Does trade foster resource management? Evidence on fishing quotas*

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Abstract

Does international trade change a regulator's ability or incentive to manage a renewable resource sustainably? Theoretical predictions are ambiguous and this is the first empirical analysis to shed light on the effect of trade on resource management. I use detailed country-species level fisheries data to investigate whether trade facilitates the introduction of quota and Territorial Use Rights for Fishing (TURF) programs for fisheries. The empirical evidence suggests a negative relationship between the resource price and the introduction of quota and TURF programs. The values of landings and exports are positively correlated with the introduction of fisheries management.

JEL codes: Q27, Q22, Q28, F18

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1 Introduction

Several theoretical papers link the management of renewable resources to international trade. While Demsetz (1967); Copeland and Taylor (2009); Hotte et al. (2000); Tajibaeva (2012) papers argue that trade openness can facilitate the introduction or enforcement of property rights for renewable resources, another stream of the literature shows that trade openness can lead to the collapse of resource management systems (Sethi and Somanathan, 1996; Barbier et al., 2005). Empirical evidence on the effect of trade on renewable resource management is sparse.

This is the first empirical analysis to shed light on the effect of trade on resource management. We use detailed country-species level fisheries data to investigate whether higher prices and export values facilitate the introduction of catch share programs such as individual transferable quotas (ITQs).[1] The results suggest a positive relationship between a fishery's exports value and the introduction of quota or TURF programs.

Research on the effect of trade on the introduction of catch share programs is not only of academic interest but of high policy relevance. Fishery products have become one of the most highly traded food commodities and more than one third of global fish production is exported (FAO, 2016). At the same time fisheries collapse is a widespread phenomenon. According to Pinsky et al. (2011) and Costello et al. (2012), the world's fisheries are overfished and between 17% and 25% of the world's fisheries have collapsed. It is obvious that the world's fisheries need to be managed in a more sustainable way. Catch share programs have turned out to be successful instruments in avoiding fisheries collapse (Costello et al., 2008). Hence, a study of the factors that motivate a government to introduce catch share programs can give important insights for the sustainability of the world's oceans.

In order to be able to study the effect of trade on fisheries management, we assemble a detailed dataset with global coverage. The dataset contains information on the adoption of catch share programs, prices, landings as well as trade patterns at the country-species level. Moreover, it covers a large number of country-level indicators including the number of fishermen, technology and regulatory quality.

The analysis is centred around the factors that motivate a government's initial decision to introduce catch share programs. This is best modelled using survival analysis. Our main interest is in the relationship between the price and fisheries management. However, the analysis also investigates the relationship between the introduction of catch share programs and other indicators for trade openness.

[1] Catch share programs allocate secure privileges to individual entities. They can either be quota-based or area-based. Area-based programs are also known as Territorial Use Rights for Fishing programs (TURFs) and allocate the privilege to fish in specific areas to groups or individuals. Quota based catch share programs allocate the right to fish a certain percentage of a total allowable catch to individuals, groups or vessels.

The results suggest a negative relationship between the price and the introduction of catch share programs. We discuss three mechanisms that can potentially explain this finding. Firstly, an increase in the price could lead to a collapse of social norms and thus hamper fisheries management. Secondly, a higher price could foster lobbying efforts against catch limits and thus halt their introduction, particularly in corrupt countries. Thirdly, the result could be explained by different fishing costs across species.

Even though the theoretical literature models trade openness as an exogenous increase in the price, our analysis explores the relationship between the introduction of catch share programs and other proxies for trade openness. The data do not suggest that openness to trade, measured as the sum of exports and imports relative to domestic production of the respective fish species, is a significant factor in the decision to introduce catch share programs. Moreover, the likelihood that a fishery is managed does not differ significantly between fisheries that export their products and those that do not. However, the results suggest that a higher export value may induce governments to introduce catch share programs. This is in line with the finding that governments are more likely to manage fisheries with higher revenues. Part of these revenues are generated on export markets. The overall value of fisheries may be an important determinant for the introduction of catch share programs due to the cost associated with the introduction and enforcement of catch shares.

The results also reveal that overcapacity in a fishery is not conducive to fisheries management. Fisheries with more fishermen or with access to smaller fishing grounds are less likely to be managed. Moreover, good governance seems crucial for the introduction of catch share programs. Corrupt countries are significantly less likely to introduce these rights-based management tools. Governments are also less likely to introduce catch share programs for fisheries which have collapsed. This corroborates the previous two points since fisheries collapse is a sign of both overcapacity in the fishery and poor governance.

This paper provides important insights the effect of international trade on the management of renewable resources. The theoretical predictions differ considerably. Hence, empirical evidence is needed to identify whether international trade fosters or hampers successful management of renewable resources.

To the best of our knowledge, this paper provides the first comprehensive analysis of the relationship between international trade and the adoption of catch share programs. However, a study on catch share programs in developing countries gives a first idea of the relationship between trade and fisheries management. Jardine and Sanchirico (2012) compare the characteristics of developing countries which introduce catch share programs to the characteristics of developing countries which do not use right-based approaches to fisheries management. They find that the total value of fisheries exports at the country level is higher in developing countries which introduce catch share programs. However, Jardine and Sanchirico (2012)'s findings reveal that the majority of fish species for which governments implement catch share programs are in the low or medium price category. This is consistent with our empirical evidence, which reveals that lower price species are more likely to introduce catch share programs.

Our work adds to insights from Jardine and Sanchirico (2012) in four ways. First of all, we have trade data at the species level. Therefore, we can study the effect of trade in fisheries products of a particular species on the management of that species. Secondly, our dataset contains information on the price of all fish species and not just the fish species that introduce catch share programs. This allows us to compare the adopters of catch share programs to the non-adopters. Most importantly, the panel nature for our dataset allows us to investigate the features of fisheries which adopt catch share programs at the point in time in which the catch share programs are introduced. Jardine and Sanchirico (2012) compare fisheries at the end of the sample period in 2008 or 2009. However, as pointed out in their paper, this does not allow them to infer, whether factors like the price or the export value affects a government decision to introduce catch share programs due to reverse causality. The introduction of catch share programs could lead to long-term adjustment in the fishery and affect the price and the export value. Using data from the point in time in which the catch share programs were introduced mitigates this problem. Finally, we use a global dataset and our analysis is not restricted to developing countries.

This paper uses detailed and global data on the introduction of catch share programs. It can provide externally valid insights and help to reconcile inconclusive evidence from cases studies on the relationship between trade and the management of renewable resources. Existing case studies come to contradictory conclusions. According to Demsetz (1967), fur trade lead to the development of property rights amongst American Indians, since it increased the value of furs. Copeland and Taylor (2009) also mention the geoduck fishery in British Columbia as an example for a positive effect of trade on resource management. The geoduck fishery experienced high export demand from Asia and managed the transition from an open access fishery to a fishery with individual catch limits.

