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What Drives Ecologically Sustainable Fisheries?

A Fishery-Country Level Data Analysis Using Fishery Performance Indicators

Carlos Chávez, Jorge Dresdner, Nuria González, Mauricio Leiva, and Miguel Quiroga

Central America
Research Program in Economics and Environment for Development in Central America Tropical Agricultural Research and Higher Education Center (CATIE)

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Research Nucleus on Environmental and Natural Resource Economics (NENRE)
Universidad de Concepción

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Environmental Economics Program in China (EEPC)
Peking University

Colombia
The Research Group on Environmental, Natural Resource and Applied Economics Studies (REES-CEDE), Universidad de los Andes, Colombia

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Ho Chi Minh City, Vietnam

What Drives Ecologically Sustainable Fisheries? A Fishery-Country Level Data Analysis Using Fishery Performance Indicators

Carlos Chávez, Jorge Dresdner, Nuria González, Mauricio Leiva, and Miguel Quiroga*

Abstract

We empirically analyze drivers of the stock health of marine resources. We follow Copeland and Taylor (2009) to evaluate the extent to which the state of the stocks are explained by factors such as excess fishing effort and capacity, the ability of the government to enforce regulations, and incentives for the regulator to protect the resource. Our study is based on a unique cross-sectional dataset. We use Fishery Performance Indicators data and open source data from 95 fisheries in 27 countries. These fisheries represent about 12% of the world catch during 2016. We use the cross-sectional variability existing between different fisheries and countries to identify the effects. We find empirical support for the central hypotheses of the model, with expected signs for several indicators associated with excess fishing capacity, the capacity of managers to effectively control fishing effort, and the incentives and ability to enforce regulations.

Keywords: fisheries performance indicators; fish stock health; fishing effort and capacity; government enforcement; incentives for protection

JEL Codes: Q38; Q22; Q28

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*Carlos Chávez (corresponding author: cchavez@utalca.cl), Universidad de Talca, Talca, Chile; Interdisciplinary Center for Aquaculture Research (INCAR), Concepción, Chile; and Research Nucleus on Environmental and Natural Resource Economics (NENRE/EfD-Chile), Concepción. Jorge Dresdner, Universidad de Concepción, INCAR, and NENRE. Håkan Eggert, University of Gothenburg, Sweden. Nuria González, NENRE. Mauricio Leiva, Universidad Católica de la Santísima Concepción, Concepción, Chile, and NENRE. Miguel Quiroga, Universidad de Concepción, INCAR, and NENRE. We gratefully acknowledge financial support from the Swedish International Development Cooperation Agency (Sida) through the Environment for Development Initiative (EfD) at the University of Gothenburg, through the Blue Resources for Development program. Chávez, Dresdner, and Quiroga also acknowledge partial funding by CONICYT/FONDAP/15110027.

1. Introduction

Capture fisheries are a source of income and food security contributing to human wellbeing all around the world. In 2018, total landings amounted to 84.4 million tonnes, an increase of about 3 percent from 2017, which was caught by 39 million fishers around the globe (FAO, 2020). However, the development towards sustainable fisheries faces several challenges. In 1980, about 90 percent of the global fish stocks were assessed to be within biologically sustainable levels, a number that was reduced to 66 percent in 2017. Costello et al. (2016) estimate that improved management of global fisheries could result in sustainable increases of landings by almost 20 percent or 16 million tonnes.

Unsustainable fishing practices are drivers of the global decline in the status of fish stocks (Hannesson, 2002); such practices include inappropriate incentives, high demand for limited resources, poverty and lack of livelihood alternatives, lack of knowledge (social, economic, bioecological), ineffective governance, and interactions between fishing sectors and other aspects of the environment (FAO, 2002). In some studies, rights-based approaches are considered the primary mechanism for successful fisheries management (Grafton et al., 2006). However, a fishing rights regime alone may not be enough. Beddington et al. (2007) highlight that, for successful management, a dual approach is required, one in which authorities provide incentives for conservation based on fishing rights, supported by strong management incorporating legally enforced and tested harvest strategies.

While increasing trade is generally seen as potentially welfare improving, the combination of open access and trade liberalization has the potential to result in welfare reductions (Brander and Taylor, 1997). Fisher (2010) examines the literature on trade and management of renewable resources and finds interactions that are complex and often ambiguous: in some situations, trade can facilitate conservation, but in other situations it can encourage overexploitation and even extinction of natural resources. Empirical studies of fisheries and trade have shown a quality exchange, where developing countries export high-quality seafood in exchange for lower-quality seafood (Asche et al., 2015). A case study of the boom in Nile perch export from fisheries at the Tanzanian part of Lake Victoria, from the early 1990s to 2008, finds that it led to increasing average income and a reduction in the share of household expenditure on food (Eggert et al., 2015).

Although fishing practices, fisheries management, and international trade might help to explain the decline in fish stocks, looking at each of these factors separately might be a limited way to study the problem. Copeland and Taylor (2009) present a theoretical framework that broadens the view. In their setting, an existing government regulates the use of a renewable resource for a pool of agents who are bestowed with harvest rights. The government sets rules limiting harvests, but agents may cheat on these allocations and risk punishment. Property rights are endogenous in this framework because the government must account for agents' incentives to cheat. As a result, the effective protection for the resource, or what we refer to as the *de facto* property rights regime, may be far from perfect, even though property rights would be perfectly enforced if there were no monitoring costs. Copeland and Taylor's model provides a set of conditions that link the characteristics of the country and the fishery with the success or failure of fisheries management.

We use this theoretical framework to analyze how country and fishery characteristics might explain the differences in the health of fish stocks, using this variable as an indirect measure of the success in resource management.[1] Our objective is to empirically analyze the factors influencing the stock health of marine resources and, indirectly, the effectiveness of fisheries management. Moreover, the basic framework allows us to have theoretical predictions on the expected effects. We test Copeland and Taylor's (2009) theory regarding the extent to which fishery stock health is explained by the three dimensions identified as the main drivers: excess fishing effort and capacity, the ability of the government to enforce the regulations, and the incentives for the regulator to protect the resource.

Our empirical study is based on a unique cross-sectional dataset. We use Fishery Performance Indicators (FPIs) data from 95 fisheries in 27 countries with different levels of development (Anderson et al., 2015; Environment for Development (EfD) Initiative Marine Program, 2020). The information for the statistical analysis includes open source data from, among others, the Human Development Index (HDI) (UNDP, 2018), Worldwide Governance Indicators (World Bank, 2020), and KOF Index of Economic Globalisation (Gygli et al., 2019). We use the cross-section variability existing between different fisheries and countries to identify the significant effects. We also estimate similar specifications covering sub-samples of the fisheries to explore structural differences. To the best of our knowledge, there have been no attempts to date to empirically test the implications of Copeland and Taylor's (2009) theory.

[1] We understand that stock health is a multifactorially determined concept, where several dimensions, such as the state of the habitat, the stock dynamics, the degree of overfishing and its trajectory, and mortality sources, among others, contribute to the assessment of the exploitation status of the fish stock. We define later how we measure this variable. However, the model, with its emphasis on fisheries management, implicitly assumes that stock health, finally, depends on human activities and behavior.

We find empirical support for the central hypotheses of the model, with expected signs for several indicators associated with each of the three main dimensions as drivers of the stock heath of fisheries. The results also indicate that management regimes are not significant, suggesting that what matters for stock health are primary drivers that determine the effectiveness of those regimes, such as the capacity of managers to effectively control fishing effort and excess fishing capacity, along with the incentives and ability to enforce regulations.

We organize the paper as follows. In section 2, we present the conceptual framework for our empirical analysis, including the main hypotheses we want to evaluate and the supporting theory. Section 3 contains a description of the empirical strategy and data. Section 4 presents the results. Finally, in section 5 we discuss the results and present the main conclusions from our work.

