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Article

Drivers of Seafood Consumption at Different Geographical Scales

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ABSTRACT

As an important source of essential amino acids and micronutrients, fish is critical in the fight against malnutrition, especially in low income and food deficient countries. However, because fish consumption is reportedly linked to overfishing and the generation of negative environmental consequences from fish farming. There have been calls to reduce fish consumption, which may have implications for fish intake and the drive to reduce childhood malnutrition in many developing countries. Here we assess the role of urbanization, income, fish prices, preferences, nutritional knowledge, and cultural attitudes in fish demand. We conducted analysis using the fixed effect model at three geographical scales: global—151 countries drawn from all continents that consume over 90% of global seafood supply; at the continental; and at the national scales, where we assessed seafood consumption in Nigeria, Portugal, Bangladesh and the United States. Our results suggest that at the global level, a 10% increase in disposable income leads to a 5% increase in fish consumption, although a 10% increase in domestic fish price leads to 8% decrease in fish consumption. In our continental level analysis, we found distinct drivers of seafood consumption across continents, for example, urbanization drives fish consumption in Africa, while domestic fish prices influence fish consumption in South America and Oceania regions. The estimates of the current study are broadly consistent with other earlier studies, showing a uniformly income-driven demand for seafood. World population is often presented as a key driver for the growth in seafood demand. A subtle driver for fish (and other animal source food) consumption is income. At the national level, the case studies highlight that qualitative variable such as preferences, nutritional knowledge, and cultural attitudes across countries are also important drivers for fish consumption. However, we suggest that future study could endeavor to assess how income and fish price influence peoples' consumption of specific fish species.

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KEYWORDS: seafood consumption; fixed and random effects; fish price; disposable income

INTRODUCTION

Fish is an important source of essential micronutrients, which makes it particularly attractive in the current fight against malnutrition in low income and food deficient countries [1–4], but also a major source of livelihood around the world [5,6]. For instance, about 179 million tonnes (Mt) of seafood was extracted in 2018, which supported more than 20 percent of global demand for animal protein [7], and employed over 108 million people [1]. In 2018, the global fish production was estimated at USD 401 billion, of which 82 Mt, valued at USD 250 billion came from aquaculture production [8]. The aquaculture sector experienced an annual growth rate of 8.2 percent between 1980–2018 [9]. In recent times growth in the aquaculture sector has been linked to expansion in global trade, decline in the availability of wild fish, competitive product pricing, rising incomes, and urbanization [10].

Globally, aquaculture production has been associated with negative environmental consequences such as loss of aquatic life, decreased water quality (especially pH) and dissolved oxygen and the use of fishmeal and fish oil to feed farmed fish [11–14]. For example, in some Provinces in China, aquaculture pollution accounts for more than 20% of the total input of nutrients into freshwater environments [15]. This has led to the prohibition of aquaculture in many public water bodies that are essential drinking water sources, and are important for other vital ecosystem services [16].

Recent studies shown that negative consequences associated with the aquaculture sector is relatively lower than the terrestrial meat production sector [10]. Aquatic animal production systems have a lower carbon footprint per kilogram of output when compared with other terrestrial animal production systems [17]. Added to this, nitrogen and phosphorus emissions (kg of nitrogen and phosphorus produced per tonne of protein produced) from aquaculture systems are much lower than those in beef and pork production systems [2]. Amidst the negative impact of fish production and consumption on the environment, global fish consumption levels keep rising. Over a 57-year period, seafood consumption per capita (kg/person/year) in edible weight has more than doubled from 7 kg/cap/year in 1961 to 15 kg/cap/year in 2017 as shown in Figure 1. Within the same period, aggregate volume of fish consumption, measured in live weight, increased from 27.7 Mt to 152 Mt [8]. While the global population rose from 3 billion to 7.6 billion within the period. This shows that a growth at 3.5% rate of seafood supply has effectively been growing faster than the world population growth rate of 1.8% over the period. If aquaculture production grows at the same rate and constant real prices for fish, global fish consumption will double by the mid-century [10].

However, excessive focus on the trends of global fish consumption will mask some important regional differences in fish consumption. For instance, as the volume of fish consumed differs across regions, the drivers of fish consumption across regions also differ. In terms of volume of fish consumed, Asia accounts for almost two-thirds of global consumption at a rate of 20.7 kg per capita while Africa records the lowest consumption per capita of 9.9 kg in 2017 [8]. Disposable income drives fish consumption in most parts of the world especially in Europe, however, it should be stressed that in Asia (especially in Japan, and the Republic of Korea), preference for fish has developed and endured traditionally [8]. This is because for centuries, populations within Asia have been eating fish-based proteins, and so the drivers there are different. The aforementioned issue thus suggests significant variation thus exist in drivers of growth in fish consumption across countries and regions.

