Aquaculture and Fisheries 11 (2026) 375–383

Contents lists available at ScienceDirect

Aquaculture and Fisheries

journal homepage: www.keaipublishing.com/en/journals/aquaculture-and-fisheries

Original research article

Fishery products consumption: Evidence of persistence and trends in 25 OECD countries

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ARTICLE INFO

Keywords:
Fishery products consumption
Fisheries management policy
Fractional integration
OECD countries

ABSTRACT

Given the nutritional relevance and health benefits of fishery products consumption, this article examines the statistical properties of fishery products consumption in 25 OECD countries from 1961 to 2017, focusing on the degree of persistence. Using a methodology based on fractional integration, we explore if mean reversion takes place in the series or, if on the contrary, shocks do have a permanent nature. The empirical results show the existence of positive time trends in the majority of countries, the only exceptions being Greece, Japan, Portugal and the UK. Mean reversion is found in 17 out of the 25 countries examined; the unit root null hypothesis cannot be rejected in 7, while Japan is the only country with an order of integration significantly higher than 1. These findings suggest that short-term measures are more effective than long-term interventions in promoting fishery products consumption in most OECD countries. The policy implications are discussed in the final part of the manuscript.

1. Introduction

Fish and seafood consumption contributes to enhancing well-being by promoting the health and nutrition of all individuals (Tacon & Metian, 2013). In addition, fish and seafood are an excellent source of nutrients including high quality protein. In fact, fish provides a high content of omega-3 fatty acids which may prevent risk of diseases such as cardiovascular, inflammatory, and metabolic diseases (Deng et al., 2018). Equally important, the significance of nutrients in fish has a potential contribution to combating malnutrition, especially in developing countries (Chan et al., 2019). However, fish and seafood may also harbor certain contaminants such as mercury, which can have adverse effects on human health (Jacobs et al., 2017). Not surprisingly, fishery consumption is expected to increase by 14% reaching 21.2 kg per capita globally in 2032 (OECD and FAO Agricultural Outlook, 2023).

Considering the importance of fishery consumption in the diet and the health effects (Christensen et al., 2016), the aim of this study is to evaluate the persistence of the fishery products consumption series across 25 OECD countries over the period 1961–2017. The research question associated with this paper can be stated as: does persistence of the fishery products consumption series exist? Through the application of fractional integration methods, this study distinguishes between countries where fishery products consumption is stationary and those where it is non-stationary. Our analysis reveals that positive trends are required in the majority of the series, the only exceptions being Greece, Japan, Portugal and the UK, and the highest values appear in the cases of the US and Mexico. On the other hand, reversion to the mean is found in 17 out of the 25 countries examined. The unit root null hypothesis cannot be rejected in 7, and Japan is the only country with evidence of d > 1. Very similar results are obtained when using the logged transformed values.

The study on the persistence of fishery products consumption is important for many reasons. The existence of persistence of fishery products consumption implies that the current increase being experienced in many countries around the world is likely to continue. This is because persistence indicates the extent at which current scenario or

Peer review under the responsibility of Editorial Board of Aquaculture and Fisheries.
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https://doi.org/10.1016/j.aaf.2025.07.003
Received 11 June 2025; Received in revised form 21 July 2025; Accepted 29 July 2025
Available online 7 August 2025

trend is likely to last. Persistence suggests that long term policies are required to boost the consumption of fishery products. Therefore, the results can help policymakers develop policies that improve access to fishery products consumption to reduce food insecurity and support more sustainable livelihoods (Marushka et al., 2021). Likewise, the findings are useful for the policymakers to design policies to promote the consumption of fishery products as a heart-healthy substitute for processed foods and land-based animal products for those countries suffering from a high incidence of heart diseases (Tacon, 2023).

On the other hand, the persistence of fishery products consumption indicates that precise forecast of future values of fishery products consumption cannot be realized by solely relying on the past values of fishery products consumption. There is a need to consider the roles of factors of fishery products consumption, when trying to forecast its future values. Possible factors of fishery products consumption include income, level of education, age, urbanicity, promotional and informational tools, location, and environmental consideration (Forleo et al., 2023; Tan et al., 2015).

There are numerous organizations and bodies that are involved in the fishery products consumption forecasts such as Food and Agriculture Organization (FAO) of the United Nations (UN) and the Organization for Economic Co-operation and Development (OECD). A shared publication of OECD and FAO projects fishery products consumption in the globe to grow by an average of increase by 1.3% per annum between 2020 and 2030. Fishery products consumption is expected to reach 21.2 kg per capita in 2030, up from 20.5 kg per capita 2020 (OECD-FAO Agricultural Outlook, 2021). Fish consumption will grow in Europe, Asia, and the North America, as the population growth in these countries is expected to outpace growth their fish production (OECD-FAO Agricultural Outlook, 2021). The publication employs AGLINK-COSIMO model, which depends on many information such as possible determinants of fishery products consumption, in the course of projecting the future values of the fish consumption. The considered series that can be treated as exogenous series include exchange rates, consumer price index, population, gross domestic production (GDP) growth, and energy prices. There are also cases where the predictions in the fishery sector have been principally based on previous values of fishery series (Hobday et al., 2016).

OECD countries have been the focus of this study for numerous reasons. The OECD countries are the main consumers of fishery products in the globe. The fisheries sectors play a crucial part in the OECD economies. In 2020, about one million people are employed in the fisheries sectors across the OECD countries (OECD Review of Fisheries, 2022). The government spending to support the fisheries sectors appears to be substantially greater in OECD relative to non-OECD nations. The government support was about USD 465 per fisherman in OECD nations, while the assistance was USD 113 per each fisherman in developing economies in 2018–2020 (OECD Review of Fisheries, 2022). Assistance is frequently offered through programs that is aimed to support the operations of fishing sector more effectively (OECD Review of Fisheries, 2022).

This article shows the following organization: Section 2 discusses the literature review; Section 3 outlines the methodology; Section 4 displays the dataset; Section 5 exhibits the empirical findings, and Section 6 offers concluding observations.

2. Literature review

Given the important role that fishery products play in nutrition which it has multitude of health advantages, fishery products should be recognized as a significant contributor in the global food basket (Krešić et al., 2022; Tacon, 2023). The literature suggests that the fishery products consumption is influenced by economic, demographic, health, and nutritional aspects (Akuffo et al., 2020). Studies like Njogu et al. (2022) reports that these factors encompass region of residence, prices, gender, household income, age, educational level, and own food production. Moreover, Olsen (2004) showed that taste, aversion, nutrition, and quality/freshness also affect attitudes towards fishery products consumption. On the other hand, the work of Pieniak et al. (2010) highlighted that consumers' knowledge of the nutritional and health benefits of fish is a crucial factor of fishery products consumption.

