavior, and, thus cross-species effects. While demand also needs to have some response to prices, so that consumers show some substitution behavior.

[8] A discussion on the different methods used for demand analysis is provided in Deaton and Muellbauer [27], Gallet [43] and Asche and Bjørndal [5].

[9] The results of the Durbin-Wu-Hausman test are presented in the Appendix. The null that the quantities are exogenous cannot be rejected. This corroborates the IAIDS suitability for the shark demand analysis in the Brazilian market. In addition, we applied the Augmented Dickey-Fuller t test for a unit root on the shares time series for confirming their stationarity, and therefore, the suitability of the model choice. The t-statistic of for angel shark, Caribbean sharpnose shark, rays, hammerhead shark, and other prices (−5.295, −8.450, −4.807, −3.785, −6.790, −5.432, respectively) suggest the absence of a unit root, and therefore confirming the suitability of the model.

where w_{it} is the expenditure share of the ith commodity, q_j is the demanded quantity, and $\ln Q$ is the Divisia volume index defined by:

$$\ln Q_t = \sum_j S_{jt} \ln q_{jt} \tag{2}$$

Where S_{jt} is the expenditure share of the jth commodity, and $\ln q_{jt}$ the logarithm of the quantity of the jth commodity.

In order to estimate demand equations consistent with consumer theory, it is necessary to apply the concept of weak separability. This concept allows one to separate the consumer's bundle into a few parts (sub-groups), each of which can be analysed independently. Then, a system of demand functions is specified by the demand functions of each good in the group, where the restrictions associated with consumer theory may be applied (i.e., adding up, homogeneity and symmetry) [6].

Important outputs can be computed from the inverse demand equations, such as flexibilities. They empirically show how prices vary with changes in own quantities, quantities of other goods, and expenditure (scale of consumption).

In particular, the Marshallian price flexibilities are given as:

$$f_i = -1 + \frac{\beta_i}{S_i} \tag{3}$$

$$f_{ij} = -\delta_{ij} + \frac{\gamma_{ij}}{S_i} + \frac{\beta_i}{S_i} S_j \tag{4}$$

where $\delta_{ij} = 1$ for i = j (f_{ii} as own-price flexibility) and $\delta_{ij} = 0$ otherwise (f_{ij} as uncompensated cross-price flexibility). Potential autocorrelation was addressed by applying the approach used in Thong [70] based on Berndt and Savin [17].

3.2. Cointegration Analysis

When data on quantities preclude a demand analysis, the prices relationship can provide some insights about the structure of the market and substitutability between the products. This approach has also been used for several seafood markets, specially for salmon, shrimp, and whitefish [3,21,49,56,57,64,66].[10] The basic relationship in the empirical analysis of market integration given as:

$$\ln P_{i,t} = \alpha + \beta \ln P_{j,t} + e_t \tag{5}$$

where P is the price observed in market (level) i at time t. The error term e_t is assumed to be white noise. If the parameter $\beta = 0$, there is no relationship between the two price series; if $\beta = 1$, then the relative prices are constant and the market integration is complete. If $\beta \neq 0$ and $\beta \neq 1$, there is a relationship between prices that varies with the price level indicating imperfect substitution. The parameter α captures transportation costs and other systematic differences in the price levels.

To test hypotheses accounting for potential non-stationarity of the price time series, the Johansen test is considered the most appropriate [11].[11] This test is based on a VAR for the price series in an error correction model:

$$\Delta P_t = \sum_{i=1}^{k-1} \Gamma_i \Delta P_{t-i} + \Gamma_k \Delta P_{t-k} + \mu + e_t \tag{6}$$

with $\Gamma_i = -I + \Pi_1 + \ldots + \Pi_i$ and $i = 1, \ldots, k$-1, μ is a constant term, and e_t ~iid (0,W). The model allows for a time trend at levels, i.e. a constant term in the cointegrating equation. In addition, for determining the appropriate number of lags the Akaike information criterion is considered.

The rank of $\Gamma_k(r)$ indicates how many stationary linear combinations of P_t exists. If no linear combinations are stationary, $r = 0$, while if the variables are stationary in levels, $r =$ N. A likelihood ratio test and a trace test are applied to identify how many cointegrating vectors ($0 \le r \le$ N) exist. Considering the data series as cointegrated, it is possible to factorize Γ_k, $\Gamma_k = \alpha\beta'$, where both α and β' are N x r matrices. The matrix β contains the cointegrating vectors or the long-run relationships and α is the speed of adjustment to disequilibrium parameters.