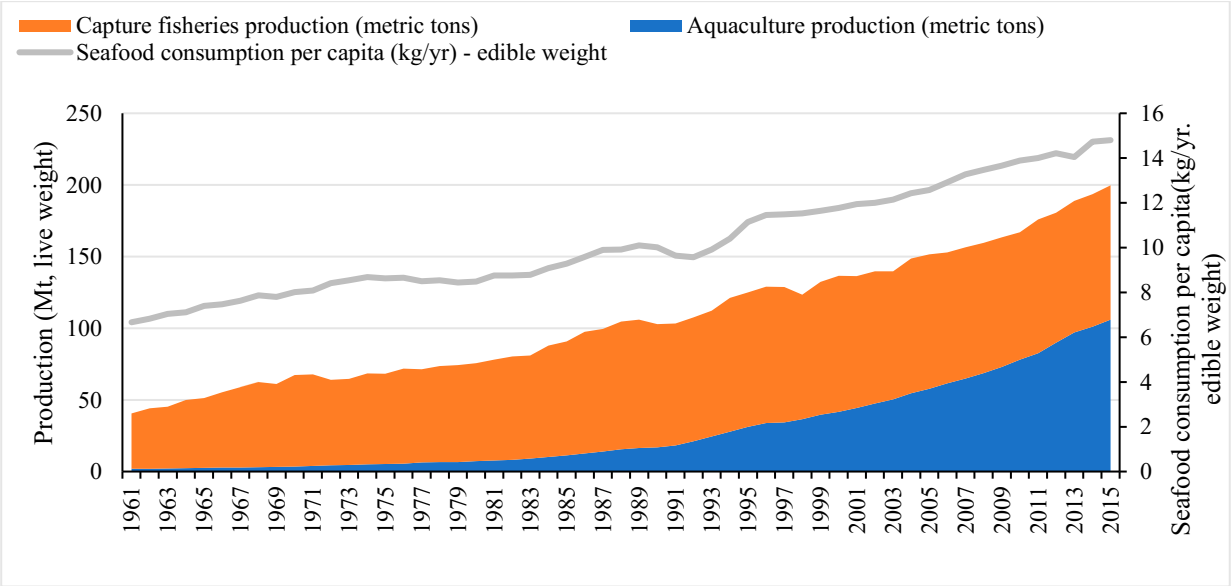

Figure 1. Global wild and aquaculture fish production and consumption per capita (1961–2017). Note that both wild and aquaculture production are in tonnes, live weight. Seafood includes all fish species, crustaceans, cephalopods, and molluscs in edible weight with conversion from live-to-edible based on aggregate fish conversion factor (0.74) reported in [18]. Data Source: FAOSTAT [8].

Geographical location, price, culturally-driven dietary preferences, purchasing ability of the consumer and income have all been identified as important drivers of global fish consumption [19]. In developed countries changes in consumer preference and health concerns about close substitutes like meat are notable drivers of the observed increase in consumption of fishery products [20]. We find from the literature that macro-level studies on the subject neglect the potential role of indicators like disposable income, domestic fish price, and urbanization. In this study we focus on fish consumption amounts by asking the following research questions: How is the consumption of fish-protein changing overtime? What is the effect of changes in disposable income, domestic fish price,

urban population and food price inflation on edible fish consumption per capita? To identify the drivers of fish consumption the study adopts a two-tier analysis (global and regional level) approach. A country level review is presented as a case study to support the empirical findings.

The main objective of this paper is to investigate the degree to which economic factors have been driving edible seafood consumption. We converted from live-to-edible weight based on conversion factors reported in [10,18] (see the secondary axis of Figure 1 above). To investigate the drivers of seafood consumption, we use descriptive statistics and an econometric fixed and random model as well as country-specific case studies to provide insight into geographic patterns of blue food demand. The fixed and random models were considered in the study since it is well documented that unobserved variables such as cultural attitudes toward consumption vary from one country to the next but are fixed within a country over time [21] and may have effects on consumer's demand.

For the global analysis, we included 151 countries, across six continents—Africa, Asia, Europe, North America, South America, and Oceania. Our 151 countries consume over 90% of all seafood supply. Accordingly, we used two measures of fish demand: (1) whether income influences people to consume fish; and (2) whether domestic fish price is a main driver of fish consumption. Results from our global analysis show that a 10% increase in per capita income leads to a 5% increase in fish consumption. The remaining section of the paper is organized as follows: Section 2 presents the background literature. Section 3 deals with the methods. Section 4 shows the results and discussion. Section 5 discusses the country case studies and Section 6 presents the conclusion.

BACKGROUND

Fish Consumption and Cultural Preferences

Global per capita fish consumption grew from 9.0 kg (live weight equivalent) in 1961 to 20.5 kg in 2018 [8]. This growth in fish consumption is also higher than the consumption of other animal protein (meat, dairy, milk, et cetera), which increased by 2.1 percent per year [2]. In 2018, about 178 Mt of fish were extracted from the global marine and inland water ecosystems of which the production from aquaculture amounted to 82 Mt. Human consumption was about 156 Mt, with the remaining 22 Mt used for non-food uses especially for the production of fish oil and fishmeal [8]. Regional data depicts significant differences in per capita growth in fish consumption. For instance, in 2013, Asian countries accounted for 70% of the increase in fish consumed as food [22] and future per capita fish consumption is expected to increase mainly in high-income countries in East Asia. Estimates show that per capita fish consumption in East Asia would continue to grow, jumping from 32.91 kg in 2008 to 38.65 kg in 2013 (which is a 3.27 percent annual growth rate per capita fish consumption).