At the same time, there is evidence to suggest that international trade and external demand lead to more pressure on renewable resources which is not accompanied by improvements in resource management. Taylor (2011), e.g., shows that foreign demand for Buffalo hides contributed to the near extinction of Buffalos in the Great Plains in North America. Similarly, trade liberalisation and the emergence export markets coupled with poor management lead to overfishing in Estonian coastal fisheries (Vetemaa et al., 2006). In many cases, trade can be considered a hindrance to resource management. For West African countries, fisheries are "an important source of revenue for some national economies, often contributing to servicing local and foreign debts" (Satia and Jallow, 2010, p. 259). Moreover, fisheries exports can be an important way of earning foreign exchange, such as in India in the 1970s (Nandakumar and Nayak, 2010, p. 280). Both in West Africa and in India, increasing fisheries exports were not accompanied by sustainable fisheries management. Furthermore, a thorough case study of palm oil exports in Nigeria in the late 19th and early 20th century by Fenske (2014) argues that communities can abandon individual harvesting rights when exporting raises the price of a renewable resource.

This paper is structured as follows. Section 2 explains the empirical strategy and the choice of the control variables. The construction of the dataset is described in Section 3. Section 4 provides summary statistics and compares the characteristics of the fisheries that introduce catch share programs to the characteristics of non-adopters. The results for the baseline regression are described in Section 5. They reveal a negative relationship between the price and the introduction of catch share programs. Section 6 tests the sensitivity of those results. We introduce individual heterogeneity and fixed effects in Sections 6.1 to 6.3. Further robustness checks in Sections 6.4 and 6.5 address concerns about measurement errors or reverse causality. Section 7 investigates whether negative relationship between the price and the introduction of catch share programs is in line with existing theoretical models and discusses mechanisms that can potentially explain this finding. Those explanations include social norms, rent-seeking and cost differences. In the main part of this paper, trade openness is modelled through the price. Section 8 investigates how the value of the fishery correlates with the introduction of catch share programs and Section 9 examines the relationship between the introduction of catch share programs and other proxies for trade openness. Section 10 concludes.

2 Empirical strategy

The theoretical literature models trade openness as an exogenous increase in the price of the renewable resource. Following that literature, our main interest is in the relationship between the price and a government's decision to introduce catch share programs. The choice of control of variables is based on the model by Copeland and Taylor (2009) and on anecdotal evidence concerning factors that hamper or foster the introduction of catch share programs. This paper studies a government's initial decision to introduce catch share programs. This can be modelled using survival analysis.

2.1 Survival analysis approach

This paper studies a country's decision to introduce catch share programs. We model the time it takes the government to adopt a catch share program at the country-species level using survival analysis. Survival analysis is expedient for the purpose of our study since it allows us to focus on a government's initial decision to introduce rights-based management approaches.[2] In our dataset, we observe every fishery until it has introduced a catch share

[2] The catch share programs which were introduced during our sample period stay in place.

program. Fisheries which do not introduce catch share programs are observed until the end of the sample period.

With this data structure, the dependent variable in our analysis is a hazard rate.[3] In the context of our analysis, the hazard rate is the defined as the probability that a fishery adopts management in year t conditional on survival up to year t (or conditional on not having adopted management after $t-1$ years).

The data used for this analysis are annual data. Hence, the analysis needs to be based on a discrete time model. We use a complementary log-log model, which is the discrete time version of a proportional hazards model. Proportional hazard models have a convenient interpretation since absolute changes in the regressor X imply proportionate changes in the hazard rate at each t. In other words, the coefficient estimates represent the elasticity of the hazard rate with respect to a one unit change in the regressor.

The results presented below are based on a non-parametric specification of the baseline hazard. In the context of our analysis a non-parametric specification of the baseline hazard is similar to a year fixed effect, since all observations enter the sample at the same time. The non-parametric specification is more flexible than a parametric specification of the baseline hazard, but it implies that we only use observations from years in which at least one fishery adopts management. Observations from the years 1987 and 2000, in which none of the countries in our sample adopt any catch share programs, are not used in our analysis.[4]

2.2 Estimating equation

The estimating equation models the likelihood that a country i adopts a catch share program for species j in year t, given survival up to time $t-1$, as a function of the price in period $t-1$, p_{ijt-1}, and the country and species specific control variables mentioned above. This motivates the following estimating equation:

$$\begin{aligned}\theta_{jit}(t,X) = F(&\beta_1 \ln(\mathrm{p})_{jit-1} + \beta_2 \mathrm{Fishers}_{jt} + \beta_3 \mathrm{Agri\ VA}_{jt} + \beta_4 \mathrm{Growth}_i + \beta_5 \mathrm{Coastline}_j \\ &+ \beta_6 \mathrm{Collapsed}_{ijt} + \beta_7 \mathrm{Corruption}_{jt} + \beta_8 \mathrm{Resource\ Rents}_{jt} \\ &+ \beta_9 \mathrm{GDP\ pc}_{jt} + \gamma_t + v_{jit})\end{aligned} \quad (1)$$

where θ_{jit} is the hazard rate, γ_t represents the baseline hazard and v_{jit} is the error term. Table 1 provides a definition of the control variables and the units of measurement and

[3]The explanation of key concepts in survival analysis draws on Stephen Jenkins (2005)'s book on survival analysis, which is available on `https://www.iser.essex.ac.uk/files/teaching/stephenj/ec968/pdfs/ec968lnotesv6.pdf`.

[4]In a robustness check, we use a cubic polynomial and a logarithmic specification of the baseline hazard. The results are not sensitive to changes in the functional form of the baseline hazard.

the following few sections provide more detail.

Table 1: Variable Definition

Variable	Description	Source
Man_{ijt}	Dummy variable that takes the value of one if a fishery is managed under a catch share programme	Environmental Defense Fund
Ln (Lagged Price_{ijt})	Natural logarithm of the lagged price measured in constant 2005 US$ per kilo	Swartz et al. (2012)
Fishers_{jt}	Number of fishermen in thousands	FAO
Agri VA_{jt}	Agricultural value added per worker (in thousands of constant 2005 US$)	WDI
Growth_{i}	Fish population growth rate	Fisheries Centre (UBC)
Coastline_{j}	Coastline in 1000 km	CIA World Factbook
Collapsed_{ijt}	Catch is less than 10 percent of the maximum catch recorded since 1950	Author's calculation
Corruption_{jt}	Ranges from -6 to 0, with a higher value indicating higher corruption	ICRG
Resource Rents_{jt}	Sum of oil, natural gas, coal, mineral, and forest rents as percentage of GDP	WDI
GDP p.c._{jt}.	GDP per capita in thousands of constant 2005 US$	WDI

2.3 Price - The main variable of interest

The theoretical literature models trade openness as an increase in the price of the renewable resource. Following that literature, our main interest is in the relationship between the price and a government's decision to introduce catch share programs.[5] We use ex-vessel price data for all countries from Swartz et al. (2012). Prices are measured in constant 2005 US$ and the data are available at the species level. This disaggregate information on prices allows us to exploit variation within countries across species, within species across countries and within country-species across time. The baseline model exploits all types of variation, especially since the theoretical models could apply to all types of variation. In the sensitivity analysis, we introduce random and fixed effects.