Several relevant hypotheses may be tested by imposing restrictions into α and β matrices using likelihood ratio tests [47]. For instance, information with respect to whether there is causation in both directions or whether there is a price leadership (long-run exogeneity test) is obtained by imposing the restriction that all the parameters in the corresponding row on the α matrix are zero. Moreover, in order to test if relative prices are constant, and, therefore, if the market integration or the price transmission is complete, the restriction $\beta' = (1, -1)$ should be imposed in a bivariate system. When the relative prices are constant, the products are competing within the same market and may be considered substitutes [8,9].

4. Results

4.1. Brazilian shark meat market from 1968 to 1998: Demand Analysis

The analysis on the Brazilian shark meat market from 1968 to 1998 was based on the Inverse Almost Ideal Demand System (IAIDS). The parameters estimated from this model (Appendix A1) are difficult to interpret. Hence, to provide relevant interpretation, estimates of the scale, own and cross price flexibilities at the means for the different shark groups are reported in Tables 1 and 2, respectively. Most of the coefficient estimates were significant at more than 5% significance level, and presented the expected signs.

Scale flexibility measures the percentage change in the price of a good related to a proportional change in the scale of consumption, which in our case refers to the aggregated quantity marketed in the wholesale market. For most of the shark groups the scale flexibility was estimated to be near 1 (Table 1). This means that the increasing the aggregated shark supply in the wholesale market would increase the share of each product by an equal proportion, i.e., the sales shares of these products are constant. Therefore, relative prices of generic sharks, angel shark, and Caribbean sharpnose shark are the main determinants that drive the development for demand for the different species.

However, since a scale flexibility smaller than − 1 in absolute terms indicates an expenditure-elastic demand, the estimated flexibilities suggest that hammerhead sharks and rays present a more expenditure-elastic demand. This means that increases in the aggregate supply in the wholesale market would lead to proportionally smaller decreases in prices, so that wholesalers' revenues for these products would still increase. Moreover, for other sharks, as the aggregate supply increase 1%, the price of other sharks declines by 1.2%.

The own and cross price flexibilities interpretation is somewhat different than own and cross price elasticities. Demand of a product is said to be inflexible if a 1% increase in supply of that product leads to less than a percentage decrease in its price. In the shark market, all own price flexibilities are negative and lower than unity as we can see from the diagonal in Table 2. Generic sharks and other sharks presented the highest own-price flexibility (−0.58) than the specific groups, such as angel and hammerhead sharks (−0.38, −0.36, respectively). This implies that the price of generic sharks, for example, is relatively more flexible, and responds more to changes in their own quantity traded. For

[10] A discussion on the different methods used for market integration analysis is provided in Asche Bremnes, and Wessells [7], and Asche, Gordon, and Hannesson [11].

[11] The Augmented Dickey-Fuller t test for a unit root have been performed for both time series (sharks wholesale and import prices), and the t-statistic of − 2.942 for the wholesale prices and − 2.071 for import prices suggest the presence of a unit root in levels, and therefore confirming the suitability of the Johansen test.

1% increase in the generic sharks traded, its prices decrease by 0.58%. While, for Caribbean sharpnose shark, an increase in its quantity traded leads to a decrease of 0.17% in its prices.

The cross-price flexibilities measure the extent to which the price of one product responds to a 1% increase in the volume of the other product in the market. Also, two products are termed substitutes if their cross-price flexibilities are negative and are complements if the cross-price flexibility is positive. A high degree of flexibility in absolute terms indicates that the product's price is more sensitive to changes in the other product's quantity. In addition, a negative sign indicates that a product faces strong competition so that its price decreases with an increase in the quantity supplied by competitors. Estimates of cross-price flexibilities reveal that the generic sharks play a more important role in formation of prices for the specific shark groups and rays. In fact, when holding all other factors constant, a 1% increase in the quantity of generic sharks traded would decrease prices of angel sharks, Caribbean sharpnose shark, and rays by 0.51%, 0.62% and 0.52%, respectively.