This represents an enormous increase when juxtaposed with the region's annual population growth rate of just 0.49% [22].

Africa has the lowest per capita fish consumption and estimates predict that average per capita fish consumption in the continent is unlikely to increase. But aggregate consumption is projected to increase [23]. Micro level analysis depicts significant differences in per capita fish consumption among different income groups over the last three decades [24]. Per capita fish consumption across income groups exhibits similar patterns over time, with low-income countries consuming less fish per capita compared to the high-income countries [24]. The development of the aquaculture sector taking place in Asia is likely to drive these observed changes in fish consumption. As fish and fishery products continue to be highly tradable commodity; it is expected that countries in Asia will continue to be the main exporters of fish for human consumption while Organization for Economic Co-operation and Development (OECD) countries will remain the main importers. This trend is unlikely to influence fish prices even though nominal prices will increase; real prices are expected to remain flat [25].

Dietary preferences are learned via our experience with food and eating [26]. People's food preferences are a result of experience with, and thus availability of, foods and the most potent factors that produce food likes (and dislikes) are social [27,28]. It is therefore not surprising that culture appears to be a key driver of general food preferences [10,27]. Culture is a term that refers to a large and diverse set of mostly intangible aspects of social life. Here we use it in its broadest sense to refer to the beliefs, customs, and social norms of a social group which structures aspects of everyday existence, such as cooking and eating. The role of culture in affecting seafood consumption is remarkably little studied [29], but studies are emerging that investigate consumer preferences for different types of seafood in Asia and Africa [30–32]. A vast majority of the fish consumption literature centers on the proximate drivers of consumption, such as availability, price, convenience, health, beliefs, self-efficacy and eating habits [33]. These are often also referred to as consumer beliefs—and this appears to be a much larger field of study. Consumer beliefs represent the information that a consumer possesses about an object and relates to product attributes [34], but belief formation is a lifelong dynamic process [35] and while it is influenced by direct observations, it is also influenced by information or previously acquired experience and knowledge [36]. As such, culture is likely to figure in habits and belief formation, but clear causal connections are elusive in the literature, at least for fish consumption. Studies show that fish consumption is strongly affected by habits that emerge and are reinforced by past experiences [37], and consuming fish regularly as a child is associated with more favorable attitudes towards fish, and a greater familiarity with it [31,38–41]. Many studies identify the important role of culture as a determinant of eating since purchasing behavior and seafood preferences are closely linked to ethnicity, even within nations [42]. While

cross-cultural studies of seafood consumption preferences are lacking, FAO statistics clearly show that different cultures are associated with strikingly different consumption quantities per capita. Some cultures are linked with high fish consumption—notably the Mediterranean, parts of Asia and Northern Europe. However, the types of fish consumed across nations/regions differ, for instance, strong focus on 'low-value' often dried pelagic fish in Africa [23] but luxury seafood consumption in China [43]. A comparison of seafood consumption across Europe indicates that preferences vary significantly and that the European Union has an amazing diversity of fish-eating cultures [44].

Disposable Income

Fish remains a necessary food item on many household foods budgets. Economic growth, population growth and GDP per capita will have major effects on gross food demand [45], increased income is expected to drive household fish demand [24]. Changes in disposable income influences individuals' purchasing power, which in turn affects consumption behavior towards food items such as fish. Hence, we expect income to provide valuable information about the characteristics of fish demand within an economy. Also, country size and regional distribution of GDP is expected to provide important information about the demographics of economic activity. We note that per capita income and consumer's purchasing power has developed substantially over time and differs among countries and regions. In China, India and other parts of Asia and the Pacific, the level of per capita income is on a steep rise. The rising middle-class in China and India could generate a huge consumption market. So, there is still a considerable shift in economic power towards Asia [46], which could increase fish consumption. Latin America and the Caribbean has seen a slower growth of its per capita income in recent years, and is expected to be overtaken by those of countries in Asia and Pacific in the early 2020s [47]. At the lowest end, in terms of both current per capita consumption and its growth, is Africa, where the ratio of population growth to economic growth has led the average GDP per capita to remain relatively flat. In sub-Saharan Africa, increased disposable income will cause an increase in consumption. The increase will be especially noticeable in the consumption of important nutrients such as proteins [23]. The change in per capita food consumption driven by the change in income is, however, difficult to estimate. Going by Engel's Law, when consumer income increases, the proportion of income spent on food decreases, ceteris paribus [48]. The Engel's law stipulates that with a given set of preferences and tastes, as income increases, consumers increase their expenditures on food items (in percentage terms) less than their rises in income [49,50]. Meaning the relationship between income and demand is non-linear [51]. Hence, demand in richer and more advanced economies is not expected to increase significantly.