2. Conceptual Framework

Our objective is to empirically analyze the drivers of fish stock health. To this purpose, we follow the theoretical model of endogenous resource management developed by Copeland and Taylor (2009) to explain the large variation in the health of marine stocks by basic country and resource characteristics. In this model, to internalize externalities, the government regulates the harvest of a resource by fishers who have the right to catch it. However, fishers may violate the regulation, risking punishment by the authority. Further, there are monitoring costs and resource characteristics determining the regulatory effort needed to induce compliance. In this setting, *de facto* property rights are endogenous because, when designing the regulation, government must consider agents' incentives to violate the regulation, as well as the cost of monitoring necessary for effective protection of the resource. The primary variables influencing effective management are organized in three main dimensions: (i) the extent of overcapacity to harvest the resource, (ii) government's ability to enforce the regulation and reduce harvesting effort, and (iii) the regulator's incentive to protect the resource.

Overcapacity is a measure of the pressure on the resource. Of course, for this problem to be relevant, the resource must be able to generate rents in such a way that fishers will be interested in capturing them. If we assume that this condition is met, there is overcapacity if the systematic application of fishing effort available in the fishery could lead to a deep reduction in the stock.[2] The extent of overcapacity depends on a measure of the effort that can be applied to the fishery and the productivity of that effort. This must be contrasted with a measure of the capacity of the resource to withstand the extraction level, which, in turn, depends on the intrinsic growth rate of the resource and the carrying capacity of the resource stock.

In the presence of overcapacity, some regulation will be necessary to reduce effort and allow the generation of rents. The ability of the government to enforce the regulation depends not only on its capacity to detect non-compliance by monitoring and to apply fines, but also on the incentives faced by fishers. Following Copeland and Taylor (2009), there are two elements influencing the government's ability to enforce a regulation: the monitoring capacity of the regulator and the preferences of the fishers to grasp benefits in the present. The enforcement power of the government will be directly influenced by the probability of detecting fishers in violation and punishing them, and inversely related to fishers' temporal preferences, which are directly related to the discount rate.

The regulator's incentive to protect the resource is related to the constraints that face the regulator when implementing an optimal policy from a social point of view, contrasting the benefit of leaving a fish in the sea with the opportunity cost of postponing harvesting. For instance, for the regulation to be incentive compatible, the government must ensure that fishers who comply with the regulations obtain a larger rent than the ones violating it. This will be possible if the regulator allows fishers to apply an effort level above a certain threshold beyond which fishers would prefer not to comply. That is, allowed catches cannot be so low that fishers would prefer to violate the regulations.

In this setting, an increase in the price of the resource will increase the optimal level of harvest effort, because it will increase the opportunity cost of leaving fish in the sea. This will make it more likely that the effort allowed by the regulator will be incentive compatible, because a smaller share of the capacity needs to be excluded from harvesting; this will make the regulator's job easier.

The results from the conceptual model of Copeland and Taylor (2009) suggest that we should expect significant variation in fisheries stock health (and indirectly the effectiveness of fisheries management) across fisheries and countries, because there are likely to be variations in the fundamental factors affecting resource management. We empirically investigate this issue in the next sections of the paper.

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[2] It is possible that the collapse of the fishery will never be reached because the critical stock level entails such high costs that it will not generate rents, eliminating the incentives for extraction.

3. Data, Empirical Strategy, and Construction of Variables

3.1 Data and Empirical Strategy

In this section, we present the estimation strategy and data used for the empirical testing of the theoretical resource management model of Copeland and Taylor (2009) applied to fisheries. To the best of our knowledge, this has not been done before. Probably, one of the reasons for this omission has been the difficulty in obtaining appropriate data to perform this task.

Our study is based on a unique cross-sectional database for fisheries and countries, which we have constructed using Fisheries Performance Indicators (FPIs) data (Anderson et al., 2015). The FPIs data set has been growing over recent years, as new fisheries from different countries have been evaluated by the FPIs methodology. According to our count, data for 146 fisheries in 37 countries that have been calculated by this methodology should be available by now – 121 fisheries from Asche et al. (2018) and 25 fisheries from the recent rounds of FPIs collection run by the Environment for Development Initiative (EfD Marine Program, 2020). However, given restrictions on access to information for the explanatory variables, our estimations are based on complete information for 95 fisheries in 27 countries.

We use the cross-sectional variation among different fisheries and countries to identify the significant effects. The analysis considers data from countries with different levels of development and geographical location, and fisheries with different types of fleets and marine species. We also estimate similar specification covering sub-samples of the fisheries to explore structural differences. The 95 fisheries represent about 12% of the global catch during 2016 (FAO, 2018). This database has been complemented with data from different sources at the fisheries and country level, such as the World Bank, the International Monetary Fund (IMF), the “Sea Around Us” project, KOF Swiss Economics Institute - ETH Zürich, and the United Nations Development Programme (United Nations, 2018).

The database used is a mix of variables measured at the fisheries level and at the country level. This is a consequence of the availability of fishery-specific data, but also of the nature of the relations specified in the theoretical model. For instance, the regulator’s incentive to protect the resource, which is a basic component of the model, is to a great extent determined by variables such as market prices, degree of openness of the economy to external trade, and intertemporal preferences of the population, which are variables that probably are better measured at the country level. In contrast, aspects such as the government’s ability to enforce regulations, also present in the theoretical model, are probably better measured if they are more specific to the fishery. However, information at this disaggregation level is probably missing in most cases, and therefore country-level information is used.

To specify the empirical model, we chose to reproduce the basic elements of the Copeland and Taylor (2009) model as closely as possible. The dependent variable is the health of the resource stock. In this case, since we are dealing with fisheries, we try to explain the stock health of the fish resource. To measure stock health, we used ecological indicators obtained from the Fishery Performance Indicators (FPIs). Specifically, we used Stock Health as the dependent variable. This variable is constructed from the following eight numerical metrics of stock health that are obtained from the FPIs database: percentage of stock overfished; degree of overfishing (stock status); stock declining, stable or rebuilding (stock dynamics); regulatory mortality[3]; selectivity; illegal, unregulated or unreported landings (IUU); status of critical habitat; and proportion of harvest with a third party certification (PHTPC).[3] Each of these eight metrics is a countable variable that can take whole numbers between one and five, where a higher number indicates a healthier stock. A simple average of the values of the eight metrics provides the value of the Stock Health indicator for each fishery. Thus, this is a continuous variable that adopts values between 1 and 5, where a higher value indicates a healthier stock.

According to the theoretical model, we identify three blocks of independent variables (dimensions) that are included in the empirical model. These are (i) *excessive fishing effort*, (ii) *the government's ability to enforce regulations*, and (iii) *the regulator's incentives to protect the resource*. To measure each of these variables, we employ different sets of indicators.

Variables related to *excessive fishing effort* are the level of overcapacity found in the fishing fleet (including its size), and the capacity of the economy to generate output from harvesting marine resources, which in turn depends on the capacity of the natural system to generate biomass growth of marine resources. These are all fishery-specific variables. The relationship between the extraction capacity of the fleet and the environment's natural growth capacity determines excessive fishing effort.

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[3] Regulatory mortality in FPI refers to: Ratio of estimated regulatory mortality to actual landings of the target species. Regulatory mortality is defined as fish loss that is induced by regulation, such as size restrictions.

[4] The metrics regulatory mortality and selectivity capture how allowable mortality is used in the fishery, and IUU is a direct measure of waste and potentially forgone ecosystem health. The metrics percentage of stocks overfished, degree of overfishing (stock status), and stock declining, stable or rebuilding (stock dynamics) capture the state of the resource and its trend. The status of the critical habitat measures the portion of the critical habitat that plays a significant role in the life cycle of the resource that is damaged. PHTPC assesses the percentage of harvest certified as ecologically sustainable

We measure these two aspects separately in the estimations; *ceteris paribus*, we expect that the level of overcapacity found in the fleet will be negatively related to the health status of the stock, while the species growth capacity will be positively related. This latter aspect is considered through the intrinsic rate of stock growth for the species.

To take account of *the government's ability to enforce regulations*, we had access to country-level data. In this case, we expect that this ability will depend on the government's effectiveness and regulatory quality, and also on the population's intertemporal preference rate. As indicators of the first attribute, we use the quality of governance and the governance responsiveness. To incorporate the second attribute, we use the risk-free interest rate from the World Bank. We expect that the enforcement capacity of the government will be positively related to the effectiveness and quality of its regulation and negatively related to the degree of "impatience" of the population.