Given the poor stock status of many of these species and strict regulations governing their exploitation, there are weak incentives to land and market these species using their specific name. In fact, by early 2000 s, many of these groups were assessed as overexploited and some species were on the Red List of Threatened Species [45]. The specific species also made up a small share of sharks traded at the wholesale market. Most of the sharks have been marketed as generic sharks. Thus, many of the attributes that differentiate shark products in this market have lost importance, resulting in commoditization of the market [2]. The prevalence of generically marketed sharks may undermine shark conservation efforts if threatened species can be harvested, traded and sold under a generic name. It seems that this has also made it relatively easier for imported sharks to enter the Brazilian market, especially since the 2000 s

4.2. Brazilian shark meat market from 1999 to 2018: Market Integration Analysis

The relationship between domestic wholesale prices for generic sharks and import prices for sharks after 1998 was further investigated. The results of the cointegration analysis for the model allowing for a trend in levels and 3 lags (defined by the Akaike information criterion) are shown in Table 3. The null hypotheses of more than one cointegrating vector could be rejected. So, there is one cointegrating vector in this system, and the prices have a long run relationship. This suggests that imported and domestic sharks compete in the same market. Moreover, the test for the constant relative prices could not be rejected, indicating that domestic sharks and imported sharks are close substitutes in the Brazilian market.

Interestingly, the price leadership hypothesis test suggests the wholesale market is the exogenous price. This means that the import prices are not formed outside the system, and that the wholesale market influences the import prices. This can be explained by the fact that Brazil is one of the world's largest markets for shark meat.

5. Discussion and concluding remarks

Economic incentives to exploit shark populations have changed in recent decades. Establishment of anti-finning policies in many nations around the world has facilitated growth in markets for shark meat. The market analyses of data from the last 40 years indicate that shark meat is not a new market in Brazil, but an old one driven by a particular interest from local consumers. In recent decades, the declining supply of domestic shark fisheries has been unable to meet demand for shark meat and imports have grown substantially.[12]

The results show that sharks landed under a generic name play an important role in formation of prices for the specific domestic shark groups and rays before 1999, and also in formation of import price after 1999. The influence of domestic price on imports is driven by the global importance of Brazil as a shark meat consumer. Thus, even with the shark fin market weakening globally, the Brazilian demand for shark meat may drive overexploitation of sharks where there is ineffective management or a narrow focus on anti-finning regulations which are not designed to reduce shark fishing mortality [18,20]. MacNeil et al. [51] show that fishing mortality limits are effective management interventions for conserving shark abundance although such directed management approaches are difficult to achieve in many developing nations and may challenge social and cultural norms.

However, given Brazil's significant domestic shark fisheries, a narrowed focus on environmental regulation may create socio-economic trade-offs for fishing communities, as is the case for Indonesia, a large shark fishing nation [19]. So, there is a need for innovative policy instruments which considers potential trade-offs between overexploitation and well-being of coastal communities [19,69].

The consequences of poorly managed shark fisheries together with increasing demand for shark meat are amplified by the fact that the Brazilian market seems to accept (and have substituted towards) the generic marketed shark. This not only undermines conservation efforts, but also provides opportunity for mislabeling of shark products [1,48]. For instance, Brazil has issued in 2004 and revisited in 2014 a list of species in which fishing is prohibited and this includes some shark species. However, there are still reports of sales of prohibited shark species, indicating that enforcement is low and illegal harvesting occurs [1]. This is the case in several other markets as well (Sims and Frost, 2019).

Consumers play an important role in the sustainable use of natural resources, and the lack of species-specific report and mislabeling makes it difficult for consumers to make informed decisions when buying seafood. In Brazil, consumer preferences for species are highly dependent on their knowledge about the seafood product [14,39], but consumers generally have very little knowledge about seafood, and, in particular, sharks [14]. The lack of species-specific reporting and marketing further prevents informed consumer decision-making. Standard market names for shark products are essential to promote conservation, fair trade, and consumer rights. In fact, some efforts to clarify and standardize seafood market names have been done, although such efforts have not been widely adopted [29].

The lack of species-specific labeling may also raise safety concerns, in particular for shark meat. In general, small shark species have lower concentrations of toxins, making them healthier options for consumption of shark meat [25]. This may be one of the reasons why dogfish, mako and tope sharks are preferred for meat, while fin products typically come from larger sharks, such as hammerhead, oceanic whitetip and blue sharks [30]. Recently, relatively larger sharks (e.g., blue shark), are widely marketed for their meat, and in many cases without the systematic testing for concentration of toxins (e.g., heavy metal) as is the case in Brazil [25]. This highlights a void that certification and traceability programs may help to address by enabling consumers to make more informed decisions with respect to consumption of shark meat, and, thus, put some pressure on the value chain to adopt sustainable practices.