Engel's law was put to test recently by [25], where food expenditure in higher-income countries represents a small share of total income (10–15

percent), per capita food consumption is reaching a plateau. Increased in GDP per capita in developed countries affect the composition of consumption rather than cause a general rise in food consumption. The GDP per capita increase in some emerging economies (developing Asia, Latin America, developing regions of the Middle East and Eastern Europe) result in both food consumption increases and composition change [52]. It is hard to predict the exact size of the expected consumption increase in developing economies due to the differing rates of economic growth seen throughout these countries. An increase in consumption of some particular products will depend not only on income but also on the cultural and religious traditions of a particular country—these add a degree of uncertainty to a prediction based purely on income gain. For instance, the extent to which increases in disposable income will translate into a significant increase in food consumption in general and fish consumption in particular remains unclear [52]. Nevertheless, demand for fish as food is particularly high in the wealthier strata of societies, including in the low-income countries, and as income will continue to increase in highly populated countries such as China and India, demand levels are likely to cause a relative increase in fish consumption [53]. We used disposable income drawn from the World Bank data as a better predictor of fish consumption per capita [10].

Fish Import Price

Increase in fish demand or its contraction may occur for a number of reasons. One of the economic causes is changes in the prices of substitute and complementary products, which are usually explicitly accounted for in demand analyses [54]. The price of fish is influenced by the state of processing and certification. For instance, Chinese consumers were willing to pay more for safe and traceable fish products making the consumption of such fish products relatively expensive [55,56]. Perception about fish safety has also been found to influence pricing of fishery products. A study found strong demand and good market potential for safe food and a higher willingness to pay (WTP) for milkfish and oysters produced under hazard analysis critical control point (HACCP) regulations among Taiwanese [57]. Perceived quality and price were significant in explaining variations in consumer attitudes toward consumption of fish in Vietnam [58]. Their study further showed that availability of fresh fish was an important factor explaining the variation in fish consumption in Vietnam [58]. Other studies have shown that consumer perception about the freshness of fish are key determinants of preferences and pricing of fish; as found in India [59,60], and in China [61]. Local studies suggest that Malaysian consumers preferred fish fresh, packed fish, and fish from the supermarket [62], while Nigerians preferred either more affordable, imported frozen fish or preserved seafoods (dried and smoked) despite seasonal income and price fluctuations [63].

Although the price level affects the intention to buy fish among most consumers [64]. In the UK, price was not a significant factor in explaining

variation in purchasing seafood [65]. This appears to be the case in Finland [66]. In contrast, household income, lack of supply of fresh fish and high price were perceived as a barrier for seafood consumption in a representative study of more than 4000 Norwegian women [40]. In situations where individuals get their fish as gifts or very cheaply from commercial recreational fishers, or they do their own fishing, price of fish may not be a barrier to consumption. Pricing is also affected by slow growth in aquaculture due to reduction in fish supply. This may result in undesirable increases in domestic prices and decreasing domestic consumption as a consequence [67]. In this study, we argued that changes in domestic fish prices will significantly influence per capita fish consumption. Hence, we used import price as a proxy for the domestic fish price by calculating import price from import value and quantities from the FAOSTAT database. Using exchange rate data obtained from the World Bank database [68], we expressed each country's unit price in the local currency. Import price is treated as a proxy for the domestic fish price in most countries for three reasons. First, it is relatively easy to obtain time series fish trade data for most economies. Second, most previous consumption studies have been conducted using fish trade data. For that reason, many of the estimated demand elasticities in previous studies are based on trade data [69]. Third, there is no better alternative to import price to serve as proxy to the domestic fish price in most nations [70]. Utilizing import price to proxy domestic price has some limitations. Developing countries, particularly countries in Asia, are mainly exporters of fish and fishery products. In fact, it is true that developing countries export high-quality fish and fishery products in exchange for lower quality one, while keeping and importing lower value fish and fishery products for their domestic supply [54,71]. Still, due to rising consumer incomes, consumers in developing economies are diversifying the types of seafood they consume through import. This has caused an increase in fish imports to developing countries [8]. For advanced economies, a sizable and growing share of the fish consumed is supplied through imports; using import prices in these economies therefore seems proper. Thus, while interpreting the estimates, especially those from low-income countries, we must keep in mind the uncertainty regarding the use of import prices as a proxy for country-level fish prices.

Food Price Inflation as a Proxy for Price of Substitute Products

Real prices of seafood, particularly relative to terrestrial animal products that substitute in demand, are important determinants of fish consumption, with consumers in developing countries being more responsive to price than consumers in developed countries [22,49,72,73]. An assessment of blue food demand across geographies and time horizons provides insight into the consumption patterns of fish species and terrestrial meat that are potential substitutes in demand [10]. We use food price inflation as a proxy for food prices in general obtained from FAOSTAT for the following reasons. Although this index also includes fish

prices as far as we understand, we observed that fish constitutes such a small proportion of the food price index in most countries, hence food price inflation is a reasonable proxy for prices of substitute products.