Fish consumption is furthermore closely related to the multidimensional concept of sustainability proposed by Işık et al. (2024a), which includes economic, environmental, social, and governance factors (ECON-ESG). Within this framework, many studies have analyzed the role of ECON-ESG factors in promoting a sustainable environment. In a similar manner, the work of Işık et al. (2024b) evaluated the influence of these factors on the load capacity factor (LCF) for the G7 economies. Research on fishery products persistence has not yet been explored in the extensive literature. Nonetheless, the persistence of several factors of fishery products consumption have been examined. In this regard, price of fish, household income, and price of beef are considered as key factors of fishery products consumption among others (Verbeke & Vackier, 2005; Anyanwu, 2014).

With respect to household income, it demonstrates a favorable correlation with the quantity of fish consumed indicating that as household income rises the demand for fishery products increases (Verbeke & Vackier, 2005; Anyanwu, 2014). Studies like Gil-Alana et al. (2019) examined the persistence on income inequality in a group of 26 OECD countries over the period 1963–2008. Using fractional integration techniques, these authors found that income inequality remains very persistent across all the countries analyzed. The results are similar at the work of Christopoulos and McAdam (2017). Applying a battery of stationary and long-run memory tests, these authors suggested that income inequality is exceptionally persistent.

Other studies such as Islam and Madsen (2015) tested the Piketty's hypothesis by analyzing income inequality data from 21 OECD countries during the period 1870 to 2011. The findings indicated that the null hypothesis of trend stationary cannot be rejected, implying that fluctuations in income inequality are likely to be temporary. In contrast, Solarin et al. (2022) investigated inequality persistence in a sample of 21 OECD countries through linear and non-linear methods. Their results showed significant persistence in the series, suggesting the absence of average reversal and permanency shocks. Recent studies like Gayán--Navarro and Sanso-Navarro (2024) analyzed the persistence of income and wealth inequality measures in the U.S. during the period 1870–2019. Using unit root and structural break tests, their results indicated that the wealth-to-income ratio demonstrates a nonstationary behavior.

Regarding the price of fish, it was identified as the foremost factor influencing fish consumption. (Lee & Nam, 2019). In this framework, the work of Floros and Failler (2007) analyzed the monthly fisheries prices of Cornwall (UK) over the period 1992–2006 employing ARFIMA models. Their findings revealed strong evidence of long memory for fish prices. These results align with the study by Floros et al. (2008) which using ARFIMA models in the Greek fisheries and aquaculture prices, showed compelling evidence of long memory.

On the other hand, fishery products consumption is positively correlated with the price of beef (Anyanwu, 2014). From this perspective, Ghoshray et al. (2014) investigated the time series dynamics of primary commodity prices relative to manufactured goods, focusing on their inherent trends and the persistence of shocks influencing price fluctuations. Using various econometric methodologies for 24 primary commodity prices over the period 1900–2008, they determined that 16 prices exhibited behavior consistent with trend stationarity evidence. Furthermore, the analysis revealed a negative trend for rice, wheat, sugar, and hides, while beef, lamb, and timber exhibited a positive trend direction.

Other studies like the work of Tiwari et al. (2015) investigated the non-linear mean reversion patterns observed in the prices of 47 agricultural commodities in India from 2000 to 2013. The study utilized a range of non-linear unit root tests and stationarity tests. The findings indicate that food grains exhibit a unit root process with drift, while the remaining price series of agricultural commodities (including egg, meat, and fish) display mean reverting behavior. More recently, Landajo and Presno (2022) observed the trend stationarity of a range of renewable commodities from 1900 to 2018. As a conclusion, the stationarity was rejected for livestock (lamb and beef).

Our study extends this literature to show evidence on stationary or non-stationary in the fishery products consumption series. Although the analysis of persistence in the fishery products consumption is a relatively new field of study, it provides an important resource for policymakers to improve food outcomes, promoting the fishery products as a crucial component of a healthy and sustainable diet (McClanahan et al., 2015).

3. Methodology

The incidence of fishery products consumption persistence connotes that any shock arising from changes in the economy will have a permanent effect on the consumption of the products. There is a relationship between the persistence of fishery products consumption and food system resilience framework. According to the framework, the food system (and by extension the fishery sector) has the capacity to continue to operate efficiently over time despite disturbances (Tendall et al., 2015). Therefore, the existence of persistence of fishery products consumption is synonymous with the presence of food system resilience. The absence of fishery products consumption persistence also connotes the effectiveness of automatic stabilizers. This is because the lack of fishery products consumption persistence suggests that any negative impact of shock on fishery products consumption will be temporary and during such period, automatic stabilizers will be sufficient to address the adverse impact on the fishery sector.

A linear trend is the most used approach when modeling trends in economic series. In particular, supposing that y(t) is the observed time series, we could consider the following model,

$$y(t) = \alpha + \beta\, t + x(t), t = 1, 2, \ldots, \tag{1}$$

where $x(t)$ is supposed to be either stationary I(0) (e.g., an ARMA model) or nonstationary I(1) (ARIMA). However, in this paper, we extend the analysis to cover fractional integration. Thus, $x(t)$ may be a process integrated of order d, or I(d) where d is a potentially fractional value. In other words, $x(t)$ is described by:

$$(1-L)^d x(t) = u(t), t = 1, 2, \ldots, \tag{2}$$

where L is the lag-operator, $Lx(t) = x(t\text{-}k)$ and $u(t)$ is stationary I(0).

In a fractional environment, the polynomial $(1 - L)^d$ can be expanded as:

$$(1-L)^d = \sum_{j=0}^{\infty} \binom{d}{j} (-1)^j L^j = 1 - dL + \frac{d(d-1)}{2} L^2 - \ldots \tag{3}$$

and thus, equation (2) can be rewritten as:

$$x_t = d\, x_{t-1} - \frac{d\,(d-1)}{2}\, x_{t-2} + \ldots + u_t. \tag{4}$$

In this context, d is the parameter that relates current values with its past history, and the higher d is, the stronger the relationship between the observations is, and so the parameter d is called the "persistence" parameter. An obvious advantage of this specification is its flexibility that permits us to consider fractional degree of differentiation and overlapping classical models based on stationarity I(0) and non-stationarity I(1). Within this fractional context, if d is smaller than 0.5, x_t is still covariance stationary; however, $d \geq 0.5$ indicates lack of covariance stationarity and higher the value of d is, the higher the level of nonstationarity is, such that the variance of the partial sums rises in scale with d. Values of d which are below 1 support the hypothesis of reversion to the mean, with shocks having transitory effects. Finally, if $d \geq 1$, there is lack of mean reversion implying permanency of shocks.