Our results suggest a commoditization of shark products over time. However, differentiated products facilitate higher prices in limited consumer segments ([10]; [73]). So, research on willingness-to-pay for certified shark products could provide better insights on whether the Brazilian market would pay a premium for products produced with more sustainable practices, and thus, provide incentives for producers to change their practices accordingly.

Finally, prices for all shark groups decrease less than proportionally with quantity marketed, indicating that prices tend to be relatively steady despite increases in supply. High market prices may provide

[12] This pattern has also been seen for the two other main wild caught species in Brazil, Brazilian sardines [56] and shrimps [57].

incentives for countries with ineffective or weak fisheries governance to overexploit shark fisheries to supply demand in Brazil and other consumption markets. This further supports the need for species specific reporting and sustainable sourcing practices along the value chain.

Authors Statement

R.B.M.P. designed the study, compiled and analysed the data. All authors contributed writing the manuscript.

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Appendix

See appendix. Tables. A1 and A2.

Table A1
Durbin-Wu-Hausman endogeneity test.

Product	Endogeneity test	Ho: quantity variables are exogenous	Ho: price variables are exogenous
Generic sharks	Durbin (score) chi2(6)	3.74	15.828 * *
	Wu-Hausman F(6106)	0.554	2.609 * *
Angel shark	Durbin (score) chi2(6)	1.969	9.587
	Wu-Hausman F(6106)	0.287	1.493
Caribbean sharpnose shark	Durbin (score) chi2(6)	2.325	17.603 * **
	Wu-Hausman F(6106)	0.34	2.951 * *
Rays	Durbin (score) chi2(6)	2.523	17.433 * **
	Wu-Hausman F(6106)	0.37	2.917 * *
Hammerhead shark	Durbin (score) chi2(6)	6.305	8.792
	Wu-Hausman F(6106)	0.955	1.350
Other	Durbin (score) chi2(6)	10.930 *	1.065
	Wu-Hausman F(6106)	1.723	0.154

Table A2
Parameters estimates from the Inverse Almost Ideal Demand System model (IAIDS).

	sharks share	angel shark share	caribbean sharpnose shark share	rays share	hammerhead shark share
variables	coef. (st. error)	coef. (st. error)	coef. (st. error)	coef. (st. error)	coef. (st. error)
sharks quantities	0.231 * ** (0.008)	-0.092 * ** (0.005)	-0.062 * ** (0.003)	-0.043 * ** (0.004)	-0.007 * ** (0.002)
angel shark quantities	-0.092 * ** (0.005)	0.125 * ** (0.006)	-0.014 * ** (0.003)	-0.013 * ** (0.003)	-0.005 * ** (0.002)
caribbean sharpnose shark quantities	-0.062 * ** (0.003)	-0.014 * ** (0.003)	0.091 * ** (0.003)	-0.010 * ** (0.002)	0.001 (0.001)
rays quantities	-0.043 * ** (0.004)	-0.013 * ** (0.003)	-0.010 * ** (0.002)	0.067 * ** (0.0034)	0.002 (0.001)
hammerhead shark quantities	-0.007 * ** (0.002)	-0.005 * ** (0.002)	0.001 (0.001)	0.002 (0.001)	0.012 * ** (0.001)
other quantitites	-0.028 * ** (0.004)	-0.002 (0.003)	-0.006 (0.002)* **	-0.004 (0.002)	-0.003 (0.001)
Divisia Index	0.003 (0.009)	-0.015 (0.009)	-0.010 * * (0.004)	0.017 * ** (0.006)	0.011 * ** (0.004)
first quarter	-0.003 (0.009)	0.002 (0.007)	-0.007 (0.003)	-0.001 (0.005)	0.000 (0.003)
second quarter	0.011 (0.009)	-0.007 (0.007)	-0.006 (0.003)	0.001 (0.004)	0.000 (0.003)
third quarter	0.011 (0.009)	-0.002 (0.007)	-0.011 * ** (0.004)	0.004 (0.005)	-0.003 (0.004)
constant	0.543 * ** (0.011)	0.136 * ** (0.009)	0.147 * ** (0.005)	0.067 * ** (0.006)	0.039 * ** (0.004)
R^2	0.857	0.941	0.927	0.855	0.572

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