Finally, *the regulator's incentives to protect the resources* is captured by a globalization index from KOF Swiss Economics Institute - ETH Zürich to measure the effect of the market dimension and prices on the incentives to protect the resource, as well as a risk-free real interest rate to reflect intertemporal preferences. We expect a negative relationship between these two variables and stock health. Since we have country-level heterogeneity in the database, we also include an indicator of the country's socioeconomic conditions, to identify potential differences in intertemporal preference rates not captured by the financial system. We expect that higher socioeconomic conditions will be related to higher incentives to protect the resources and higher stock health. In this case, we used countrywide variables. The intrinsic growth rate of the resource, which is a fishery-specific variable, is also included in the first dimension of *excessive fishing effort*. This variable might affect both dimensions, but in both it is positively related to stock health.

To take account of the heterogeneous nature of the fisheries included in the data set, we also included as controls variable whether the fishery was regulated or under open access. In the former case, we also consider whether the fishery was under a harvest rights regulation or only under restricted access.

Given the cross-sectional nature of the data and the continuous form of the dependent variable, we estimated with ordinary least squares (OLS). According to the theoretical model used to select the left-hand variables, these should be exogenous. However, given that the aggregated dependent variable was constructed as a simple average from count data variables that reflect many qualitative assessments, and therefore are not very precise, we also tested a count data model. We defined a three-level count data dependent variable, with increasing levels for stock health. The actual measurement in stock health ranges from 2.12 to 5.00 in our database at the fisheries level. We define the three levels as values between 2.12 and less than 3.00, values between 3.00 and less than 4.00, and, finally, a third level with stock health values between 4.00 and 5.00. We present the results obtained with this model, as a robustness check.[5]

3.2 Construction of Explanatory Variables and Descriptive Statistics

The explanatory variables, based on Copeland and Taylor (2009), are grouped into three main factors. In each group, we have a subset of explanatory variables. These variables are shown in Table 1.

[5] We also performed a different division of the levels of the count variable as a second robustness check. In this case, the variable adopts the value one if the stock health is less than 2.8. The second category is when the variable takes the value of two if the stock health is greater than or equal to 2.8 but less than 4.2. Finally, the last category adopts the value of three if the stock health is greater than or equal to 4.2.

Table 1. Description of Explanatory Variables

Factor	Variable	Unit	Level of disaggregation	Source
Excessive fishing effort	Growth rate by species (parameter K)	Unit/time	Fishery	Scientific articles and www.fishbase.org
	Number of vessels *Growth rate by species	Number* unit/time	Fishery	FPIs, www.fishbase.org, scientific articles and Sea Around Us project
	Number of vessels*Artisanal(Dummy)	Number	Fishery	FPIs, scientific articles and Sea Around Us project
	Number of vessels*Industrial(Dummy)	Number	Fishery	FPIs, and scientific articles and Sea Around Us project
	Number of vessels*Mixed(Dummy)	Number	Fishery	FPIs, and scientific articles and Sea Around Us project
Government's ability to enforce the regulations	Control of Corruption (Governance)	Index	Country	World Bank (Worldwide Governance Indicators)
	Real Interest Rate	%	Country	World Bank and International Monetary Fund
Regulator's incentive to protect the resource	KOF Index of Economic Globalisation (Trade Opening)	Index	Country	KOF Swiss Economics Institute - ETH Zürich
	Human Development Index	Index	Country	United Nations Development Programme
Controls	Access Rights	Dummy Variable	Fishery	FPIs and Asche *et al* 2018
	Harvest Rights	Dummy Variable	Fishery	FPIs and Asche *et al* 2018
	Unregulated Open Access (OA)	Dummy Variable	Fishery	FPIs and Asche *et al* 2018

Source: Own elaboration.

3.3 Excessive Fishing Effort-Overcapacity

This factor includes two key components. The first is the excess of fishing capacity in the fishery. The second is the capacity of the economy to generate output from capturing marine resources, which in turn depends on the capacity of the natural system to generate growth of the biomass of marine resources. This latter aspect is considered through the intrinsic rate of stock growth for the species.

3.3.1 Overcapacity

We do not have a direct measure of excess fishing capacity for each of the fisheries; therefore, as a proxy variable, we use the number of vessels per fishery, controlling by type of fishery: artisanal, industrial or mixed. The mixed category applies to those fisheries that share landings between artisanal and industrial fleets. The number of vessels attempts to measure the level of overcapacity of the fleet and we control this overcapacity by dummies for each type of fleet.

3.3.2 Resource's Intrinsic Growth Rate

To measure the resource's intrinsic growth rate, we compiled information from different sources on the parameter K of the growth equation of Von Bertalanffy (1938). K indicates the rate at which the fish grows until reaching its theoretical maximum length (Santana et al., 2020). Some species, most of them short-lived, reach asymptotic length in one or two years and have a high K value. Other species have a flattened curve with low K and take many years to reach asymptotic length. We use this parameter for each species of each of the fisheries under consideration.[6] (Table A.1 in the appendix presents detailed information for this variable and others across species/fisheries). We used this variable by itself in the estimation, but we also interacted it with the log of the number of vessels in the fishery. The basic idea was that, for a given rate of growth, the higher the number of vessels in the fishery, the lower will be the effect of resource growth on the stock health. Thus, for this second variable, we expect a negative relationship with the dependent variable.

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[6] The main source for this variable is the information available at fishbase.org. We also reviewed scientific publications reporting estimations for the K parameter. We obtained the parameter K by species for 126 of the 146 fisheries and for a total of 86 species. In the case of mixed fisheries, only the growth rate of one species is used. For this case, the first species contained in the description of the fishery is selected (in fishery profiles or www.fpilab.org). In the case of not finding parameter K, information is sought for the second species and so on.

3.4 Government's Ability to Enforce the Regulations

For government regulations to preserve resources, fishers and others associated with the related economic activities must comply with them. The government's ability to enforce the regulations is influenced by the intertemporal preference rate, captured through the discount rate in the economy, and the probability that violators will be detected and penalized.

3.4.1 Probability of being Detected and Sanctioned

We do not have data at the fishery level, so we use country-wide data. As a proxy for this variable, we explored different components of the Governance Index by country prepared by the World Bank. The selected component is *control of corruption*, which captures perceptions of the extent to which public power is exercised for private gain, including minor forms of corruption, as well as "capture" of the state by elites and private interests. The selection of this variable is based on the fact that some studies have found that national governance capacity and occurrence of corruption tend to correlate with levels of illegal, unreported and unregulated (IUU) fishing (Österblom et al. 2010; Agnew et al., 2009) and that the national prevalence of corruption tends to decrease the likelihood of sustainable fisheries management (Mora et al., 2009)

3.4.2 Intertemporal Preference Rate

This rate will affect the present value of the future rents that individuals will receive from fishing activities. We use the Real Interest Rate, provided by the World Bank. The Real Interest Rate is the lending interest rate, adjusted for inflation as measured by GDP deflator, according to the World Bank.

3.5 Regulator's Incentive to Protect the Resource

This factor is influenced by the intertemporal preference rate, trade openness, and an indicator of socioeconomic conditions in the country. The first variable was defined earlier, so we concentrate on the last two.

3.5.1 Globalization Index

This variable measures the degree of openness of the economy. As a proxy, we use the KOF Index of Economic Globalisation (KOF Index) that reflects different dimensions of economic globalization, including trade restrictions, such as tariffs and barriers to investment, and actual flows, such as trade in goods or cross-border investments (Erhardt, 2017).

3.5.2 Socioeconomic Conditions of the Country

We use the Human Development Index (HDI). This index is a summary measure of achievements in three key dimensions of human development: a long and healthy life, access to knowledge, and a decent standard of living. The HDI is the geometric mean of normalized indices for each of these three dimensions. The health dimension is assessed by life expectancy at birth. The education dimension is measured by average years of schooling completed by adults aged 25 years and over and expected years of schooling for children of school-entering age. The standard of living dimension is measured by gross national income per capita. (United Nations, 2018). This index is a numerical variable that is divided into four categories, and each country is in a category, which includes low, middle, high, and very high level of development.