4. Data

Due to availability of data, we use data of total fishery products consumption in 25 OECD countries spanning from 1961 to 2017 in the analysis (which are all in metric tons). The series is the aggregate of eight components of fishery products including freshwater and diadromous fish (including carps, eels, barbels, and sturgeons), demersal fish (including hakes, cods, redfishes, and flatfishes), pelagic fish (including sardines, herrings, mackerels and anchovies), marine fish, other (including unidentified marine fish), crustaceans (including crabs, krill, and lobsters), molluscs excluding cephalopods (such as oysters, clams, scallops, and abalones), cephalopods (including squids, and cuttlefishes) and aquatic animals, others (such as frogs, sea-urchins, and turtles). We use only total fishery products consumption because some of the components of the total consumption have zero figures in some of the years under consideration. The data has been generated from FishStatJ of the Food and Agriculture Organization.

The global consumption of aquatic foods has witnessed a substantial surge in recent years and is poised to sustain this upward trajectory. By the year 2030, an estimated 90 percent of the entire output from aquatic animal production will be earmarked for human consumption, marking an overall increase of 15 percent in comparison to the baseline of 2020 (FAO.The State of World Fisheries and Aquaculture, 2022). This escalating trend in fish consumption is conspicuously evident across the 25 OECD countries subjected to analysis. Fig. 1 delineates this temporal surge for all nations, albeit with a less distinct manifestation in the instances of Portugal and Japan.

Growing awareness of the health benefits associated with fish consumption, as well as increased demand due to population growth and economic development, have contributed to this growth. On the one hand, population growth has led to increased demand for food, and fish is considered an important source of protein and nutrients for many communities. On the other hand, the increase in fish consumption is also linked to economic development, as societies with higher incomes tend to have more varied diets and can afford to consume more seafood. Rising income and urbanization, improvement in post-harvest practices and changes in food trends are projected to lead to a 15 percent increase in aquafeed consumption, to provide an average of 21.4 kg per capita by 2030 (FAO.The State of World Fisheries and Aquaculture, 2022).

In numbers and according to FAO statistics (2022), global consumption of aquatic foods rose at an average yearly rate of 3.0% since 1961, in comparison to a population growth rate of 1.6%, i.e. the increase in consumption is almost double the growth in population. In our sample of countries, the average annual increase in fish consumption from 1961 to 2017 (1.5%) is almost three times the average annual increase in population (0.4%) (see Table 1). Consumption grows on average annually for the different countries between 0.3% and 6.5%, while the rate of population growth for the countries analyzed takes values in the range [0.2%, 2.3%].

Fig. 2 shows that Australia, Colombia, Costa Rica, Korea, Mexico and Turkey are the countries with the highest growth in their fish consumption. However, this growth is minimal in Japan, Portugal and Turkey.

5. Empirical results

We consider the following model,

$$y(t) = \alpha + \beta t + x(t), (1-B)^d x(t) = u(t), \tag{3}$$

where $y(t)$ is the series under investigation; α and β are unknown coefficients dealing with a constant and a time trend respectively, and $x(t)$ is an I(d) process, determined by the fractional polynomial $(1-L)^d$ in L with fractional degree d, which render the $u(t)$ process to be integrated