The introduction of catch share programs limits the amount of fish that fishermen are allowed to catch. The resulting reduction in supply could lead to an increase in the price if the country is not open to trade. In order to avoid reverse causality between the price and management, we use the lag of the price variable. Using the lagged variable is also reasonable as the introduction of catch share programs often takes some time.

[5] Section 9 uses data on trade and domestic landings to analyse the effect of trade openness on catch share programs. Due to the incomplete data coverage of trade data at the species level, we use the price in our baseline specification.

Since the distribution of the price variable is heavily skewed, we use the natural logarithm of the price rather than the level. This implies that the coefficient estimate for the price variable represents the elasticity of the hazard rate with respect to the price.

2.4 Control variables - Additional factors motivating the adoption of catch share programs

Our choice of control of variables is based on the model by Copeland and Taylor (2009), which provides insights on the country and species characteristics that can affect the decision to introduce catch share programs. Based on this model, we control for overcapacity in the fishery and enforcement power. Anecdotal evidence suggests that the health of fish stocks, resource abundance and GDP.

Overcapacity in the fishing industry is one potential factor affecting the introduction of catch share programs according to the model by Copeland and Taylor (2009). Copeland and Taylor (2009) argue that overcapacity in the fishing industry hinders the introduction of catch limits if monitoring is imperfect. Large overcapacity makes it difficult to introduce regulations which fishermen comply with and which generate positive profits at the same time. In the context of Copeland and Taylor (2009)'s model, overcapacity has three components: The labour force that could potentially go fishing, fishing technology and the fish population growth rate.

The first component of overcapacity is the labour force which could potentially go fishing. A larger potential labour force increases pressure on the resource and makes management less likely. Hence, Copeland and Taylor (2009) predict a negative relationship between the labour force that could go fishing and the introduction of quotas.[6] Hence, governments in countries with a large number of fishermen may be more wary about introducing catch limits. We use data on the number of fishermen at the country level to measure the labour force that could potentially go fishing. The number of fishermen is measured in thousands.

Fishing technology is the second component of overcapacity in Copeland and Taylor (2009). As the fishing technology improves, every fisherman can catch a larger number of fish and the pressure on the resource increases. Unfortunately, fishing technology is difficult to measure. Advanced technology would be reflected in fishing vessels with large capacity, good equipment to locate fish and adequate nets. We do not have information on any of these factors. However, it is possible to use proxy variables. Fishing technology is very likely to be correlated with a country's agricultural technology. Hence, we use country-level data on agricultural value added per worker from the World Development Indicators, measured in thousands of constant US$, as a proxy for fishing technology.

[6] Anecdotal evidence also suggests that governments in Norway (Steinshamn, 2010) or the United Kingdom (Pascoe and Tingley, 2010) are concerned about employment in remote coastal communities.

More advanced technology is likely to be reflected in a higher agricultural value added. Since WDI data on agricultural value added comprise value added in fisheries, they are a useful proxy for fishing technology.

Finally, overcapacity in a fishery depends on the fish population growth rate. Fish stock which replenish more slowly are under more pressure. Hence, it may be more complicated to introduce regulations that fishermen comply with. The resource growth rate is measured using data on fish population growth rates from the UBC Fisheries Centre. The variable is species-specific and time-invariant.

We also control for the length of a country's coastline measured in 1000 km. A longer coastline implies that a country has access to larger fishing grounds. Holding the number of fishermen, the fishing technology and the fish population growth rate constant, a longer coastline should reduce the pressure on the resource. The country-level data on the length of the coastline are from the CIA World Factbook.

Copeland and Taylor (2009) show that low **enforcement power** can hinder the introduction of catch limits in an environment with imperfect monitoring. If enforcement power is low, it is difficult for the government to introduce catch limits that fishermen comply with. Anecdotal evidence supports this idea and highlights weak governance and corruption as important obstacles for fisheries management (Williams and Staples, 2010; Satia and Jallow, 2010; Nandakumar and Nayak, 2010). Our set of control variables, thus, includes a corruption indicator from the PGR Groups's International Country Risk Guide (ICRG). The ICRG provides corruption data on 140 developed, emerging and frontier markets from 1984 onwards. In its assessment of corruption, the PGR group assigns each country risk points. A higher number of risk points indicates a lower risk. In order to make the interpretation of our coefficient estimates more intuitive, we rescale the corruption variable such that a higher value represents higher corruption.

Anecdotal evidence suggests that several countries have introduced catch share programs in response to declining fish stocks.[7] We want to account for this motive in the empirical analysis. Scientific evidence on fish stocks is sparse.[8] However, it is common practise to infer fisheries collapse from landings statistics. Following Worm et al. (2006) and Costello et al. (2008), we define a fishery j in country i as collapsed in year t if the catch in that year is less than 10 percent of the maximum catch since 1950. The catch data used to define a fishery as collapsed are from Swartz et al. (2012), who use data are from the *Sea Around Us* catch database. The latter database maps landings to the origin of the catch on a spatial grid of the ocean based on individual country's landing statistics, information on foreign access to a country's Exclusive Economic Zone as well

[7] The countries include Canada (Parsons, 2010), Iceland (Matthiasson and Agnarson, 2010) and New Zealand (Connor and Shallard, 2010). Moreover, the introduction of the TURF program in Chile was a response to severe overfishing in the *loco* fishery (San Martín et al., 2010).

[8] The FAO provides very aggregate information if fish stock in 15 regions of the world's ocean.

as distribution of fish species.[9] Since the Sea Around Us data map the landings to the country's EEZ, they allows us to identify whether catch within one country has declined drastically.

We do not have strong priors concerning the relationship between the introduction of management and fisheries collapse. On the one hand, it is possible that governments use catch share programs as a last resort once other attempts at managing the fishery have failed and the fishery has collapsed. In that case, a collapsed fishery would be more likely to adopt catch share programs. On the other hand, governments may recognise the potential of rights-based management approaches and adopt catch share programs as a logical consequence of a successful history of managing a particular fishery with other instruments. In the latter case, the percentage of fisheries which collapsed prior to the introduction of management might be small.