Urban Population

The rapid expansion in fish production reflects escalating demand, particularly in the developing world, which has been driven largely by increases in urban areas and growth in per capita incomes. Urbanization can be credited for the transition towards animal-based protein. Here we argued that urbanization (as percentage of the total population) driven by population growth, is an important factor to terrestrial-source food consumption in general and fish demand in particular [17]. Urbanization alone has driven changes in food preference in the past, and accounts for an extra 5.7–9.3 kg per capita consumption of fish and meat per year [74]. Similarly, the urban population with the highest income growth tends to increase fish consumption while low-income people will experience reductions in their fish consumption [2]. In both Bangladesh and Ethiopia, growth in population due to urbanization increases animal food consumption rates independently of income [75]. Here we're hypothesizing that the consumption of seafood is strongly influenced by urban population. In this paper, we used urban population (% of total population) as an exogenous variable, from the publicly available World Bank data. Considering that population is already part of the endogenous variable, we argue that urbanization is the driving factor behind fish demand.

METHODS

Distribution of Countries Per Region

The distribution of countries in the unbalanced panel data set is presented in Supplementary Table S1. The selection and inclusion of a country in the dataset was based on availability of data points for the various indicators across the stated horizon of the study. In the Africa region 41 countries were included in the data, Asia had 34 countries, Europe 38, North and South America 2 and 30 respectively. The Oceania region had 6 countries in the unbalanced panel dataset.

Estimation Strategy

Since we are interested in testing the relationship between our measures of per capita fish consumption (kg/cap/year, in edible weight) and the fish consumption predictors discussed above, we specify both country and time fixed effects econometric model:

$$logC_{it} = \alpha + \beta log(Y_{it}) + \gamma log(P_{it}) + \theta log(X_{it}) + \mu_i + \lambda_t + \varepsilon_{it} \quad (1)$$

where i represents 151 countries; t denotes time in years. The dependent variable is per capita fish consumption (C_{it}) expressed in kg/person/year, in edible weight. Per capita fish consumption is calculated as the net supply

divided by the population in country i in year t. Y_{it} is disposable income (current US$) in country i, in year t; P_{it} is domestic fish price (aggregate import quantities and values) in country i, in year t; X_{it} is a set of factors that may affect per capita fish consumption such as urban population (% of total population) and food price inflation in country i, in year t; μ_i is country fixed effect that captures countries idiosyncratic preference over fish consumption; λ_t denotes time effect; β, γ and θ represent elasticity parameters, whiles ε_{it} is the error term. Because the model is expressed in logarithms, the estimated parameters can be interpreted as elasticities [76]. Although the signs (and magnitudes) of the coefficients are not dictated by economic theory, we would expect γ to be negative. In addition, we expect β and θ to be positive at least for food commodities—consistent with the low-income elasticity for most agricultural commodities as well as the long-term impact of technological progress in fish supply (e.g., increased contribution from aquaculture) on commodity markets.

To better understand how demand shifts in one country or region impacts prices and quantities in other countries, it is useful to analyze all countries where fish is consumed by using panel data for all countries with substantial consumption. This enables the researcher to account for irregular demand shift by including fixed effects and time variables [54]. Hence, we utilized a panel dataset comprising countries and time periods in years. We estimate Equation (1) using fixed and random effects regression [21,77]. With panel data we can control for factors that could cause omitted variable bias if they are omitted such as cultural attitudes towards fish consumption.

RESULTS AND DISCUSSIONS OF GLOBAL ANALYSIS

Supplementary Tables S1, S2 and S3 present distributions of countries in our dataset, the variable description and summary statistics of drivers of fish consumption, respectively. For the dependent variable, the mean value for fish consumption is 18.7 kg/cap/year, which ranges from 0.02 kg/cap/year to 191.8 kg/cap/year. A key driver influencing consumers' demand for fish is domestic price of fish with an average price of fish per metric ton equivalent to US$2072. Disposable income which has been identified as the key driver of fish consumption [23] has an average value of US$9693 and a maximum value of US$118,824. The impact of urbanization on fish consumption is mixed. A comprehensive empirical analysis of the role of urbanization in seafood demand is needed to identify dietary preferences and structural features and underlying this relationship, including the role of out-of-home consumption [10]. In contrast, aggregate domestic demand for fish has increased with the rising urban population in Bangladesh [78]. The minimum and maximum values for urban population (% of the total population) are 5.3%, and 100% respectively. To assess the effect of price of substitute products on fish consumption, we used an index for food price inflation in general which measures the average change in prices over time that consumers pay for a basket of goods and services per year. The price of substitute products is a key variable of interest, which has an average value

of 7 and a maximum value of 481. There are 2547 observations in the sample corresponding to roughly 30 years of annual data.

Supplementary Table S4 shows the correlation matrix among variables used in the study. Fish consumption and disposable income have a positive and significant relationship at least at the 10% level. Likewise, nearly all relationships between fish consumption and the independent variables are significant except for the prices. The correlation between fish consumption and various independent variables again shows the absence of multicollinearity in the model.