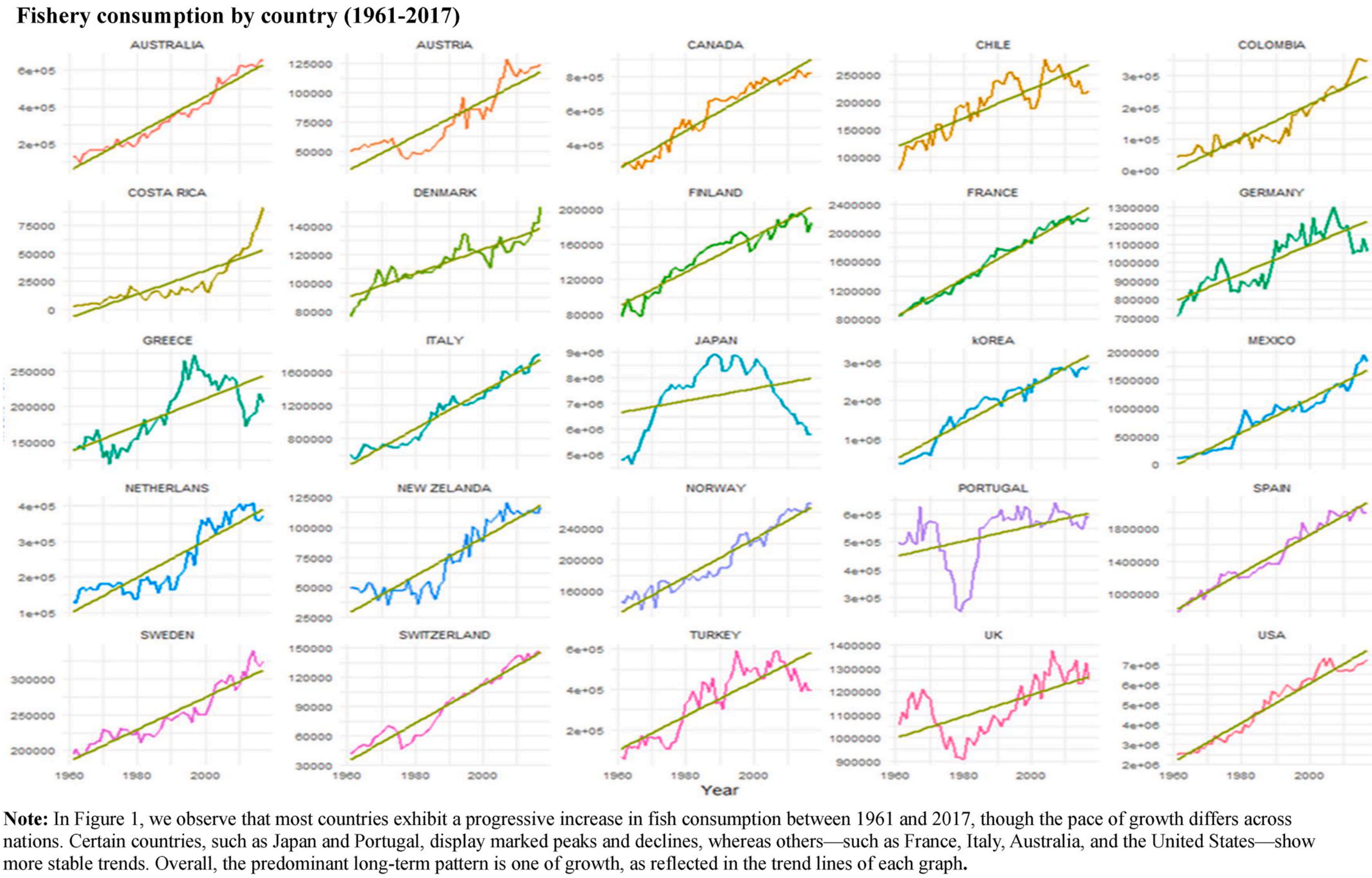

Fig. 1. Fishery consumption by country (1961–2017)
Note: In Fig. 1, we observe that most countries exhibit a progressive increase in fish consumption between 1961 and 2017, though the pace of growth differs across nations. Certain countries, such as Japan and Portugal, display marked peaks and declines, whereas others—such as France, Italy, Australia, and the United States—show more stable trends. Overall, the predominant long-term pattern is one of growth, as reflected in the trend lines of each graph.

of order 0 or I(0).

Tables 2 and 3 refer to the original data while Tables 4 and 5 to the logged data. In Tables 2 and 4 we display the estimates of d in Equation (3) under three different scenarios: i) first, supposing that $\alpha = \beta = 0$ a priori; ii) with $\beta = 0$ a priori, i.e., including a constant; and iii) including a constant and a linear time trend. We mark in these two tables the selected model for each series in relation with these deterministic terms (see Table 6 for details).

Starting with the original data, we observe that the time trend is required in the majority of the cases, the only insignificant trends being obtained in the cases of Greece, Japan, Portugal and the UK. For the rest of the cases, the trend coefficient is significantly positive in all cases, and the highest values correspond to the US and Mexico (see Table 3). Looking at the selected orders of integration, we observe that mean reversion, i.e., significant evidence of an order of integration below 1, is found in 17 out of the 25 countries examined. The lowest values correspond to Norway ($d = 0.52$), Spain (0.57), New Zealand (0.62), Canada (0.66) and France and Korea (0.67). Within the 8 countries where reversion to the mean is not observed, the unit root null hypothesis ($d = 1$) cannot be rejected in 7, Japan being the only country with evidence of $d > 1$.

Looking at the logged values, in Tables 4 and 5, we notice that the time trend is required in the same countries as with the original data. Thus, the time trend coefficient is found to be statistically insignificant only for the cases of Greece, Japan, Portugal and the UK, and the highest values correspond now to Costa Rica (0.0579) and Mexico (0.0523) followed by Korea, Colombia, Turkey and Australia. Dealing with the orders of integration, mean reversion is found in 16 cases and the lowest values of d correspond to Australia (0.29), Colombia (0.30) and Norway (0.32), and evidence of d above 1 is only found in the case of Japan.

The foregoing results suggest evidence for mean reversion of fishery products consumption in 68% of the countries under investigation. As there are no existing papers on the persistence of fishery products consumption, it is difficult to compare the results of the current paper with existing papers of fishery products consumption. However, the mean reversion of the determinants of fishery products consumption have been established in the literature. There is evidence for the mean reversion of inflation (Osman, 2021), real GDP (Canarella et al., 2020), exchange rate (Jorion & Sweeney, 1996). According to Solarin et al. (2022), a series that is dependent on other mean reverting series variables that are persistent will absorb the mean reversion from the other variables.

One of the reasons for the mean reversion of fishery products consumption in several OECD countries is the presence of automatic stabilizers in these countries. Unlike in the developing countries, where the fiscal policy is dominated by discretionary fiscal policy, automatic stabilizers are present in the fiscal policy of several OECD countries. Automatic stabilizers provide crucial support during economic downturns because they react almost instantly to unemployment and income changes, operating as a first line of defense devoid of legislative bottleneck. Unemployment insurance, food stamps, social farm price supports, supplemental nutrition assistance, and family assistance programs, are examples of automatic stabilizers (Şen & Kaya, 2021), which will ensure that any economic shocks will have short term impact on general consumption in the economy, especially on fishery products consumption.

Another possible reason for the mean reversion of fishery products consumption in several OECD countries is that the series are essential for

Table 1
Fishery consumption and population.

Country	FISHERY CONSUMPTION (metric ton)			POPULATION		
	1961	2017	average annual rate (%)	1961	2017	average annual rate (%)
Australia	133808.2	658323.3	2.9	10483000	24592588	1.5
Austria	49889.3	124406.6	1.6	7086299	8797566	0.4
Canada	276971.6	817043.3	2.0	18271000	36545236	1.2
Chile	78379.2	221590.9	1.9	8313535	18368577	1.4
Colombia	41733.3	345482.3	3.8	16182414	48351671	2.0
Costa Rica	2754.4	91416.7	6.5	1396138	4993842	2.3
Denmark	76195.7	153182.1	1.3	4611687	5764980	0.4
Finland	77944.7	185342.0	1.6	4461005	5515225	0.4
France	833732.5	2230067.0	1.8	47161641	66918020	0.6
Germany	706599.2	1055185.4	0.7	73377632	82657002	0.2
Greece	141473.1	205524.9	0.7	8398050	10754679	0.4
Italy	603929.7	1805504.2	2.0	50536350	60536709	0.3
Japan	4783397.1	5842968.0	0.4	94055000	126972000	0.5
Korea	340990.3	2922513.9	3.9	25765673	51361911	1.2
Mexico	97952.9	1832268.4	5.4	37439317	122839258	2.1
Netherlands	132198.9	374531.0	1.9	11638712	17131296	0.7
New Zealand	49936.6	117452.1	1.5	2419700	4813600	1.2
Norway	146820.4	272011.0	1.1	3609800	5276968	0.7
Portugal	496243.6	584804.2	0.3	8929316	10300300	0.3
Spain	781075.4	1981834.1	1.7	30739250	46593236	0.7
Sweden	195879.3	325020.3	0.9	7519998	10057698	0.5
Switzerland	41166.1	143569.3	2.3	5434294	8451840	0.8
Turkey	67580.0	398133.9	3.2	28255002	80312698	1.9
UK	1051706.3	1249536.9	0.3	52800000	66058859	0.4
USA	2465134.5	7283297.9	2.0	183691000	325122128	1.0
TOTAL	**13673492.3**	**31221009.5**	**1.5**	**742575813**	**1249087887**	**0.4**