Countries differ in their resource abundance and it is possible that resource abundant countries have more experience in managing resources. In that case, countries may be more prone to introduce catch share programs if resources contribute a larger proportion to their GDP. We use data on the resource rent as a percentage of GDP from the World Development Index to measure resource abundance. The resource rents are defined as the sum of oil, natural gas, coal, mineral and forest rents.

In poor countries, commercial and subsistence fisheries are not only a source of employment but also contribute to food security. Therefore, governments in poor countries may be hesitant to introduce catch limits. Moreover, the countries with a higher income may have a higher demand for environmental quality and healthy fish stocks.[10] Both factors suggest that countries with a higher GDP per capita are more likely to introduce catch share programs. We use data on GDP per capita, measured in thousands of constant 2005 US$, from the World Development Indicators.

3 Data

In order to be able to study the effect of trade on fisheries management, we assemble a large and unique dataset. The dataset contains information on the adoption of catch share programs, prices, fish population growth rates, landings as well as trade patterns at the country-species level. Moreover, it covers a large number of country-level indicators including the number of fishermen, technology and regulatory quality. This section describes the dataset. A summary of all data sources is provided in Table 1.

[9] See Watson and Kitchingman (2004) for a description of the Sea Around Us catch database.

[10] This is a common argument in the literature on the Environmental Kuznets Curve (EKC) (see e.g. Grossman and Helpman (1993) for an early empirical contribution in the EKC literature and Copeland and Taylor (2003) for a theoretical derivation of the EKC phenomenon).

3.1 Adoption of catch share programs

This study uses data on the adoption of catch share programs from the Environmental Defense Fund (EDF). The dataset contains information on catch share programs in all countries at the species-level. Even though the EDF data also provide information the management of freshwater fish species, this study focuses on the management of marine fish, since price data are only available for marine fish species.

Since the information on catch share programs is used in combination with other data, it is necessary to highlight a few features of the EDF data and explain how we merge the catch share data to the rest of the data. A few countries have different regulations for different segments of their fishing fleet. There are a few instances in which the catch share programme for a particular species is introduced in different years for different fleet segments. We record a particular species as managed as soon as a country adopts a catch share program for one particular segment of its fleet which targets the respective species. This assumption is unlikely to have a large impact on the results since the problem is not very prevalent.

For the purpose of the analysis it is important to know when the catch share program was adopted. Information on the year of adoption is missing for 146 observations in the original EDF dataset. We use information from government home pages and scientific articles and contacted the respective governments to complete this information where possible. For some country-species combinations it was impossible to find out when the catch share programs were introduced. Those country-species combinations are deleted from the dataset. Table 12 in the Appendix shows the number of catch share program for which the start year is missing by country of adoption. The start year is missing for all managed fisheries in Belgium, Finland, Germany, Latvia, Lithuania, Malta, Papua New Guinea and Poland. These countries are, thus, not in our sample. This is unlikely to introduce a sample selection issue, since this covers a large spectrum of countries.

3.2 Landings, prices and trade data

The management data are matched with data on **landings and prices** from Swartz et al. (2012).[11] The level of aggregation at which the countries report their landings statistics varies. Most countries provide landings statistics at the species level. Landings statistics for a few countries, like Austalia, are more aggregate. If a country does not provide catch statistics at the individual species level, the matching between the catch data and the management data is more complicated. This can be illustrated using an example. Australia implemented catch share programs for different kinds of lanternsharks including smooth lanternshark, short tail lanternshark, pink lanternshark and others.

[11] Swartz et al. (2012) use catch data from the Sea Around Us catch database, which is described in detail in Watson and Kitchingman (2004).

Australian catch statistics, however, do not distinguish between these categories and only report landings of lanternsharks in general. In that case, we assume that lanternsharks are managed as soon as the Australian government introduces management for the first lanternshark species.

The information on fish **prices** is from Swartz et al. (2012). The dataset contains fish prices for almost all countries in the world and covers the time period from 1950 to 2006. The fish prices are at the same level of aggregation as the landings statistics. Note that Swartz et al. (2012) estimate missing fish prices. The percentage of estimated observations is larger for the beginning of the sample period and for developing countries.

3.3 Control variables

The **fish population growth rates** are from the Fisheries Centre at UBC. The intrinsic population growth rate is proxied by the maximum population growth rate.[12] The data on the fish population growth rates are matched to the landings and price data based on the fish species' common name. We use information from FishBase to construct the concordance table between the common names.

The analysis also makes use of variables that vary at the country level. Data on the number of fishermen are from the FAO. FAO (1999) provides data for the years 1970 to 1997. Data for the years 1995, 2000 and 2004-2012 are available from the FAO (2014). Data on GDP per capita, agricultural value added and resource rents as a percentage of GDP are from the World Development Indicators. The corruption data are from the PGR Group's International Country Risk Guide. Data on the length of the coastline are from the CIA World Fact Book.

3.4 Trade data and aquaculture data

Section 9 also uses trade and aquaculture data with variation at the country-species level. Disaggregate **trade data** for almost all countries are available from the FAO Fisheries Commodities Production and Trade data. The trade data are matched with the data on landings and management at the species level. There is no existing concordance table for the landing statistics and the trade statistics. Hence, this table was constructed in the process of the research undertaken for this project. The next few paragraphs describe the matching in detail.

Table 2 provides some examples for categories in the trade data and shows two important features. Firstly, it shows that the FAO trade data provide information on the way the fish is processed. For the purpose of our analysis, it does not matter whether the fish is fresh, frozen or prepared. Therefore, we sum the weight or the value of the fish over all

[12]See Cheung and Sumaila (2015) on details about the fish population growth rates.

Table 2: Categories in the trade data

Atlantic cod, fresh or chilled
Atlantic cod, frozen
Atlantic cod, meat, frozen
European plaice, fresh or chilled
European plaice, frozen
Mussel meat nei, frozen
Mussel meat, prepared or preserved
Mussels nei, other than live, fresh or chilled
Mussels, live, fresh or chilled, nei

the different ways in which the fish is processed. In our dataset, exports of cod include fresh or chilled and frozen cod as well as frozen cod meat.

Table 2 also shows that exports and imports are recorded at the species level for some kind of fish like Atlantic cod and European plaice. For other species, such as mussels, the trade statistics are reported in more aggregate categories. The category mussels includes a whole range of species and the landings data would generally provide information at a more disaggregate level. Since it is not possible to know which of the species in our landings data are traded and which ones are not traded, we cannot use the trade data for aggregate categories like Mussels for the purpose of our analysis.