Supplementary Tables S5 and S6 present the global and regional regression estimates for the predictors of fish consumption respectively. For all results displayed, each specification was tested applying pooled regression, fixed and random effects. However, the Hausman test indicates that the fixed effect model was appropriate for the data at the global level. The coefficient on the key variable of interest, β1 could be either positive or negative, and we are interested in testing whether the effect of disposable income on fish consumption is statistically significant. In our specification, disposable income influences fish consumption positively. Its coefficient is statistically significant at least at the 1% level, implying that 10% increase in income increases fish consumption by 5%. Urban inhabitants drive per capita fish demand. Urban population generally have more disposable income to spend on animal proteins such as fish, and they eat away from home more often. Also, the infrastructure (e.g., supermarkets are developing rapidly throughout Africa) available in urban areas permits more efficient distribution, storage and marketing of fish products [8].

Although population growth is an important variable in determining the number of mouths to feed, income and associated changes in dietary habits are more important drivers of fish demand (and other animal sourced foods) [79,80]. However, the relationship between domestic fish price and per capita fish consumption is significant. We found that a 10% increase in the price of substitute products leads to about 6% decline in fish consumption. The F-statistics was significant, so we reject the null that the coefficients for all years are jointly equal to zero, therefore time-fixed effects are relevant. However, Supplementary Tables S7, S8 and S9 show fish demand elasticities, annual average demand growth in different periods (%) and fish consumption per capita respectively. As shown in Supplementary Table S7, we found small coefficients for own price and income elasticities in the literature review which are similar to our estimates in both the global and the regional analysis.

The motivations for why people are eating fish differ by continents. From 1988 to 2017, Asia recorded the highest annual average demand growth rate (i.e., compound annual growth rate) of 2.4% while North America recorded the lowest rate of 0.05% (Supplementary Table S8). Viewing consumption patterns over time for six continents, we provide additional insight into the roles of domestic fish prices, urbanization, and economic determinants of fish demand. Results from fixed and time

random regressions indicate that, after controlling for other covariates of fish consumption, we found that disposable income, urbanization, and domestic prices appear to be key drivers of seafood consumption. We also observed that countries' fixed and time effects are jointly statistically significant which implies that changing national or cultural attitudes play a leading role in determining fish consumption. Also, time effects make the findings of our explanatory variables much more robust.

Urbanization matters for fish consumption, especially urbanization with rising income may be key determinants of fish consumption. In fact, the fish supply per capita has more than tripled in the last half century, from 6 kg/year in 1950 to 18.8 kg/year in 2011 thereby outpacing the world's population growth [13], thus increasing its contribution to food security and nutrition [81]. The findings of this paper align with consumer theory [82,83], indicating that seafood demand as a function of income, relative prices, population, and preferences; other determinants include regional demographic characteristics, as well as other household characteristics such as employment and urban versus rural residence are embedded in preferences.

Our study has limitations. First, although we attempted to measure fish consumption at the global level as well as across six continents, we failed to be specific about fish species groups (e.g., freshwater fish, pelagics, demersals, et cetera). While we do not believe that being specific about the type of fish would change our results significantly (if at all), future research could endeavor to assess how income and fish price influence people's consumption of specific fish groups. Second, when markets are integrated globally, demand shifts in one region impact prices and quantities in other regions [54], as a result, a more representative sample would be having access to panel data for all countries of substantial fish consumption. This would allow the researcher to account for irregular demand shocks by including interaction terms between the fixed effects and a time variable.

COUNTRY CASE STUDIES FINDINGS

Our empirical findings so far indicate that after controlling for other covariates of fish consumption, disposable income and price of fish are key drivers of fish consumption in many countries. However, our quantitative empirical analysis may not be able to control for unobserved cultural attitudes across countries. In order to provide qualitative evidence that our estimated drivers of fish consumption are likely to capture a causal rather than a spurious effect. Case studies of Nigeria, Portugal, Bangladesh and the US provide further insight into geographic patterns of fish demand at national and sub-national scales. Nigeria—the most populous country with the largest economy in Africa, fish is traditionally complemented to rice in the diet of Bangladeshi, the US—strong disposable income and, Portugal—one of the most important seafood markets in Europe. Also, these four countries were selected on the basis of their large sizable roles in global fish production, consumption,

long coastlines and extensive freshwater bodies. In addition, the four countries have recently conducted households or national surveys using income and price elements, which, as, our quantitative analysis shows, are important drivers of fish consumption.

Fish represent a major food in the average diet in Nigeria; disaggregating nationally representative data from Nigeria based on richer South from the poorer North, and urban and rural. In Nigeria, fish consumption is widespread and increasing: 59% of Nigerians ate fish in 2010 versus 72% in 2015; the North stayed steady at about 50%, while the South leapt from 71% to 90% in the 5 years [84]. Demand for imported, smoked and dried fish is mainly due to differences in income and refrigerator ownership. Like some countries in Asia, series of household survey studies in the past two decades indicated that rising incomes, falling fish prices, and changes in dietary trends, pointing towards better nutrition and diet, with fish playing a key role in this regard are key drivers of the rapid increase in Nigerian fish consumption [85].