Note: The table shows that, between 1961 and 2017, fish consumption increased in all countries, although at very different rates. Costa Rica (6.5%) and Mexico (5.4%) stand out with very high average annual growth rates, while countries such as Japan (0.4%) and Portugal (0.3%) show nearly stagnant growth. In terms of population, the increase is more moderate (around 0.4%–2% annually), highlighting that the growth in fish consumption significantly outpaces demographic growth in most cases**.**

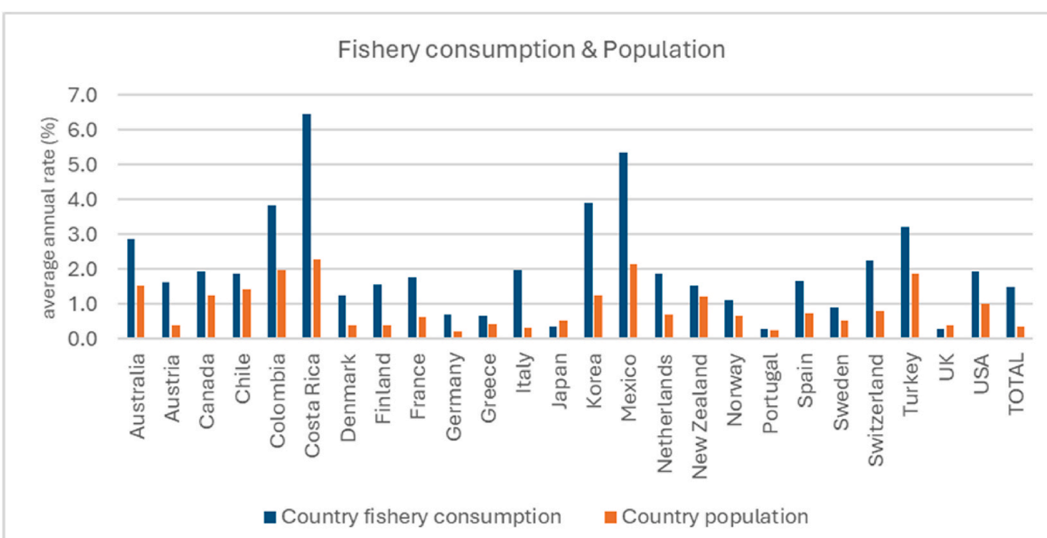

Fig. 2. Fishery consumption and population (average annual rate, %)
Note: Population data source:
https://datos.bancomundial.org/indicador/SP.POP.TOTL?name_desc=false
It is observed that in nearly all countries, fish consumption is growing faster than the population, with Costa Rica, Mexico, South Korea, Colombia, and Turkey standing out due to very high peaks. In contrast, countries such as Portugal, Japan, and the United Kingdom exhibit low rates, close to demographic growth. This confirms the patterns shown in the previous graphs and tables: the increase in fish consumption significantly exceeds population growth in most countries.

human well-being. There are several forms of subsidies to the producers of fishery products in the OECD countries to ensure that any negative shock will not have lasting impact on the consumption of the products. The governments in the OECD countries provide around USD 10.7 billion subsidies annually to the fishing sector (OECD Review of Fisheries, 2022). About half of the subsidies are meant for fisheries management, which ensures continuous supply of fishery products for consumption at reasonable prices. Subsidies can be helpful to address market failures or emergencies. The available of the various subsidies will ensure that any sudden shock will have limited impact on fishery products' consumption.

The results are not in tandem with the hypothesis of Smyth (2013) which suggests that variables with relatively smaller values are more likely to be mean reverting. Therefore, figures with greater values are

Table 2
Orders of integration. Original data.

Country	No terms	A constant	A constant with a time tren
AUSTRALIA	0.77 (0.68, 0.94)	0.84 (0.77, 0.96)	**0.74 (0.60, 0.93)**
AUSTRIA	0.82 (0.67, 1.02)	0.79 (0.71, 0.91)	**0.75 (0.62, 0.90)**
CANADA	0.52 (0.42, 0.95)	0.75 (0.67, 0.88)	**0.66 (0.51, 0.86)**
CHILE	0.85 (0.54, 1.13)	0.75 (0.60, 1.03)	**0.78 (0.60, 1.03)**
COLOMBIA	0.78 (0.68, 0.94)	0.79 (0.70, 0.94)	**0.73 (0.60, 0.92)**
COSTA RICA	1.08 (0.95, 1.28)	1.06 (0.92, 1.26)	**1.07 (0.94, 1.27)**
DENMARK	1.08 (0.90, 1.34)	0.53 (0.41, 1.17)	**0.84 (0.54, 1.16)**
FINLAND	0.89 (0.31, 1.26)	0.74 (0.64, 0.98)	**0.73 (0.58, 0.99)**
FRANCE	0.89 (0.58, 1.17)	0.77 (0.71, 0.88)	**0.67 (0.52, 0.87)**
GERMANY	0.86 (0.68, 1.09)	0.73 (0.60, 0.97)	**0.73 (0.57, 0.97)**
GREECE	0.85 (0.67, 1.07)	**0.83 (0.71, 1.01)**	0.83 (0.71, 1.01)
ITALY	0.80 (0.64, 1.04)	0.82 (0.73, 0.98)	**0.73 (0.56, 0.96)**
JAPAN	1.00 (0.85, 1.23)	**1.25 (1.13, 1.44)**	1.25 (1.13, 1.42)
KOREA	0.57 (0.50, 0.77)	0.71 (0.64, 0.84)	**0.67 (0.54, 0.84)**
MEXICO	0.89 (0.73, 1.19)	0.92 (0.76, 1.23)	**0.89 (0.65, 1.25)**
NETHERLANDS	0.78 (0.63, 1.02)	0.79 (0.69, 0.96)	**0.75 (0.61, 0.96)**
NEW ZEALAND	0.66 (0.54, 0.90)	0.71 (0.64, 0.83)	**0.62 (0.50, 0.79)**
NORWAY	0.86 (0.67, 1.10)	0.70 (0.62, 0.81)	**0.52 (0.37, 0.73)**
PORTUGAL	0.93 (0.77, 1.14)	**0.93 (0.79, 1.12)**	0.93 (0.79, 1.12)
SPAIN	0.77 (0.51, 1.04)	0.73 (0.66, 0.85)	**0.57 (0.39, 0.80)**
SWEDEN	0.91 (0.73, 1.17)	0.76 (0.66, 0.95)	**0.70 (0.53, 0.94)**
SWITZERLAND	0.90 (0.74, 1.14)	0.98 (0.85, 1.20)	**0.97 (0.79, 1.21)**
TURKEY	0.74 (0.58, 0.97)	0.78 (0.66, 0.99)	**0.78 (0.63, 0.99)**
UK	0.92 (0.75, 1.15)	**0.78 (0.66, 0.96)**	0.77 (0.64, 0.96)
USA	0.79 (0.53, 1.11)	0.81 (0.72, 0.95)	**0.75 (0.61, 0.94)**

Note: The values indicate the estimates of d for the three selected deterministic cases; in parenthesis are the 95% confidence bands. Those in bold are the corresponding to the selected specification for each series.