3.6 Other Controls

Additionally, we incorporate a variable that indicates the type of management system under which the fishery operates. This variable is interesting on its own, since there has been a long debate about the role of management systems in the health of fish stocks. But within the Copeland and Taylor model, it also can be seen as an indicator of the regulatory authority's determination to reduce incentives for resource extinction. The management systems are divided into open access, access right and harvest right, following the work of Asche et al. (2018). Open access includes fisheries with very limited or no management, in which access to the fishery is not regulated through a licensing or permitting process or restricted through technical measures, such as fishing days. Access right is a management scheme that limits access to the fishery. Fishing rights is a regime where fisheries are managed with catch quotas or territorial use rights.

The descriptive statistics of both dependent and explanatory variables for the 95 fisheries included in the analysis are presented in Table 2.

Table 2. Descriptive Statistics of the Variables

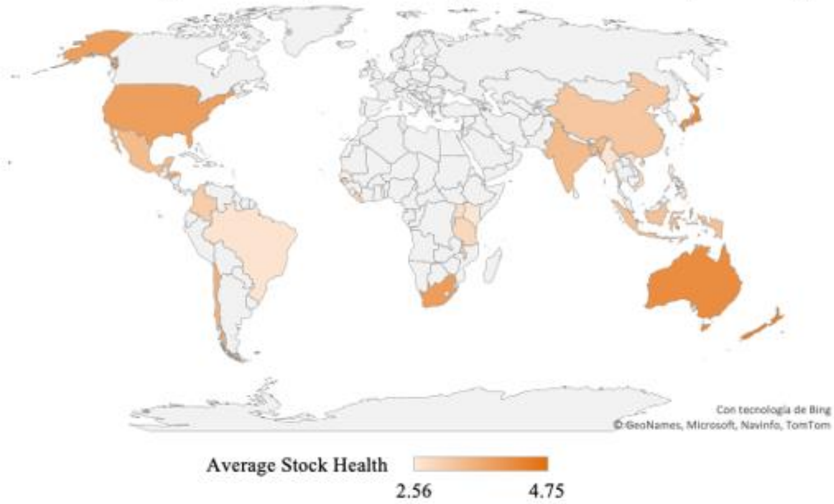
Variable	Mean	Std. Dev.	Min	Max
Dependent Variable				
Stock Health	3.4270	0.7589	2.1250	5.0000
Explanatory Variables				
Growth Rate by Species	0.4604	0.3708	0.0500	2.4000
Ln(Nr of vessels)*GrowthRate	3.0381	3.1367	0.1609	20.5224
Nr of vessels*Artisanal	2293.0320	8073.4670	0.0000	65000.0000
Nr of vessels*Industrial	1296.7260	10397.9800	0.0000	100000.0000
Nr of vessels*Mixed	1797.1680	11923.6100	0.0000	114575.0000
Control_of_Corruption	0.1816	0.9864	-1.0935	2.3379
KOF Globalisation Index	66.4747	11.9503	44.4000	81.7000
Real Interest Rate	6.0825	6.7376	-9.7494	33.8323
Human Development Index	2.9684	0.9942	1	4
Harvest_Rights	0.1957	0.3989	0	1
Access_Rights	0.5543	0.4998	0	1
Unregulated_OA	0.2500	0.4354	0	1

4. Results

To analyze fisheries' stock health and its determinants, we use a database containing 95 fisheries in 27 countries. According to the Human Development Index (HDI), of the 27 countries in the final dataset, 22% show a very high level of development, 30% a high level of development, 22% a medium level of development, and 26% a low level of development. Moreover, according to the United Nations classification, 23 countries (85.2%) are developing and 4 (14.8%) are developed countries (United Nations, 2019).

Figure 1 shows a map with these countries and the mean stock health by country. The five countries with higher average stock health are Maldives, New Zealand, Japan, Australia, and South Africa. However, Maldives and New Zealand each contribute only one fishery to our database. The five countries with the lowest mean stock health in our sample are Myanmar, Kenya, the Philippines, Senegal, and Sierra Leone. Among these, Kenya and the Philippines each contributed one fishery to our database. The details of ranking by fishery and country are presented in Tables A.2 and A3 in the appendix.

Figure 1. Map of Average Stock Health by Country



We performed estimations using two types of econometric models: an OLS and a Poisson model as a robustness check. In the OLS model, the dependent variable is the stock health, which is a variable that adopts a value between 1 and 5, where higher numbers indicate a better state of the stock. This variable is continuous. For the Poisson model, we created a dependent variable considering three categories. The variable adopts the value of one if the stock health is less than 3. We call this category "low" stock health. The second category is "medium" and the variable takes the value of two if the stock health is greater than or equal to 3 but less than 4. Finally, we define a category as "high," which takes the value of three if the stock health is greater than or equal to 4. A summary of the distribution of the fisheries when Stock Health is treated as a categorical variable is presented in Table 3.

Table 3. Distribution of Categorical Stock Health Variable

Stock Health	Freq.	Percent
1 (Low)	32	33.7
2 (Medium)	35	36.8
3 (High)	28	29.5
Total	95	100

To check the stability of the estimated results, we also made estimations with two subsamples separated by the countries' level of development. The first subsample of developing countries includes 64 fisheries. The second, for developed countries, includes 31 fisheries.

We test for the presence of multicollinearity for our base model with the variance inflation factor (VIF) test, and rejected it. The VIF by each explanatory variable, after performing the OLS regression, turned out to be less than 10, which suggests a limited degree of multicollinearity that should not have a significant effect on the results (Miles, 2014). However, when we included the KOF_Globalisation_Index variable, in model 2, this variable was non-significant due to the high correlation between Control of Corruption and KOF_Globalisation_Index (correlation coefficient = 0.9). Following Copeland and Taylor's (2009) model, we decided to keep the the KOF_Globalisation_Index variable in model 2. In addition, we estimated with robust standard error matrices.

The results from our econometric estimations using OLS models are presented in Table 4. (We present the results of the Poisson models in Table A.4 and Table A.6 of the Appendix). In general, the results show the expected sign for most explanatory variables. The models explain an important part of the observed variability of stock health across the fisheries and countries in the sample. Model 1 and Model 2 consider specifications without control variables. The major differences between these models are related to the inclusion of the KOF_Globalisation_Index variable. Model 3 and Model 4 are the previous specifications but include control variables.

Table 4. Table. Econometric results. Ordinary Least Squares. Dependent Variable: Stock Health

	(1) Model 1	(2) Model 2	(3) Model 3	(4) Model 4
GrowthRate	0.738521	0.745704	0.863991*	0.878767*
	(0.437037)	(0.439372)	(0.491139)	(0.495888)
Ln(Nr of vessels)*GrowthRate	-0.109446**	-0.111230*	-0.121129**	-0.123999**
	(0.052725)	(0.054191)	(0.056831)	(0.059078)
Nr of vessels*Artisanal	-0.000009**	-0.000009**	-0.000008	-0.000008
	(0.000004)	(0.000004)	(0.000005)	(0.000005)
Nr of vessels*Industrial	0.000006***	0.000006***	0.000007***	0.000007***
	(0.000002)	(0.000002)	(0.000002)	(0.000002)
Nr of vessels*Mixed	-0.000007***	-0.000007***	-0.000007***	-0.000007***
	(0.000002)	(0.000002)	(0.000002)	(0.000002)
Control_of_Corruption	0.217231**	0.193905	0.207141*	0.175395
	(0.092330)	(0.119139)	(0.115037)	(0.141176)
Real Interest Rate	-0.017681**	-0.017022*	-0.016811**	-0.015961
	(0.007306)	(0.009318)	(0.007407)	(0.009688)
Human Development Index	0.141426	0.122606	0.143900	0.122000
	(0.085720)	(0.165349)	(0.095017)	(0.171526)
KOF_Globalisation_Index		0.003631		0.004554
		(0.021666)		(0.022126)
Harvest_Rights			0.064140	0.060576
			(0.144934)	(0.138656)
Unregulated_OA			-0.027683	-0.036194
			(0.157533)	(0.154047)
Constant	3.092637***	2.909606**	3.053587***	2.821749**
	(0.249333)	(1.059695)	(0.269805)	(1.102551)
N	95	95	92	92
R2	0.4204	0.4208	0.4232	0.4237
Adjusted R2	0.3665	0.3594	0.3520	0.3445
Prob > F	0.0000	0.0000	0.0000	0.0000

Note: *p<0.1; **p<0.05; ***p<0.01

Robust standard errors by cluster of countries in parentheses.