Fish is an important element of the Portuguese diet and also a part of the traditional European diet. Portugal is one of the most important seafood markets in Europe, and surveying the seafood consumers in this market will help identify the seafood consumption preferences and patterns in the Portuguese population. Geography and cultural dietary preferences appear to have a strong influence on consumption patterns in Portugal. Portuguese consumers prefer wild to cultured fish as well as fat to lean fish. Chilled fish is preferred over frozen, salted/dried, canned, and smoked fish, being the latter the least preferred. Soaked cod, hake, and canned tuna are the most eaten seafood products. Men prefer to a greater extent wild and smoked fish. Men consume more cephalopods and sardines and women eat more frequently hake, pink cusk-eel, and redfish. Coastal populations prefer wild fish. Algarve (southern Portugal) consumers exhibit a stronger tendency to wild and whole fish and consume more sardine and sole. Madeira archipelago consumers are particularly fond of black scabbard fish [86].

Bangladesh is blessed with vast sea fish resources and fish is traditionally complemented to rice in the diet of Bangladeshi [87]. Thus, its daily consumption is pretty normal. Although, a number of researches have been done on river fish and its consumption, there seems a few in the public that specifically studied consumer preference for sea fish consumption in Bangladesh. Disaggregating more than 36,000 records from successive Bangladesh Demographic and Health Surveys, annual fish price fluctuations, household income, maternal education, and gender are key drivers of fish consumption [87]. Similarly, annual income, level of education, age, gender, and religious view were found to have significant positive association with household fish consumption [30].

Contrary to Nigeria and Portugal, consumer preferences for product attributes of seafood and production source (wild-harvested, farm-raised), product origin (home state, US, imported), and certification status (organic, sustainably harvested, non-certified), influence consumption patterns in

the US. A nationwide online survey of coastal residents capturing consumption choices for oysters, mussels, clams, scallops, and seaweed indicates that while consumers express preferences for wild-harvested products, the magnitude may differ for shellfish and seaweed products. In addition, consumers are willing to pay more for products that bear a certification label or are from their home state. Further analysis suggests that seafood marketing strategies and development of labeling programs must account for the influence of multiple attributes on consumer choice in the US [88]. Across these four countries, the relationship between income growth and fish consumption per capita is varied (Figure 2). In summary, the case studies highlight that qualitative variables such as preferences, nutritional knowledge, and cultural attitudes across countries are also important drivers for fish consumption.