Aquaculture data at the species level are from FAO Fishstat J. Those data are matched with the landings statistics at the species level using ASCIP codes. Not all species are suitable for aquaculture production. Hence, we assume that aquaculture production is zero if FishStat J does not report aquaculture production of a particular species. Both the value of aquaculture production and the trade values are deflated using the US consumer price index from the US Bureau of Labour Statistics. We use the consumer price index for meat, poultry and fish for June. Deflation allows us to compare trade and aquaculture production to the value of landing reported in the dataset by Swartz et al. (2012), which are also deflated using the consumer price index from the US Bureau of Labour Statistics.

4 Summary statistics

This section provides summary statistics about the fisheries which introduce catch share programs. The summary statistics give a first idea of the factors which affect a government's decision to introduce catch share programs.

The sample period covers the years 1984 to 2003. During that time, 179 fisheries in our sample introduce catch share programs. Table 13 in the Appendix shows the number of fisheries which adopted catch share programs in every year. By 1994, 50% of the catch share programs in our sample were in place. A few catch share programs were introduced prior to 1984. However, delayed entry is not a problem for our analysis. Only 5 percent of all catch share programs were introduced between 1900 and 1984 and almost half of those were customary use rights programs which are based on social norms. The empirical analysis in this paper does consider customary use rights programs.

Table 3 provides summary statistics for all variables used in the analysis. This first column of Table 3 shows the mean of each variable for all fisheries which adopt management in the year in which they adopt management. In other words, the summary statistics in Column 1 of Table 3 give a snap shot of the managed fisheries at the time at which management is introduced. The second column of Table 3 provides summary statistics for unmanaged fisheries. This group includes both the fisheries which are unmanaged at a particular point in time but adopt management at a later point in time as well as the fisheries which are unmanaged throughout the sample period. Table 4 displays the results of t-tests for a difference in means between the managed and unmanaged fisheries.

Table 3: Summary statistics for catch share fisheries and others

	(1) Catch share mean	(2) No catch share. mean
Ln (Lagged price)	0.34	0.43
Ln (Lagged Price), Data	0.01	0.68
Open (Lag)	23.59	1510.57
Growth	0.36	0.50
Fishers	44.93	353.54
GDP p.c.	25.43	13.20
Agri VA	23.99	10.83
Corruption	-4.99	-3.56
Coastline	3.82	1.23
Collapsed	0.13	0.18
Resource rents	3.23	6.09
Observations	179	56637

Tables 3 and 4 show that the average log of the lagged price of fish species for which governments introduce catch share programs does not differ significantly from the average log of the lagged price for non-adopters. This means that, without conditioning on country and fisheries characteristics, there is little evidence that the price affects the adoption of catch share programs.

The description of the dataset in Section 3 explained that part of the price data are estimated. If we only use the price data which are not estimated, the average price is significantly lower for fisheries which introduce catch share programs, as demonstrated by the variable "Ln (Lagged Price), Data" in Tables 3 and 4.[13]

[13]The correlation Table 14 in the Appendix shows the unconditional correlation between management and

Table 4: T-test for difference in means

	(1)	
Ln (Lagged price)	0.0919	(1.13)
Ln (Lagged Price), Data	0.671***	(4.13)
Open (Lag)	1487.0	(0.47)
Growth	0.138*	(2.53)
Fishers	308.6***	(3.55)
GDP p.c.	-12.23***	(-11.85)
Agri VA	-13.17***	(-14.28)
Corruption	1.425***	(14.19)
Coastline	-2.592***	(-11.78)
Collapsed	0.0517	(1.80)
Resource rents	2.859***	(3.78)
Observations	56816	

t statistics in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 5 provides information on the sources of variation in the dataset. Is shows the overall standard deviation in Column 2, the standard deviation between country-species combination in Column 3 and the standard deviation within country-species over time in Column 4.

Most of the country level control variables, like the number of fishermen, the agricultural value added and GDP per capita vary considerably more between countries than within country-species over time. For the species level indicators, i.e. the price and the dummy variable which indicates fisheries collapse, the variation across time contributes more to the overall variation.

5 Results

The results for our baseline regression, which are presented in Column 1 of Table 6, show that there is a statistically significant negative relationship between the price and the introduction of catch share programs. An increase in the price by one percent is associated with a reduction in the hazard rate by 0.24 percent. This suggests that valuable species are less likely to be protected using catch share programs.

In order to assess the importance of the price in determining the adoption of catch share

all of the covariates used in the analysis. The price is not significantly correlated with the introduction of catch share programs. The table also reveals that the adoption of catch share programs is positively correlated with GDP per capita, agricultural value added and the length of the coastline. Management is significantly negatively correlated with the fish population growth rate, the number of fishermen, corruption and resource rents. Trade openness is not significantly correlated with the introduction of rights-based management.

Table 5: Summary statistics

	(1) Mean	(2) Overall Sd.	(3) Between Sd.	(4) Within Sd.
Ln (Lagged price)	0.428	1.082	0.982	0.527
Growth	0.502	0.728	0.698	0.000
Fishers	352.739	1162.118	1126.341	176.156
GDP p.c.	13.225	13.808	14.244	2.115
Agri VA	10.883	12.418	12.715	3.886
Corruption	−3.556	1.342	1.215	0.649
Coastline	1.238	2.942	2.800	0.000
Collapsed	0.181	0.385	0.303	0.261
Resource rents	6.166	10.316	10.568	3.210
Observations	56816	56816	56816	56816

programs, we calculate the predicted change in the hazard rate as the price increases by one standard deviation. Table 7 shows that such an increase in the price is associated with an increase in the hazard rate by 0.2 percent. This effect is small. However, the small effect of the price on the hazard rate is not surprising if we consider that only 179 out of almost 57 000 observations in our dataset are adopters of catch share programs. With catch share programs being this rare, the estimated effect of any regressor on the hazard rate is bound to be low.

Our study cannot explain the mechanism that leads to a negative relationship between the price and the introduction of catch share programs. Potential explanations for this result include lobbying against the introduction of catch share programs for higher-price species and cost differences. However, we defer a detailed interpretation of the negative coefficient estimate for the price variable to Section 7.

Moreover, the results indicate that, given survival up to time $t-1$, fisheries are more likely to be managed in time t if they are in technologically advanced countries. The coefficient estimate for the variable "Agri VA" suggests that an increase in agricultural value added per worker by 1000 constant US$ is associated with an increase in the hazard rate by 0.03 percentage points. Table 7 reveals that an increase in agricultural value added by one standard deviation is associated with an increase in the hazard rate by 0.37 percent.