The results suggest that an increase in the *growth rate by species* improves stock health. In all models, the significance level is around 10% or better. Moreover, as expected, the effect is reduced as the size of the fleet increases. That is, given the growth rate of the species, the larger the fleet, the lesser the impact on the stock health. These results are consistent with the Copeland and Taylor (2009) model predictions. The effect of the size of the fleet on the stock health, when controlling for the type of fisheries, is negative in the case of artisanal and mixed fisheries. A larger fleet should reduce the level of the stock, once the growth rate of the species is considered. However, we find a positive effect for the industrial fishery. This latter effect could be related to the relative ease of exerting control over a less numerous fleet of large vessels compared to many and small artisanal vessels. In this sense, it could reflect the conditions faced by the authorities in monitoring the fisheries. It could also reflect a major effort of regulators to enforce regulations for larger vessels, because of their potential greater effect on stock health (FAO, 2018; Hilborn et al., 2014).

For the variables related to the government's enforcement ability, our results indicate that both *control of corruption* and the *risk-free interest rate* have a significant impact on the stock health of the fisheries. The *control of corruption* variable, used as a proxy for the probability of being detected and sanctioned, has a positive sign and is statistically significant in all the OLS estimations (models 1 and 4). This result suggests that a country with better control of corruption would have fisheries with better stock health, compared with fisheries in countries with poor control of corruption, because corruption is associated with capacity to enforce the law. In contrast, we find the higher the real interest rate, the lower the stock health of a fishery. This outcome is associated with higher discount rates that give a greater weight to the benefit obtained in the present than in the future, increasing the fishermen's incentives to not comply with the regulations. These two results are also consistent with the predictions of the Copeland and Taylor model. However, when we include the *KOF Globalisation Index* as a variable in the model, the *control of corruption* variable does not show a significant impact on the stock health.

In columns (3) and (4), we present the estimated models with variables that control for type of management. These variables are fishery-specific, so one should expect a closer relationship to the dependent variable. Interestingly, when we control for the rest of the variables in the model, none of the management variables is significant in our estimations. This suggests that, when we consider the effect of the rest of the variables in the model, the type of management is not significant to explaining the level of the stock health.

In the appendix, we show the results for the Poisson models (see Table A.4 and Table A.5). The results are well in accordance with the OLS estimations. The precision of the estimates seems somewhat higher with the Poisson results. The results indicate that the more fishery-specific variables tend to be more significant, with the expected signs. The fish species intrinsic growth rate is positively related to stock health, although decreasing in the fleet size, and the number of vessels reduces stock health, except for the industrial fleet, which may be related to the number of vessels. Moreover, the interest rate and the control of corruption are, respectively, negatively and positively related to the dependent variable, although the significance level is less strong. Finally, the type of management regime does not affect the health of the fish stock.

In Table 5, we present the results for subsamples of fisheries. We divide between fisheries that belong to developing countries and developed countries. This is used as a check for model stability, although it is interesting in itself in relationship with the theoretical framework used in this article. It is possible to argue that developing countries might have higher rates of time preference and also weaker governance structures, which makes it harder for the government to enforce regulations. For the subsample of developed countries, the *Human Development Index* is very high for all concerned countries and we do not include it as an explanatory variable.

Table 5. Econometric Results. Ordinary Least Squares. Dependent Variable: Stock Health Sub-Sample: Developing vs Developed Countries

Sub-Sample:	Developing Countries Model 1	Developing Countries Model 2	Developed Countries Model 1	Developed Countries Model 2
GrowthRate	0.807205	0.821587	-0.462660	-0.651778
	(0.548705)	(0.544089)	(1.062259)	(1.097788)
Ln(Nr of vessels)*GrowthRate	-0.124989*	-0.129593**	0.206229	0.261106
	(0.060300)	(0.059964)	(0.135584)	(0.141377)
Nr of vessels*Artisanal	-0.000008*	-0.000008*	-0.000826**	-0.000896***
	(0.000004)	(0.000004)	(0.000145)	(0.000151)
Nr of vessels*Industrial	0.000006**	0.000006**	-0.001747	-0.001063
	(0.000002)	(0.000002)	(0.002795)	(0.002716)
Nr of vessels*Mixed	-0.000008***	-0.000008***	0.000088**	0.000065**
	(0.000002)	(0.000002)	(0.000015)	(0.000016)
Control_of_Corruption	0.116491	-0.015765	1.113219*	0.901003
	(0.260199)	(0.240355)	(0.414313)	(0.482551)
Real Interest Rate	-0.017760**	-0.015117	-0.113412	-0.071784
	(0.008442)	(0.010893)	(0.048732)	(0.066459)
Human Development Index	0.166504	0.105996		
	(0.099145)	(0.181165)		
KOF_Globalisation_Index		0.013715		-0.074889**
		(0.023258)		(0.018839)
Constant	3.002666***	2.263376*	2.339034**	8.599094***
	(0.362574)	(1.162034)	(0.461837)	(1.452917)
N	64	64	31	31
R2	0.3128	0.3221	0.3291	0.3370
Adjusted R2	0.2128	0.2091	0.1249	0.0958
Prob > F	0.0000	0.0000	0.1249	0.0958

Note: *p<0.1; **p<0.05; ***p<0.01
Robust standard errors by cluster of countries in parentheses.

The general results obtained for the developing countries' subsample are quite similar to the ones obtained with the full sample, but this is not the case for the developed countries' subsample. All but one of the results obtained with the full sample are obtained for the developing countries subsample. The only result that does not hold is the one related to the governance indicator. The presumption that this variable should be especially important for developing countries is not supported by our results. This is significant for the developed countries' subsample (model 3) but not for the developing countries' subsample. So, at first sight, the Copeland and Taylor model would seem more appropriate for the developing countries than the developed ones.[7]

[7] One should consider, however, that the number of observations in the sample with developed countries' fisheries is far smaller than the sample of the developing countries, and that the low number of degrees of freedom may affect the estimated results.

The result that does seem to be very similar in both subsamples is the effect of the number of vessels in the fleet. In artisanal and mixed fleets, the larger the number of vessels, the lower the health of the stock. In the case of the industrial fleet, the effect is significant and positive only in the developing countries' sample. The results of the corresponding Poisson models are presented in Table A.6 in the appendix.

5. Conclusions

In this study, we have applied the Copeland and Taylor (2009) model to analyze the health of fish stocks in a heterogeneous sample of fisheries and countries. Using this model as a reference, we have tested for the main dimensions that should affect stock performance. These are (i) *excessive fishing effort*, (ii) *the government's ability to enforce regulations*, and (iii) *the regulator's incentives to protect the resource*. To measure each of these factors, we employ different sets of indicators.

As a general assessment, we find empirical support for the central hypotheses of the model. We find significant results with expected signs for several indicators associated with each of the three main dimensions of the model. These results are obtained with the two different econometric models chosen to test the theory.

The results also indicate that, when including the explanatory variables considered in the Copeland and Taylor model, the control variables for management regimes are not significant. These results seem to suggest that, more so than the presence and type of regulation or management scheme, what matters for stock health of fisheries is the capacity of managers to effectively control fishing effort and excess fishing capacity, along with the incentives and possibilities to enforce regulations. Put another way, the focus on management regimes for stock health, and in general for fisheries management, appears to be too narrow.

We evaluate the stability of the results by dividing our sample into developed and developing countries. There are arguments related to the theory that can justify this separation. We find that the model structure is different between the fisheries that belong to these different groups of countries. The general results seem to be more in accordance with the situation of the fisheries in the developing countries and not in the developed ones. The argument that lack of governance plays a role in fishery health in less developed countries does not find empirical support in our regressions, which is in contradiction to what is expected. However, these results could be a consequence of too small a subsample of fisheries for developed countries in our database.