Table 3
Estimated coefficients. Original data.

Country	No terms	A constant	A constant with a time trend
AUSTRALIA	0.74 (0.60, 0.93)*	111565.93 (5.66)	9534.32 (8.65)
AUSTRIA	0.75 (0.62, 0.90)*	47325.04 (7.80)	1341.70 (3.84)
CANADA	0.66 (0.51, 0.86)*	2628.97 (8.87)	103.89 (7.74)
CHILE	0.78 (0.60, 1.03)	83139.13 (5.01)	2623.76 (2.51)
COLOMBIA	0.73 (0.60, 0.92)*	31795.79 (1.72)	5314.64 (5.29)
COSTA RICA	1.07 (0.94, 1.27)	1340.97 (2.33)	1646.50 (2.41)
DENMARK	0.84 (0.54, 1.16)	76216.92 (15.93)	1232.62 (3.39)
FINLAND	0.73 (0.58, 0.99)*	78577.41 (12.36)	1976.83 (5.72)
FRANCE	0.67 (0.52, 0.87)*	821163.93 (18.99)	25654.35 (12.79)
GERMANY	0.73 (0.57, 0.97)*	7233.11 (13.91)	6972.25 (2.46)
GREECE	0.83 (0.71, 1.01)	143596.07 (10.47)	–
ITALY	0.73 (0.56, 0.96)*	5589.27 (11.12)	21632.81 (7.92)
JAPAN	1.25 (1.13, 1.44)	4745827.01 (21.76)	–
KOREA	0.67 (0.54, 0.84)*	315490.50 (2.66)	47618. (8.65)
MEXICO	0.89 (0.65, 1.25)	59120.22 (1.68)	31029.05 (4.01)
NETHERLANDS	0.75 (0.61, 0.96)*	127197.33 (5.61)	4525.94 (3.47)
NEW ZEALAND	0.62 (0.50, 0.79)*	43644.79 (6.56)	1307.51 (4.75)
NORWAY	0.52 (0.37, 0.73)*	139580.34 (20.32)	2259.03 (9.53)
PORTUGAL	0.93 (0.79, 1.12)	496829.06 (11.24)	–
SPAIN	0.57 (0.39, 0.80)*	780992.56 (15.49)	22618.43 (11.98)
SWEDEN	0.70 (0.53, 0.94)*	192138.04 (23.36)	2271.18 (5.51)
SWITZERLAND	0.97 (0.79, 1.21)	39372.62 (9.23)	1835.41 (3.62)
TURKEY	0.78 (0.63, 0.99)*	65865.25 (2.31)	6773.73 (2.19)
UK	0.78 (0.66, 0.96)*	1072750.62 (22.90)	–
USA	0.75 (0.61, 0.94)*	2341808.75 (11.04)	88761.79 (7.27)

Note: The values in column 2 are the estimates of d and the 95% confidence bands; in columns 3 and 4 we display the intercept and the time trend, with t-values in parenthesis. * indicates evidence of mean reversion at the 95% level.

more likely to be persistent. Countries such as Chile, Denmark, Japan, Mexico, Portugal and Switzerland are found to be persistent using both raw and logged version of the data. Only Japan is among the top five consumers of fishery products during the 1961–2017. The results are not also in tandem with the hypothesis in Smyth and Narayan (2015) which states more volatile series are more likely to be persistent. None of the countries with persistent fishery products consumption are among the five-top countries in terms of the size of standard deviation of the series (OECD Review of Fisheries, 2022).

Finally, as a robustness check we implemented alternative approaches including for example, Sowell's (1992) maximum likelihood approach in the time domain. The results supported the same conclusions as those found in this work, supporting the hypothesis of mean reversion in the same seventeen countries as in our case. Other alternative methods, like those based on the log-periodogram regression (Geweke & Porter-Hudak, 1983; Robinson, 1995) should produce similar results.

6. Conclusion

In this paper we have explored fishery products consumption in 25 OECD countries by looking at the magnitude of persistence of the series and the mean reversion property. For this purpose, we use fractionally integrated techniques which seems to be an appropriate technique, rather flexible and more general than the standard unit root approaches. The empirical findings show the existence of positive time trends in the majority of countries, the only exceptions being Greece, Japan, Portugal and the UK. Mean reversion is found in 17 out of the 25 countries examined. In 7 countries the unit root null hypothesis cannot be rejected, while Japan is the only country with an order of integration significantly higher than 1.

An implication of the results is the absence of persistence or lack of

Table 4
Orders of integration. Logged data.