A larger number of fishermen is estimated to have a statistically significant negative effect on the adoption of catch share programs. The coefficient estimate for the variable "Fishers" in Table 6 indicates that an increases in the number of fishermen by 1000 reduces the hazard rate by 0.004 percent. Table 7 shows that the variation in the number of fishermen can explain more of the variation in the hazard rate than any of the other variables. An increase in the number of fishermen by one standard deviation is associated

Table 6: Cloglog model - Country FE

	(1) Baseline	(2) Frailty	(3) Baseline 2	(4) Country FE
Managed				
Ln (Lagged price)	-0.204***	-0.209***	-0.190***	-0.140*
	(0.069)	(0.075)	(0.069)	(0.073)
Growth	-0.187	-0.205	-0.070	-0.020
	(0.156)	(0.167)	(0.146)	(0.147)
Fishers	-0.004***	-0.004***	-0.004***	0.034**
	(0.001)	(0.001)	(0.001)	(0.015)
GDP p.c.	-0.015	-0.019	-0.049***	0.079
	(0.011)	(0.013)	(0.011)	(0.063)
Agri VA	0.030***	0.035***	0.047***	-0.003
	(0.009)	(0.011)	(0.009)	(0.026)
Corruption	-0.732***	-0.803***	-0.490***	-1.129***
	(0.122)	(0.137)	(0.139)	(0.286)
Coastline	0.025*	0.035*	-0.018	
	(0.015)	(0.018)	(0.015)	
Collapsed	-0.611***	-0.591**	-0.579**	-0.492**
	(0.224)	(0.236)	(0.225)	(0.226)
Resource rents	0.005	0.006	0.092***	0.120
	(0.013)	(0.013)	(0.025)	(0.081)
Year FE	Yes	Yes	Yes	Yes
Country-Species RE	No	Yes	No	No
Country FE	No	No	No	Yes
N	56816.000	63155.000	18914.000	16021.000

Standard errors in parentheses

* p<0.1, ** p<0.05, *** p<0.01

Table 7: Predicted change hazard rate

	(1) Change
Ln (Lagged price)	-0.221
Growth	-0.136
Fishers	-4.892
GDP p.c.	-0.209
Agri VA	0.372
Corruption	-0.982
Coastline	0.073
Collapsed	-0.235
Resource rents	0.050
Observations	56816

Predicted increase in the hazard rate as the respective variable increases by one standard deviation.

with a reduction in the hazard rate by almost 5 percent.

This finding is in line with anecdotal evidence. Pascoe and Tingley (2010), Steinshamn (2010), Satia and Jallow (2010) and Nandakumar and Nayak (2010) highlight that concerns about employment in fisheries can be a key obstacle to sustainable management, both in developed and developing economies. It is thus not surprising that the number of fishermen is strongly negatively correlated with the introduction of catch share programs.

Moreover, fisheries in countries with a longer coastline are more likely to be managed. As the coastline increases by 1000 km, the hazard rate is predicted to increase by 0.025 percent. A longer coastline implies that a country has access to larger fishing grounds. Hence, this result suggest that access to fishing grounds could make management more likely. However, variation in the length of the coastline cannot explain much of the variation in the adoption of catch share programs. An increase in the coastline by one standard deviation is predicted to raise the hazard rate by merely 0.07 percent (see Table 7). This small effect of the coastline on the hazard rate could be due to the fact that the access to fishing grounds does not inform us about the availability of fish in the country's coastal area.

The finding that catch share programs are more likely in countries with a longer coastline and particularly in countries with fewer fishermen suggests that lower capacity in the fishing industry is favourable for the adoption of resource management. The positive coefficient estimate for the dummy variable "Collapsed", which indicates fisheries collapse, is in line with that interpretation. Governments are 0.73 percent less likely to introduce catch share programs in collapsed fisheries, given survival up to time $t-1$. This finding is surprising, considering the anecdotal evidence that poster child adopters of catch share programs like Canada and Iceland introduced catch share programs as a reaction to overfishing and declining fish stocks (see Parsons, 2010; Matthiasson and Agnarson, 2010). Yet, it is important to bear in mind, that fisheries collapse has become very prevalent over the course of our sample period. 21 percent of the unmanaged fisheries in our sample have collapsed by 2003. Fisheries collapse is less prevalent amongst the adopters of catch share programs. Despite the fact that catch share programs are often introduced in response to overfishing, governments in countries which embrace these rights-based management tools seem more likely to react before a serious crisis hits the fishery. This hints towards better governance in countries which introduce catch share programs.

The results support this idea. Governance is proxied though the variable "Corruption". The statistically significant negative coefficient estimate for this variable indicates that corruption hinders the adoption of catch share programs. Corruption is measured on a point scale with 6 points. An increase in the corruption indicator by one point is associated with a reduction in the hazard rate by 0.73 percent. Table 7 suggests that corruption is the second most important determinant for the adoption of catch share programs. An increase in the corruption indicator by one standard deviation is associated with a reduction in the hazard rate by 1 percent. This finding is in line with anecdotal evidence, which suggests that weak governance and corruption are important obstacles to sustainable fisheries management (see e.g. Williams and Staples, 2010; Satia and Jallow, 2010; Nandakumar and Nayak, 2010).

There is no statistically significant relationship between resource rents as a percentage of GDP and the introduction of fisheries management. Resource abundance does not seem to generate any spillovers that would lead to better management of a renewable resource like fisheries.

Moreover, the fish population growth rate and GDP per capita are not significantly related to the adoption of catch share programs. The summary statistics in Section 4 reveal that fisheries which introduce catch share programs are located in countries with higher GDP per capita. However, the correlation table 14 shows that GDP per capita is highly correlated with the agricultural value added per worker and corruption. It is, thus, possible that GDP per capita does not affect management once we have controlled for those two variables.

6 Sensitivity analysis

This section explores the sensitivity of our results. The discussion focuses on the relationship between the price and the introduction of catch share programs.

6.1 Individual heterogeneity

The results presented in our baseline regression exploit variation across country-species combinations as well as variation within country-species combinations across time. Our baseline model does not control for individual heterogeneity. This section explores whether controlling for country-species-specific heterogeneity changes the results.

We allow for country-species specific effects v which scale the hazard rate in the following way:

$$\theta(t, X, v) = v\theta(t, X) \tag{2}$$

The variable v is assumed to be independent of t and X. Models which allow for this type of heterogeneity are also called models with frailty in survival analysis.

The results for a regression which allows for country-species-specific heterogeneity are displayed in Column 2 of Table 6. The significance pattern and the magnitude of the coefficient estimates are very similar to the results in Column 1 of Table 6. A likelihood ratio test comparing the baseline model and the model with frailty allows us to conclude that individual heterogeneity is not important in the context of our analysis. Therefore, we focus on models without country-species-specific heterogeneity for the remainder of this paper.