There are different ways to extend our work. Exploring the drivers of different components of stock health by using more disaggregated data is worth pursuing. Also, increasing the number of fisheries and countries for analysis may better identify heterogeneity of impacts across different dimensions. In general, improving our understanding of fishery stock health globally may promote better approaches to the sustainability of oceans and fisheries.

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APPENDIX

Table A.1. Variables by Fishery: Species, Growth Rate, Number of Vessels, Landings and Type of Fishery

Fishery	Species or genus	Parameter k (unit/time)	Number of Vessels	Landings (tons)	Type of fishery
Australia Western Zone Abalone	*Haliotis rubra*	0.28	23	544	Artisanal
Australia Spencer Gulf Prawn	*Melicertus latisulcatus*	0.7	39	2361	Industrial
Australia Southern Zone Rock Lobster	*Jasus edwardsii*	0.13	181	1250	Industrial
Bangladesh Kailin Nadi	*Cyprinae*	0.148	100		Artisanal
Bangladesh Beel Chatra	*Cyprinae*	0.148	400		Artisanal
Bangladesh Pabna Sadullaspracole	*Cyprinae*	0.148	145		Artisanal
Brazil Sardine Purse Seine	*Sardinella brasiliensis*	0.4	174	100000	Industrial
Brazil Madeira River	*Piaractus mesopotamicus (pacu)*	0.16	1005	801	Artisanal
Brazil Seabob Shrimp	*Xiphopenaeus kroyeri*	0.25	724	1495	Artisanal
Chile - Sardine and Anchovy	*Strangomera bentonki*	0.7	588	401404	Mixed
Chile Northern Anchovy	*Engraulis ringens*	1.2	129	551304	Mixed
South China Sea	*Nemipterus bathybius*	0.4	114575	3517879	Mixed
China Shandong Spanish Mackerel	*Scomberomorus niphonius*	0.5	19320	165151	Mixed
Taiwan Longline Tuna	*Thunnus albacares*	0.5	1700	65000	Industrial
China Guangdong Cuttlefish-Squid	*Uroteuthis (Phtololigo) duvaucelii*	0.27	6347	51181	Mixed
China - Gillnetting gazami crab	*Portunus trituberculatus*	0.89	1559	172000	Industrial
China Fujian Swimming Crab	*Charybdis natator*	1.36	17794	117345	Industrial
China - Japenese &Australian Mackerels	*Scomberomorus niphonius*	0.5	471	188393	Industrial
Colombia Industrial Shrimp	*Litopenaeus vannamei*	0.5796	40	1586	Industrial
Colombia - Industrial Deep Sea Shrimp Fishery	We did not find growth rate for the species, we used k of *Farfantepenaeus Subtilis*	1.08	18	570	Industrial
Colombia - Artisanal Queen Conch Fishery	*Strombus gigas Linnaeus*	0.36	15		Artisanal

Gambia Artisanal Sole and Catfish	*Cynoglossu senegalensis*	0.34	200	927	Artisanal
Honduras - Spiny Lobster	*Panulirus argus*	0.2	128	1800	Mixed
India Gujarat Trawl	*Sardinella longiceps*	1.2	11500	386402	Artisanal
EU Indian Ocean Purse Seine Tuna	*Katsuwonus pelamis*	0.5	49	243000	Industrial
South India Trawl	*Sardinella longiceps*	1.2	9500	664356	Artisanal
Indonesia N. Sumbawa Yellowfin Tuna	*Thunnus albacares*	0.5	423	2343	Artisanal
Indonesia Blue Crab	*Portunus pelagicus*	1	65000	34000	Artisanal
Indonesia SE Sulawesi Blue Swimming Crab	*Portunus pelagicus*	1	2311	1200	Artisanal
Indonesia S. Sumatra Blue Swimming Crab	*Portunus pelagicus*	1	200	6000	Artisanal
Indonesia Longline Tuna	*Thunnus albacares*	0.5	100000	38000	Industrial
Indonesia Kaimana Bagan Baitfish	*Sardinella longiceps*	1.2	12	216	Mixed
Indonesia Kaimana Mud Crab	*Scylla serrata*	0.85	137	4	Artisanal
Indonesia S. Sumbawa Yellowfin Tuna	*Thunnus albacares*	0.5	392	2343	Artisanal
Indonesia S. Sumbawa Snapper and Grouper	*Plectropomus leopardus*	0.2	906	6100	Artisanal
Indonesia SE Sulawesi Skipjack Tuna	*Katsuwonus pelamis*	0.5	100	2323	Artisanal
Indonesia Kaimana Artisanal Finfish	*Lutjanus malabaricus*	0.3	456	1800	Artisanal
Indonesia N. Sumbawa Snapper and Grouper	*Plectropomus leopardus*	0.2	2945	6100	Artisanal
Indonesia Lombok Shark	*Sphyrna lewini*	0.05	45	6000	Artisanal
Indonesia S. Sulawesi Grouper	*Lutjanus campechanus*	0.2	11500	7400	Artisanal
Indonesia Central Sulawesi Artisanal	*Etelis coruscans*	0.3	34000	7000	Artisanal
Japan Ofunato Saury	*Cololabis saira*	0.4	220	15000	Mixed
Japan Toyama Bay Set-Net	*Seriola quinqueradiata*	0.3	115	1250	Industrial
Japan Toshi Small Boat	*Scomberomorus maculatus*	0.4	591	22747	Artisanal
Japan Ofunato Set Net Salmon	*Oncorhynchus masou*	0.8	20	12000	Mixed
Japan Nanao Bay Sea Cucumber Trawl	*Pagrus major*	0.2	10	300	Industrial
Japan Naya-ura Set Net	*Trachurus japonicus*	0.3	152	6444	Mixed
Kenya Shimoni Artisanal	*Siganus sutor*	0.6	910	197	Artisanal
Liberia Westpoint Artisanal	*Pseudotolithus senegalensis*	0.4	400	16154	Artisanal

Liberia Westpoint Artisanal	*Pseudotolithus senegalensis*	0.4	400	12500	Artisanal
Malawi Lake Chiuta	*Tilapia*	0.64	365	1322	Artisanal
Maldives Skipjack Tuna	*Katsuwonus pelamis*	0.5	750	110000	Industrial
Mexico Purse Seine Tuna	*Thunnus thynnus*	0.1	5	10000	Industrial
Myanmar Artisanal	*Lagocephalus sceleratus (puhherfish)*	0.26	492	500	Artisanal
Myanmar Mawlamyine Croaker-Hilsa	*Otolithes ruber*	0.2	1000	5	Mixed
Myanmar Small-Scale Purse Seine	*Katsuwonus pelamis*	0.5	230	29900	Artisanal
Myanmar Bilugyun Stationary Trawl	*Harpadon nehereus*	0.86	120	8	Industrial
New Zealand Hoki	*Macruronus novaezelandiae*	0.2	65	130000	Industrial
Philippines Blue Crab	*Portunus pelagicus*	1	2522	34000	Artisanal
Senegal Artisanal	*Epinephelus aeneus*	0.2	17000	40001	Artisanal
Senegal Ngaparou Artisanal	*Epinephelus aeneus*	0.2	143	2400	Artisanal
Seychelles Inshore Artisanal	*Aprion virescens*	0.1	500		Artisanal
Sierra Leone Tombo Artisanal	*Sardinella aurita*	0.4	1288		Artisanal
Sierra Leone Sherbro Artisanal	*Sardinella aurita*	0.4	2594	243000	Artisanal
South Africa - Hake Longline (HLL)	*Merluccius capensis*	0.1	48	8434	Industrial
South Africa - Small pelagic purse seine	*Sardinops sagax*	0.3	74	65000	Mixed
South Africa - West Coast Rock Lobster	*Jasus lalandi*	0.1	85	575	Artisanal
South Africa - Hake Deep Sea Trawl (HDST)	*Merluccius capensis*	0.1	51	112000	Industrial
Tanzania – Dagaa	*Rastrineobola argéntea*	1	8272	130000	Artisanal
Tanzania - Lake Victoria Nile Perch	*Lates niloticus*	0.2	15327	112000	Artisanal
US Florida Blue Crab	*Callinectes sapidus*	0.7	772	3011	Mixed
US California Spot Prawn	*Pandalus platyceros*	0.157	30	192	Mixed
US SE Alaska Salmon	*Oncorhynchus keta*	0.5	1889	101366	Mixed
US Bristol Bay Sockeye Salmon	*Sockeye salmon*	0.4	2430	91435	Mixed
US Alaska Pollock	*Gadus chalcogrammus*	0.3	133	1302815	Mixed
US Louisiana Shrimp	*Farfantepenaeus duorarum*	0.216	4841	33790	Mixed