Country	No terms	A constant	A constant with a time tren
AUSTRALIA	0.92 (0.75, 1.16)	0.71 (0.64, 0.81)	**0.29 (0.07, 0.60)**
AUSTRIA	0.93 (0.76, 1.18)	0.82 (0.73, 0.95)	**0.79 (0.67, 0.95)**
CANADA	0.93 (0.76, 1.17)	0.72 (0.64, 0.85)	**0.69 (0.57, 0.84)**
CHILE	0.95 (0.78, 1.19)	0.64 (0.52, 0.99)	**0.76 (0.59, 1.00)**
COLOMBIA	0.93 (0.77, 1.18)	0.59 (0.51, 0.71)	**0.30 (0.11, 0.58)**
COSTA RICA	0.96 (0.79, 1.19)	0.65 (0.54, 0.93)	**0.69 (0.50, 0.95)**
DENMARK	0.95 (0.77, 1.18)	0.51 (0.40, 1.21)	**0.89 (0.65, 1.19)**
FINLAND	0.94 (0.77, 1.19)	0.72 (0.62, 0.98)	**0.77 (0.63, 1.00)**
FRANCE	0.94 (0.77, 1.17)	0.75 (0.68, 0.95)	**0.81 (0.68, 0.98)**
GERMANY	0.94 (0.77, 1.18)	0.75 (0.60, 0.99)	**0.76 (0.59, 0.99)**
GREECE	0.93 (0.76, 1.17)	**0.78 (0.67, 0.94)**	0.78 (0.65, 0.94)
ITALY	0.93 (0.76, 1.17)	0.82 (0.72, 1.02)	**0.75 (0.57, 1.00)**
JAPAN	0.94 (0.77, 1.18)	**1.21 (1.10, 1.37)**	1.20 (1.10, 1.35)
KOREA	0.94 (0.77, 1.18)	1.02 (0.86, 1.22)	**1.02 (0.91, 1.18)**
MEXICO	0.93 (0.77, 1.17)	1.02 (0.81, 1.30)	**1.02 (0.86, 1.26)**
NETHERLANDS	0.93 (0.77, 1.18)	0.74 (0.64, 0.94)	**0.70 (0.54, 0.94)**
NEW ZEALAND	0.93 (0.77, 1.17)	0.69 (0.61, 0.82)	**0.59 (0.45, 0.76)**
NORWAY	0.94 (0.77, 1.10)	0.63 (0.57, 0.73)	**0.32 (0.16, 0.57)**
PORTUGAL	0.93 (0.77, 1.18)	**1.05 (0.88, 1.25)**	1.05 (0.88, 1.25)
SPAIN	0.93 (0.77, 1.18)	0.69 (0.62, 0.82)	**0.67 (0.52, 0.86)**
SWEDEN	0.93 (0.77, 1.17)	0.74 (0.64, 0.92)	**0.65 (0.48, 0.91)**
SWITZERLAND	0.94 (0.77, 1.18)	1.03 (0.81, 1.32)	**1.03 (0.81, 1.31)**
TURKEY	0.93 (0.76, 1.16)	0.73 (0.60, 0.94)	**0.76 (0.62, 0.94)**
UK	0.94 (0.77, 1.10)	**0.80 (0.69, 0.99)**	0.80 (0.67, 0.99)
USA	0.93 (0.76, 1.18)	0.78 (0.70, 0.90)	**0.75 (0.60, 0.90)**

Note: The values indicate the estimates of d for the three selected deterministic cases; in parenthesis are the 95% confidence bands. Those in bold are the corresponding to the selected specification for each series.

Table 5
Estimated coefficients. Logged data.

Country	No terms	A constant	A constant with a time trend
AUSTRALIA	0.29 (0.07, 0.60)*	11.709 (146.45)	0.0312 (25.84)
AUSTRIA	0.79 (0.67, 0.95)*	10.796 (140.68)	0.0165 (3.33)
CANADA	0.69 (0.57, 0.84)*	7.915 (115.47)	0.0206 (6.16)
CHILE	0.76 (0.59, 1.00)	11.340 (116.45)	0.0178 (3.10)
COLOMBIA	0.30 (0.11, 0.58)*	10.685 (110.54)	0.0365 (13.03)
COSTA RICA	0.69 (0.50, 0.95)*	7.943 (41.32)	0.0579 (6.17)
DENMARK	0.89 (0.65, 1.19)	11.240 (268.91)	0.0115 (3.08)
FINLAND	0.77 (0.63, 1.00)	11.278 (207.01)	0.0155 (4.67)
FRANCE	0.81 (0.68, 0.98)*	13.631 (436.76)	0.0176 (8.20)
GERMANY	0.76 (0.59, 0.99)*	13.487 (261.32)	0.0076 (2.48)
GREECE	0.78 (0.67, 0.94)*	11.880 (162.80)	–
ITALY	0.75 (0.57, 1.00)	13.277 (274.42)	0.0201 (7.23)
JAPAN	1.21 (1.10, 1.37)	15.374 (463.76)	–
KOREA	1.02 (0.91, 1.18)	12.698 (145.21)	0.0385 (3.09)
MEXICO	1.02 (0.86, 1.26)	11.438 (96.02)	0.0523 (3.08)
NETHERLANDS	0.70 (0.54, 0.94)*	11.790 (121.91)	0.0191 (3.94)
NEW ZEALAND	0.59 (0.45, 0.76)*	10.719 (103.72)	0.0173 (4.32)
NORWAY	0.32 (0.16, 0.57)*	11.858 (437.48)	0.0114 (14.52)
PORTUGAL	1.05 (0.88, 1.25)	13.114 (137.28)	–
SPAIN	0.67 (0.52, 0.86)*	13.586 (337.47)	0.0170 (9.10)
SWEDEN	0.65 (0.48, 0.91)*	12.173 (402.90)	0.0089 (6.69)
SWITZERLAND	1.03 (0.81, 1.31)	10.600 (175.38)	0.0223 (2.50)
TURKEY	0.76 (0.62, 0.94)*	11.153 (58.24)	0.0333 (2.93)
UK	0.80 (0.69, 0.99)*	13.881 (333.75)	–
USA	0.75 (0.60, 0.90)*	14.701 (320.61)	0.0200 (7.60)

Note: The values in column 2 are the estimates of d and the 95% confidence bands; in columns 3 and 4 we display the intercept and the time trend, with *t*-values in parenthesis. * indicates evidence of mean reversion at the 95% level.

hysteresis in fishery products consumption of many OECD countries. Therefore, shocks to the fishery products consumption are temporary and or short-term in nature. Hence, elongated long-term policies or excessive interference from the political authorities will be a misfit in boosting fishery products consumption. Rolling short-term measures are suitable to boost fishery products consumption in majority of the OECD countries. These policies include the introduction of phased short-term financial relief for fishery companies and the implementation of phased discounts on fishery products consumption. Other short-term policies include lessening administrative hindrances and regulatory burdens that could create short-term bottlenecks in the fishery sector.

It also implies that governments should be cautious in introducing overreaching measures through huge discretionary fiscal policy to boost fishery products consumption after a negative economic and non-economic shock (such as the case COVID-19 pandemic) that has negatively affected consumption in the country. Instead, the focus should be on establishing different forms of automatic stabilizers in these countries, which will immediately respond to any economic shocks that negatively affect fishery products consumption. Automatic stabilizers can involve an automatic rise in tax incentives for producers and consumers of fishery products. Automatic rise in subsidies fishery products for consumer is another possible example of automatic stabilizers in the fishery sector. Another potential automatic stabilizer is the emergence of fishery products vouchers during recession. This voucher can be used to exclusively purchase fishery products by those negatively affected by recessions. The OECD governments must be prepared for a rise in budgets as increasing sizes of the automatic stabilizers will enhance government expenditures.