6.2 Fixed effects in nonlinear panel models

The use of mixed models is based on the assumption that the individual effects are uncorrelated with the regressors. This is a very strong assumption. If we believe that there are unobserved individual effects which are correlated with the regressors, the use of fixed effects would be more appropriate.

Unfortunately, the nice properties of fixed effects estimators in linear panel data models do not translate to nonlinear models. The joint estimation of a large number of fixed effects and the slope parameters β can lead to inconsistent estimates in nonlinear models. Due to the large number of species and country-species combinations, the use of country-species fixed effects or species fixed effects is not viable.[14]

It is possible to use a model with country fixed effects. There are only 15 countries which adopt catch share programs in our sample. This means that the number of country dummy variables is small and unlikely to lead to inconsistent estimates, especially since the number of observations per country is large. The use of country dummy variables implies that the sample only contains observations from countries which adopt catch share

[14]One way of incorporating fixed effects into a nonlinear model is the conditional maximum likelihood estimation of a logit model. However, there are two downsides to this approach. Firstly, the conditional maximum likelihood estimation only uses observations which switch the status during the sample period. This implies that we would only use the 179 observations of country-fisheries combinations which adopt management in the course our sample period. This would reduce our sample size considerably.

programs at some point during the sample period. The observations from countries which do not introduce catch share programs at any point cannot be used since the country dummy variables perfectly predict the (non-)adoption of the catch share programs.

Since the use of country-fixed effects reduces the sample size, any change in the coefficient estimates could either be due to the smaller sample or due to the country fixed effects. In order to be able to distinguish between these two factors, we repeat the baseline regression for the smaller sample. The results are displayed in Column 3 of Table of Table 6. They show the same pattern as the results in the baseline regression.

Results for a regression using country fixed effects are presented in Column 4 of Table 6. The results corroborate the finding that the price is significantly negatively correlated with the introduction of catch share programs, fisheries collapse and corruption are significantly negatively correlated with the introduction of catch share programs.

The country-level control variables GDP per capita, agricultural value added and the resource rents do not seem to affect the adoption of catch share programs in a regression with country fixed effects. This is likely to be due to the low within variation of these variables.

6.3 Fixed effects in a linear probability model

Due to the complication of estimating fixed effects in a nonlinear panel model, we use a linear probability model with fixed effects as a robustness check. The structure of the dataset is unchanged and the observations are deleted from the dataset once management has been adopted. Hence, the dependent variable is the hazard rate, or the probability of introducing management in year t, conditional on the fishery being unmanaged in year $t-1$.

The regression results are presented in Table 8. The first column of Table 8 shows the results for a linear probability model without fixed effects. Those results can be used as a benchmark. Just as in the non-linear model, the results suggest a negative relationship between the price and the likelihood of introducing a catch share program. However, the estimated effect of the price on management is small. An increase in the price by one US$ per kilo is estimated to make the introduction of a catch share program 0.00013 percent less likely.

When country-fixed effects are added to the model, the relationship between the price and the probability of introducing catch share programs is negative but not statistically significant (see Column 2 of Table 8). This result differs from our findings in the nonlinear model, which suggested a negative relationship between the price and management even after controlling for country fixed effects. However, this difference may not only be due to poor fit of the linear probability model but also due to the differences in the sample size. In the nonlinear model with country-fixed effects, the sample only included observations of countries which adopt catch share programs during the sample period.

The linear probability model allows us to use species-fixed-effects. Those capture time-invariant factors which affect the decision to introduce catch share programs. Copes (1986), e.g., argues that species with unstable stocks, short-lived species or flash fisheries, in which fishing has to take place within a very short period of time, do not lend themselves to management via quotas. If any of these factors are correlated with the covariates in our model, the use of species-specific fixed effects avoids an omitted variable bias.

The results for a linear probability model with species-fixed effects are shown in Column 3 of Table 8. The results confirm a negative, albeit statistically insignificant relationship between the price and the introduction of catch share programs. The coefficient estimate for the price variable is slightly smaller, in absolute terms, than the regression without species fixed effects in Column 1 of Table 8. There are two possible explanations for that: Firstly, it is possible that time-invariant species characteristics are correlated with the price variable and that the coefficient estimate for the price variable is biased downward in the model without species-fixed effects. Secondly, the coefficient estimates could differ across the two models since they exploit different types of variation. The model without fixed effects exploits variation across species and suggests that lower-price species are less likely to be managed. The fixed effects model only exploits variation within species across time and across countries and suggests that an increase in the price of a species over time or across countries does not affect the decision to introduce a catch share program.

Country-species-pair fixed effects are more suitable to analyse the effect of variation in the price within countries-species across time on the adoption of catch share programs. The results for such a model are presented in Column 4 of Table 8. Those results suggest that an increase in the price of a particular species by one percent raises the probability of introducing catch limits by 0.00071 percent. The effect is statistically significant but small. This results is contrary to our previous findings but it is not robust. If we restrict the sample to the price data which were not estimated, the coefficient estimate for the price variable is not statistically significant.

6.4 No evidence of attenuation bias

Since part of the price data were estimated, they are likely to be measured with error. Measurement error leads to attenuation bias, unless the measurement error is uncorrelated with the estimated price variable. It is thus possible, that the coefficient estimates for the price variable are biased downwards, in absolute terms, due to measurement error.

In order to investigate whether measurement error drives the results, we estimate the baseline regression using only the price data which were not estimated. This reduces our sample size significantly and the number of fisheries that adopt catch share programs during the sample period drops to 53.

Table 8: Linear probability model with fixed effects

	(1)	(2)	(3)	(4)
Ln (Lagged price)	-0.00066***	-0.00036	-0.00016	0.00071**
	(0.00025)	(0.00025)	(0.00033)	(0.00029)
Growth	-0.00041*	-0.00006		
	(0.00022)	(0.00023)		
Fishers	-0.00000***	0.00000*	-0.00000*	-0.00000
	(0.00000)	(0.00000)	(0.00000)	(0.00000)
GDP p.c.	-0.00017***	0.00027	-0.00026***	0.00140***
	(0.00005)	(0.00020)	(0.00006)	(0.00026)
Agri VA	0.00025***	-0.00013	0.00031***	-0.00013
	(0.00007)	(0.00012)	(0.00008)	(0.00013)
Corruption	-0.00218***	-0.00054*	-0.00189***	-0.00104***
	(0.00023)	(0.00028)	(0.00024)	(0.00029)
Coastline	0.00049***		0.00067***	
	(0.00019)		(0.00026)	
Collapsed	-0.00165***	-0.00127**	-0.00167***	0.00008
	(0.00050)	(0.00052)	(0.00055)	(0.00077)
Resource rents	0.00004***	0.00005**	0.00002*	-0.00002
	(0.00001)	(0.00002)	(0.00001)	(0.00002)
Year FE	Yes	Yes	Yes	Yes
Country FE	No	Yes	No	No
Species FE	No	No	Yes	No
Country-Species FE	No	No	No	Yes
R^2	0.00843	0.02116	0.04139	0.00680
N	63155.00000	63155.00000	63155.00000	63155.00000

Cluster robust standard errors in parentheses

* p<0.1, ** p<0.05, *** p<0.01

The results for a regression using the small sample are displayed in Table 9. The negative coefficient estimate for the price variable is larger, in absolute terms, than in the baseline regression in Table 6 and statistically significant.