US Florida Spiny Lobster	*Panulirus argus*	0.2	540	2688	Artisanal
US Pacific Groundfish	*Anoplopoma fimbria*	0.2	108	10938	Mixed
US Gulf of Mexico Snapper	*Lutjanus campechanus*	0.2	368	2400	Mixed
US California Spiny Lobster	*Panulirus argus*	0.2	150	432	Mixed
US California Sea Cucumber	*(Parastichopus parvimensis*	0.6	112	140	Mixed
US Prince William Sound Salmon	*Sockeye salmon*	0.4	833	165471	Mixed
US Florida Spiny Lobster	*Panulirus argus*	0.2	781	1760	Artisanal
US California Nearshore Finfish	*Semicossyphus pulcher*	0.3	157	135	Artisanal
US California Urchin	*Strongylocentrotus franciscanus*	0.23	215	5208	Artisanal
US Alaska Halibut	*Hippoglossus stenolepis*	0.1	2236	22282	Mixed
US New England Groundfish	*Gadus morhua*	0.1	1431	15835	Mixed
US West Coast Sablefish	*Anoplopoma fimbria*	0.2	164	1638	Mixed
US California Urchin	*Strongylocentrotus franciscanus*	0.23	202	5375	Artisanal
US California Salmon	We did not find growth rate for the specie, we used k *Oncorhynchus keta*	0.5	655	1018	Artisanal
US Alaska Salmon	*Sockeye salmon*	0.4	8191	33167	Mixed
Uganda Nile Perch	*Lates niloticus*	0.2	15270	200000	Artisanal
Vietnam Offshore Fish Trawl	*Saurida undosquamis*	0.7	1700	764645	Artisanal
Vietnam - Tuna fisheries	*Katsuwonus pelamis*	0.5	4478	112625	Mixed
Vietnam - Anchovy fisheries	*Encrasicholina heteroloba*	2.4	5172	108000	Artisanal

Source: own elaboration based on scientific publications and open source information: www.fishbase.org and www. seaaroundus.org

Table A.2. Ranking of Average Stock Health by Country

Country	Average Stock Heath
Maldives	4.75
New Zealand	4.38
Japan	4.27
Australia	4.17
South Africa	3.89
United States	3.87
Honduras	3.70
Seychelles	3.62
Chile	3.53
The Gambia	3.50
India	3.38
Mexico	3.38
Bangladesh	3.33
Indonesia	3.26
China	3.17
Colombia	3.07
Malawi	3.00
Liberia	2.94
Tanzania	2.87
Vietnam	2.79
Uganda	2.75
Brazil	2.67
Myanmar	2.66
Kenya	2.62
Philippines	2.62
Senegal	2.56
Sierra Leone	2.56

Source: Own elaboration.

Table A.3. Ranking of Stock Health by Fishery

Fishery	Year	Country	Stock Health
US Bristol Bay Sockeye Salmon	2016	United States	5.00
US SE Alaska Salmon	2016	United States	4.88
US Alaska Pollock	2013	United States	4.88
US Prince William Sound Salmon	2016	United States	4.88
US Alaska Halibut	2011	United States	4.88
US Alaska Salmon	2009	United States	4.88
Maldives Skipjack Tuna	2013	Maldives	4.75
Indonesia Kaimana Mud Crab	2016	Indonesia	4.50
Japan Toyama Bay Set-Net	2016	Japan	4.50
Australia Spencer Gulf Prawn	2011	Australia	4.38
Japan Ofunato Set Net Salmon	2016	Japan	4.38
Japan Naya-ura Set Net	2016	Japan	4.38
New Zealand Hoki	2011	New Zealand	4.38
South Africa - Small pelagic purse seine	2018	South Africa	4.38
US California Spot Prawn	2015	United States	4.38
Indonesia Kaimana Bagan Baitfish	2016	Indonesia	4.25
Australia Western Zone Abalone	2011	Australia	4.12
Chile Northern Anchovy	2019	Chile	4.12
Indonesia SE Sulawesi Skipjack Tuna	2016	Indonesia	4.12
Japan Ofunato Saury	2016	Japan	4.12
Japan Toshi Small Boat	2016	Japan	4.12
Japan Nanao Bay Sea Cucumber Trawl	2016	Japan	4.12
China - Gillnetting gazami crab	2019	China	4.05
Australia Southern Zone Rock Lobster	2012	Australia	4.00
China - Japenese &Australian Mackerels	2018	China	4.00
EU Indian Ocean Purse Seine Tuna	2013	India	4.00
US Florida Blue Crab	2016	United States	4.00
US West Coast Sablefish	2015	United States	4.00
Indonesia Lombok Shark	2016	Indonesia	3.88
South Africa - Hake Deep Sea Trawl (HDST)	2019	South Africa	3.86
South Africa - Hake Longline (HLL)	2019	South Africa	3.78
US Pacific Groundfish	2011	United States	3.75
US Florida Spiny Lobster	2010	United States	3.75
US California Urchin	2015	United States	3.75
Honduras - Spiny Lobster	2019	Honduras	3.70
Indonesia Longline Tuna	2013	Indonesia	3.62
Seychelles Inshore Artisanal	2011	Seychelles	3.62

South Africa - West Coast Rock Lobster (WCRL) Offshore sector	2019	South Africa	3.56
Colombia - Industrial Deep Sea Shrimp Fishery	2019	Colombia	3.53
Bangladesh Beel Chatra	2010	Bangladesh	3.50
Gambia Artisanal Sole and Catfish	2010	Gambia	3.50
Indonesia S. Sumbawa Yellowfin Tuna	2016	Indonesia	3.50
Liberia Westpoint Artisanal	2015	Liberia	3.50
US Louisiana Shrimp	2010	United States	3.50
US California Sea Cucumber	2015	United States	3.50
US California Urchin	2010	United States	3.50
Vietnam - Tuna fisheries	2018	Vietnam	3.50
Bangladesh Kailin Nadi	2010	Bangladesh	3.38
Brazil Madeira River	2016	Brazil	3.38
Indonesia N. Sumbawa Yellowfin Tuna	2016	Indonesia	3.38
Mexico Purse Seine Tuna	2013	Mexico	3.38
US Florida Spiny Lobster	2016	United States	3.38
Tanzania - Lake Victoria Nile Perch	2018	Tanzania	3.36
Artisanal Queen Conch Fishery for the Colombian Caribbean	2018	Colombia	3.30
China Shandong Spanish Mackerel	2016	China	3.25
Indonesia Kaimana Artisanal Finfish	2016	Indonesia	3.25
US California Spiny Lobster	2015	United States	3.25
Bangladesh Pabna Sadullaspracole	2010	Bangladesh	3.12
Taiwan Longline Tuna	2013	China	3.12
India Gujarat Trawl	2015	India	3.12
Indonesia S. Sumatra Blue Swimming Crab	2016	Indonesia	3.12
South India Trawl	2015	India	3.00
Malawi Lake Chiuta	2013	Malawi	3.00
Chile - Sardine and Anchovie Artisanal-Industrial	2018	Chile	2.94
Myanmar Small-Scale Purse Seine	2016	Myanmar	2.88
US Gulf of Mexico Snapper	2014	United States	2.88
US California Nearshore Finfish	2015	United States	2.88
US California Salmon	2015	United States	2.88
China Guangdong Cuttlefish-Squid	2016	China	2.75
China Fujian Swimming Crab	2016	China	2.75
Indonesia N. Sumbawa Snapper and Grouper	2016	Indonesia	2.75
Uganda Nile Perch	2010	Uganda	2.75
Indonesia SE Sulawesi Blue Swimming Crab	2016	Indonesia	2.62
Kenya Shimoni Artisanal	2013	Kenya	2.62
Myanmar Artisanal	2016	Myanmar	2.62
Myanmar Mawlamyine Croaker-Hilsa	2016	Myanmar	2.62
Philippines Blue Crab	2010	Philippines	2.62