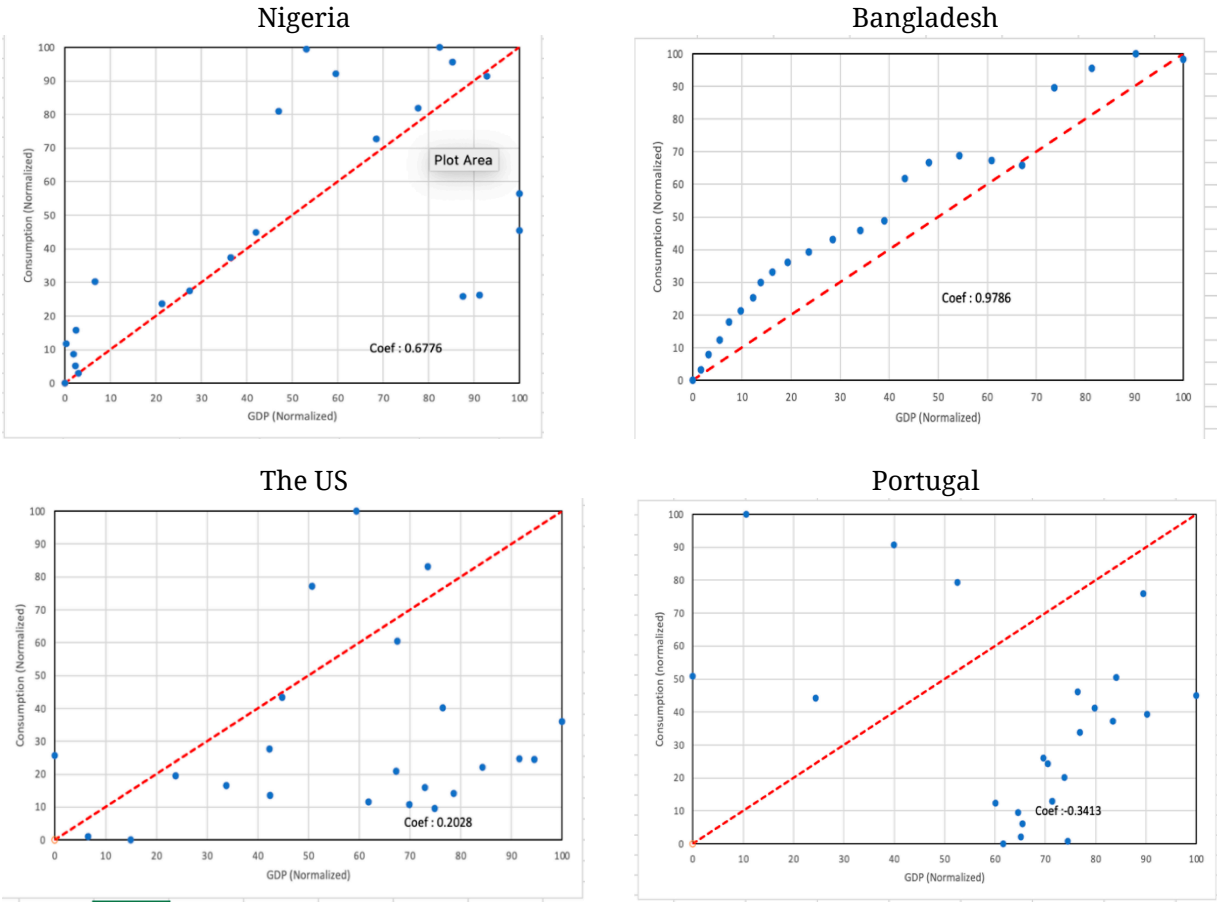

Figure 2. Per capita fish consumption relative to GDP per capita for four case study countries from 1995 to 2017. The case study countries include Nigeria, Bangladesh, Portugal and the US. Both GDP per capita and per capita apparent fish consumption were normalized between 0 and 100 for comparability across countries. Each year is represented by a blue dot. Bangladesh shows a strong positive correlation between consumption per capita and GDP per capita (r = 0.98); Nigeria shows a moderately high positive correlation between fish consumption per capita and GDP per capita (r = 0.68), with greater variation at mid to high income levels; the US shows a low positive correlation between fish consumption per capita and GDP per capita (r = 0.20); Portugal shows a negative correlation between consumption per capita and GDP per capita (r = −0.34), with fish consumption falling as income rises. Data Source: FAOSTAT [8].

CONCLUSION

This paper investigates the relationship between income, urbanization and price and fish consumption, the results of which underscore the importance of analyzing socio-cultural drivers of fish consumption across geographic scales. This study contributes to the literature on drivers of fish consumption by adding empirical findings across 151 countries with varying levels of disposable incomes and with different geographies and dietary histories. After controlling for other covariates of fish consumption, we found that a 10% increase in disposable income leads to about 5% increase in fish consumption; while a 10% increase in domestic fish price leads to an 8% decrease in fish consumption globally. National data on seafood prices should be improved and harmonized for policy purposes given the nutritional and food justice consequences of rising prices for low-income consumers or food insecure populations. We observed that countries' time fixed effects are jointly statistically significant, which implies that even when income differences between countries disappear, changing national or cultural attitudes play a leading role in determining seafood consumption. We observed distinct drivers of seafood consumption across continents: urbanization drives fish consumption in Africa, while domestic fish prices influence fish consumption in South America and Oceania regions. We corroborated this quantitative evidence with insights from country case studies of Nigeria, Portugal, Bangladesh, and the US. Consistent with the results from our global quantitative analysis, rising incomes (in the case of Nigeria), cultural preferences (Portugal) and changes in dietary habits, which are all elements of cultural phenomena (the US) are key drivers of fish consumption. Hence, the findings of this study have a number of important implications for improving blue food consumption. A reasonable approach to tackle this issue is that the government should balance the four dimensions of food security (availability, affordability, utilization and stability) by ensuring that fish go to the lowest strata of societies or those who need them most as well as integrating seafood into national and global strategies on sustainable food systems and nutritional security.

SUPPLEMENTARY MATERIALS

Supplementary Table S1: Distribution of countries in dataset. Supplementary Table S2: Variable description. Supplementary Table S3: Summary statistics. Supplementary Table S4: Correlation matrix. Supplementary Table S5: Dependent variable: Global per capita fish consumption (kg/cap/year). Supplementary Table S6: Dependent variable: per capita fish consumption (kg/cap/year). Regional panel data. Supplementary Table S7: Fish demand elasticities. Supplementary Table S8: Annual average growth in consumption per capita in different periods

(%). Supplementary Table S9: Fish consumption per capita based on countries (2017).

DATA AVAILABILITY

The datasets generated for this study are available on request from the corresponding author.

AUTHOR CONTRIBUTIONS

II: Conceptualization, Methodology, Writing—original draft, Writing—review & editing. EWD: Conceptualization, Methodology, Writing—original draft, Writing—review & editing. NPRD: Conceptualization, Methodology, Writing—original draft, Writing—review & editing. ID: Conceptualization, Methodology, Writing—original draft, Writing—review & editing. URS: Conceptualization, Methodology, Writing—original draft, Writing—review & editing All authors contributed to the article and approved the submitted version.

CONFLICTS OF INTEREST

The authors declare that there is no conflict of interest.

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