However, long term policies are needed in the countries that have been found to have persistent fishery products consumption such as Chile, Denmark, Japan, Mexico, Portugal and Switzerland. Long term policies include infrastructural support such as improvement in ports

Table 6
Policy implications according to the estimated order of integration (*d*).

Estimated *d*	Mean Reversion & Shock Impact	Recommended Policy Horizon	Countries
***d* < 1**	Mean reversion present but slower; shocks are transitory but persistent	Primarily short-term, but monitor medium-term effects (e.g., gradual financial relief, progressive discounts, regulatory burdens)	Australia, Austria, Canada, Colombia, Finland, France, Germany, Italy, Korea, Netherlands, New Zealand, Norway, Spain, Sweden, Turkey, UK and USA
***d* ≥ 1**	No mean reversion; shocks have permanent effects	Long-term structural policies (e.g., infrastructure support, port improvements, enhanced storage facilities, fishery products more affordable even during times of crisis)	Chile, Costa Rica, Denmark, Greece, Japan, Mexico, Portugal and Switzerland,

Note: When $d = 0$, the series is fully I(0) stationary and any shock is completely transitory.
The lower the value of d, the faster the series converges back to its original level after a shock.

and storage facilities that will make fishery products more affordable for consumption even during the time of crisis.

The results also imply that it is possible to predict the subsequent figures of fishery products consumption by principally relying on their previous values. Therefore, forecasting models should accord greater prominence to previous values of fishery products consumption in modeling the prediction of future values of fishery products consumption in most of the OECD countries. However, other determinants of fishery products consumption (inflation and real GDP and exchange rate or other established determinants) should be accorded similar prominence in the models involving the prediction of future values of fishery products consumption in Chile, Denmark, Japan, Mexico, Portugal and Switzerland.

The paper contains some limitations. Thus, from an econometric viewpoint, the linear nature employed in the specification of the deterministic trend can be extended to the nonlinear case and the possibility of structural is another issue that might be taken into account. As an example of potential breaks in the data, we examined the case of the US including in Fig. 3 the estimates of d (and the 95% bands) for the original and logged data, first with a subsample ending at 1999, and then adding one observation (year) each time.

It is observed in Fig. 3 a notable increase in the estimates of d around the 9th subsample that corresponds to the subsample with data ending at 2007 at the time of the financial crisis. It would be of interest to see if this happens to the remaining countries. Subsequent studies can also focus on areas that have not been covered by the present study. Thus, acknowledge that unobserved shocks (pandemics, technology, international trade) or policy events may also affect the results reported in this work. Future research may include subnational analyses, explores causality, or applies similar methodology to other major consumer blocs (e.g., ASEAN, MENA). The current study has concentrated on the persistence of fishery products consumption in OECD countries. Convergence analysis of fishery products consumption in OECD countries can also be examined by future studies. The existence of convergence of fishery products consumption indicates the appropriateness of using mutual policies to boost fishery products consumption among countries under review. Persistence analysis can also be conducted for other economic or regional blocs including The Middle East and North Africa (MENA) and Association of Southeast Asian Nations (ASEAN) blocs.

CRediT authorship contribution statement

Sakiru Adebola Solarin: Writing – review & editing, Writing – original draft, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Carmen Lafuente:** Writing – review & editing, Writing – original draft, Methodology, Investigation, Data curation. **Luis Alberiko Gil-Alana:** Writing – review & editing, Writing – original draft, Supervision, Software, Resources, Funding acquisition. **María Jesús González-Blanch:** Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Project administration, Methodology.

Ethics in publishing statement

I testify on behalf of all co-authors that our article submitted followed ethical principles in publishing. Title: An evaluation of the persistence of fishery products consumption in OECD countriesAll authors agree that:This research presents an accurate account of the work performed, all data presented are accurate and methodologies detailed enough to permit others to replicate the work. This manuscript represents entirely original works and or if work and/or words of others have been used, that this has been appropriately cited or quoted and permission has been obtained where necessary. This material has not been published in whole or in part elsewhere. The manuscript is not

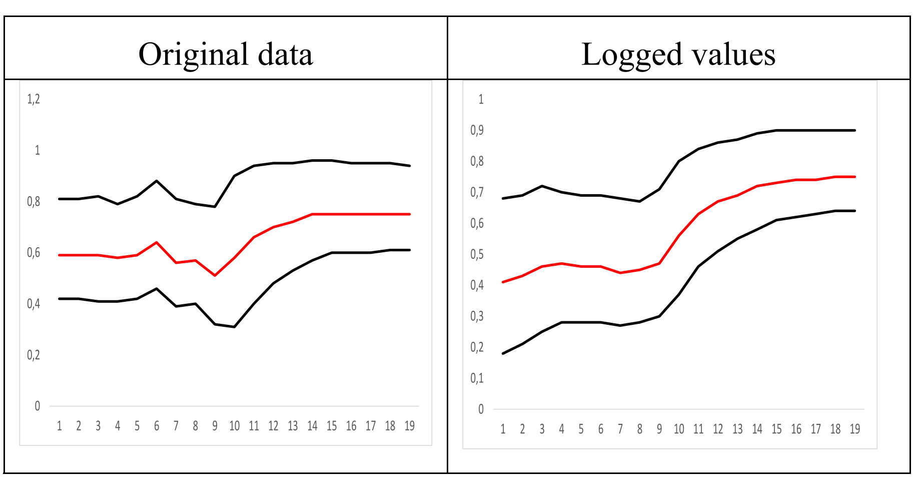

Fig. 3. Estimates of d for different subsamples: US case
Note: The values in red are the estimates of d while those in black are the 95% confidence intervals. The first point indicate a subsample ending at 1999; the following ones incorporate one observation (year) each time.

currently being considered for publication in another journal. All authors have been personally and actively involved in substantive work leading to the manuscript and will hold themselves jointly and individually responsible for its content.

Generative AI and AI-assisted technologies requirements

I testify on behalf of all co-authors that our article submitted followed generative AI and AI-assisted technologies requirements. Title: An evaluation of the persistence of fishery products consumption in OECD countriesAll authors agree that:That generative AI and AI-assisted technologies have not been utilized in the writing process or if used, disclosed in the manuscript the use of AI and AI-assisted technologies and a statement will appear in the published work. That generative AI and AI-assisted technologies have not been used to create or alter images unless specifically used as part of the research design where such use must be described in a reproducible manner in the methods section.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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