Senegal Ngaparou Artisanal	2013	Senegal	2.62
Sierra Leone Sherbro Artisanal	2013	Sierra Leone	2.62
Vietnam - Anchovy fisheries	2019	Vietnam	2.62
Brazil Sardine Purse Seine	2016	Brazil	2.50
Indonesia Blue Crab	2010	Indonesia	2.50
Indonesia S. Sulawesi Grouper	2016	Indonesia	2.50
Indonesia Central Sulawesi Artisanal	2016	Indonesia	2.50
Myanmar Bilugyun Stationary Trawl	2016	Myanmar	2.50
Senegal Artisanal	2010	Senegal	2.50
Sierra Leone Tombo Artisanal	2013	Sierra Leone	2.50
US New England Groundfish	2008	United States	2.50
Colombia Industrial Shrimp	2010	Colombia	2.38
Indonesia S. Sumbawa Snapper and Grouper	2016	Indonesia	2.38
Liberia Westpoint Artisanal	2011	Liberia	2.38
Tanzania – Dagaa	2018	Tanzania	2.38
South China Sea	2016	China	2.25
Vietnam Offshore Fish Trawl	2014	Vietnam	2.25
Brazil Seabob Shrimp	2016	Brazil	2.12

Table A.4. Marginal Effects After Poisson Model. Dependent Variable: Stock Health[a]

	(1) Model 1	(2) Model 2	(3) Model 3	(4) Model 4
GrowthRate	1.066401***	1.075503***	1.229909***	1.246223***
	(0.384959)	(0.384063)	(0.366107)	(0.362500)
Ln(Numberofvessels)*GrowthRate	-0.145378***	-0.147572***	-0.162690***	-0.165902***
	(0.052681)	(0.052842)	(0.048738)	(0.049028)
Number of vessels*Artisanal	-0.000015**	-0.000015***	-0.000014**	-0.000014**
	(0.000006)	(0.000006)	(0.000005)	(0.000006)
Number of vessels*Industrial	0.000006**	0.000006**	0.000006**	0.000006**
	(0.000002)	(0.000002)	(0.000003)	(0.000003)
Number of vessels*Mixed	-0.000006**	-0.000006**	-0.000006*	-0.000006*
	(0.000003)	(0.000003)	(0.000003)	(0.000003)
Control_of_Corruption	0.211074*	0.182167	0.211102	0.176262
	(0.112019)	(0.151748)	(0.135309)	(0.167233)
Real Interest Rate	-0.016199*	-0.015231	-0.015723*	-0.014603
	(0.009411)	(0.011624)	(0.008865)	(0.011088)
Human Development Index	0.113467	0.086692	0.108533	0.080862
	(0.121090)	(0.204528)	(0.124057)	(0.208739)
KOF_Globalisation_Index		0.004871		0.005393
		(0.026776)		(0.026776)
Harvest_Rights			0.069376	0.065393
			(0.146151)	(0.143352)
Unregulated_OA			0.028804	0.019707
			(0.191691)	(0.182603)
N	95	95	92	92
Log pseudolikelihood	-129.71724	-129.70892	-125.70537	-125.69576
Wald chi2	126.59	121.74	150.27	151.33
Prob > Chi2	0.0000	0.0000	0.0000	0.0000

Note: *p<0.1; **p<0.05; ***p<0.01

Robust standard errors by cluster of countries in parentheses.

[a]The variable adopts the value of one if the stock health is less than 3.0. We call this category “low” stock health. The second category is “medium”, and the variable takes the value of two if the stock health is greater than or equal to 3.0 but less than 4.0. Finally, we define a category as “high,” which adopts the value of three if the stock health is greater than or equal to 4.0.

Table A.5. Marginal Effects After Poisson Model. Dependent Variable: Stock Health[a]

	(1) Model 1	(2) Model 2	(3) Model 3	(4) Model 4
GrowthRate	0.822117*	0.826841*	0.933120*	0.940505*
	(0.443315)	(0.444383)	(0.505578)	(0.511318)
Ln(Numberofvessels)*GrowthRate	-0.120036**	-0.121183**	-0.130352**	-0.131814**
	(0.058992)	(0.059381)	(0.062549)	(0.063811)
Number of vessels*Artisanal	-0.000014**	-0.000014***	-0.000013**	-0.000013**
	(0.000005)	(0.000005)	(0.000005)	(0.000005)
Number of vessels*Industrial	0.000005*	0.000005*	0.000005*	0.000005*
	(0.000003)	(0.000003)	(0.000003)	(0.000003)
Number of vessels*Mixed	-0.000006**	-0.000006**	-0.000005**	-0.000005**
	(0.000002)	(0.000002)	(0.000002)	(0.000002)
Control_of_Corruption	0.164015*	0.148732	0.163399	0.147505
	(0.097997)	(0.111910)	(0.118079)	(0.128782)
Real Interest Rate	-0.010494	-0.009993	-0.009863	-0.009371
	(0.008018)	(0.009867)	(0.007816)	(0.009760)
Human Development Index	0.125765	0.111874	0.122150	0.109732
	(0.103590)	(0.170044)	(0.108956)	(0.172576)
KOF_Globalisation_Index		0.002547		0.002436
		(0.019683)		(0.019631)
Harvest_Rights			0.059564	0.057732
			(0.148161)	(0.145863)
Unregulated_OA			0.004335	0.000338
			(0.189507)	(0.187448)
N	95	95	92	92

Note: *p<0.1; **p<0.05; ***p<0.01
Robust standard errors by cluster of countries in parentheses.
[a]The variable adopts the value of one if the stock health is less than 2.8. We call this category "low" stock health. The second category is "medium", and the variable takes the value of two if the stock health is greater than or equal to 2.8 but less than 4.2. Finally, we define a category as "high," which adopts the value of three if the stock health is greater than or equal to 4.2.

Table A.6. Marginal Effects After Poisson Model. Dependent Variable: Stock Health, Subsamples: Developing vs Developed Countries

Sub-Sample:	Developing Countries Model 1	Developing Countries Model 2	Developed Countries Model 1	Developed Countries Model 2
GrowthRate	0.963868**	0.973070**	-0.383956	-0.479529
	(0.439408)	(0.430575)	(0.752406)	(0.826758)
Ln(Numberofvessels)*GrowthRate	-0.137302**	-0.141747***	0.191739**	0.220619*
	(0.054010)	(0.052744)	(0.097176)	(0.119533)
Number of vessels*Artisanal	-0.000012**	-0.000013**	-0.001107***	-0.001141***
	(0.000006)	(0.000005)	(0.000381)	(0.000392)
Number of vessels*Industrial	0.000005*	0.000004*	-0.002152	-0.001673
	(0.000002)	(0.000003)	(0.001503)	(0.001289)
Number of vessels*Mixed	-0.000006***	-0.000006***	0.000050***	0.000037**
	(0.000002)	(0.000002)	(0.000009)	(0.000016)
Control_of_Corruption	0.072466	-0.106941	1.620727***	1.478646***
	(0.260324)	(0.255822)	(0.467945)	(0.410991)
Real Interest Rate	-0.014642	-0.010648	-0.152421***	-0.126034***
	(0.009105)	(0.011353)	(0.044986)	(0.034183)
Human Development Index	0.150648	0.061279		
	(0.118009)	(0.196608)		
KOF_Globalisation_Index		0.019918		-0.044321
		(0.024665)		(0.034941)
N	64	64	31	31

Note: *p<0.1; **p<0.05; ***p<0.01
Robust standard errors by cluster of countries in parentheses.