6.5 Results not driven by reverse causality

We can think of the introduction of management as a reduction in supply. This reduction in supply does not affect the price in a small open economy. In a closed economy, it could lead to an increase in the price. A similar outcome is possible if a country is a large supplier of a particular fish species on the world market. In order to avoid reverse causality, we use the price in period $t-1$ as a regressor in the baseline model. If the introduction of catch share programs is anticipated and the capacity of the country's fishing industry is reduced in anticipation of the quota, it is possible that the supply of fish declines even prior to the introduction of management. In that case, the use of the lagged regressor would not circumvent reverse causality. However, a reduction of fishing capacity in anticipation of the catch share program is unlikely to be very prevalent. If the fishery is profitable, fishermen are likely to reap these profits until the introduction of the catch limits. For the sake of completeness, we still investigate whether this type of reverse causality could cause a problem.

Lacking an instrumental variable for the price, we make use of trade data from FAO FishStat J in order to examine whether the relationship between the price and management differs across fisheries which are closed to trade, open to trade but small exporters and larger exporters. We only use observations which can be matched at the species level. This reduces the sample size to 3072 observations.

Using these trade data, fisheries are classified as closed if the country in which the fishery is located neither exports not imports a particular fish species. 217 out of 3072 observations for which we have trade data are fisheries which do not trade. Only 3 out of those adopt fisheries management. Moreover, we classify a country as a larger exporter of a particular fish species if it exports more than 50 percent of global exports. This applies to 315 observations in our sample. 6 of those observations are managed.

The price variable is interacted with the dummy variable for large exporters and the dummy variable for closed economies. The coefficient estimates for those variables reveal whether the relationship between the price and management differs across these different types of economies.

The regression result for a model including these interaction terms are displayed in Table 9. Column 1 of Table 9 shows the results for our baseline regression for the smaller sample for which we have trade data at the species level.

Column 2 of Table 9 shows the results for the regression using the interaction terms. As in Column 1, we find and negative and statistically significant relationship between

Table 9: Clolglog model

	(1) Price data	(2) Trade data	(3) Trade data
Managed			
Pr*large			0.483
			(0.337)
Pr*closed			-0.204
			(0.391)
Ln (Lagged price)	-0.483***	-0.394***	-0.419***
	(0.127)	(0.121)	(0.132)
Growth	0.090	-0.466	-0.454
	(0.291)	(0.505)	(0.523)
Fishers	-0.005**	-0.004	-0.003
	(0.002)	(0.003)	(0.003)
GDP p.c.	-0.153***	-0.030	-0.030
	(0.025)	(0.020)	(0.020)
Agri VA	0.092***	0.020	0.020
	(0.015)	(0.017)	(0.017)
Corruption	-1.292***	-0.779***	-0.761***
	(0.337)	(0.246)	(0.244)
Coastline	-0.067**	0.037	0.038
	(0.032)	(0.035)	(0.035)
Collapsed	-0.440	-0.488	-0.442
	(0.482)	(0.356)	(0.359)
Resource rents	0.170***	0.033	0.030
	(0.057)	(0.035)	(0.036)
Year FE	Yes	Yes	Yes
Country RE	No	No	No
Species RE	No	No	No
Country-Species RE	No	No	No
N	5008.000	3072.000	3072.000

Standard errors in parentheses

* p<0.1, ** p<0.05, *** p<0.01

the price and management. The coefficient estimate is slightly larger than in Column 1 in absolute terms. This suggest that the negative relationship between the price and the introduction of catch share programs pertains for small open fisheries in which the price does not react to a reduction in supply.

The coefficient estimate for the interaction term of the price variable with the dummy variable which indicates that a country is a large exporter of a particular fish species "Pr*large" is statistically insignificant. The same holds for the interaction term between the price and the dummy variable for closed fisheries "Pr*closed". Hence, there is no difference in the relationship between the price and the adoption of catch share programs across small open fisheries, closed fisheries and fisheries which are large exporters. The results in this Table 9 suggest that the coefficient estimate for the price variable is not biased due to reverse causality.[15]

7 Price and management - Discussion

The empirical analysis in this paper reveals a robust negative relationship between the price and the introduction of catch share programs. Governments seem more likely to introduce catch share programs for lower-priced species. This section investigates whether this finding is in line with existing theoretical models and discusses mechanisms which can potentially explain a negative relationship between the price and the introduction of catch share programs. Those explanations include social norms, rent-seeking and fishing costs. We also discuss whether the findings are in line with Copeland and Taylor (2009).

7.1 Social norms

The theoretical model by Sethi and Somanathan (1996) identifies one possible mechanism via which a higher price can hamper fisheries management. In Sethi and Somanathan (1996)'s evolutionary game-theoretic framework, harvesting restrictions are based on social norms. Sethi and Somanathan (1996) show that an increase in the price, which could be caused by opening up to trade, can lead to the collapse of social norms and resource management.

[15]We conducted a range of further robustness tests. The results are not sensitive to changes in the specification of the baseline hazard or changes in the functional form. Moreover, we investigate whether our results are affected by a simultaneous introduction of catch share programs for several species within a country. Robustness checks include aggregation to the country level, which yields a negative but statistically insignificant relationship between the price and the introduction of catch share programs. Clustering standard errors at the country level and using the disaggregate dataset confirms the results of our baseline regression. Since the panel is relatively long, we tried spliting the sample into 4 intervals of 5 years. This ensures that the results are not driven by comparisions of fisheries at the end of the sample period to fisheries at the beginning of the sample period. The results suggest either a negative or statistically insignificant relationship between the price and fisheries management.

Experimental economics research on public goods provides evidence which is consistent with this story. The literature suggests that individuals contribute more to the public good if the marginal payoff for contributing is higher (see e.g. Isaac et al. (1984) and the survey article by Ledyard (1995)).[16]

We can think about fisheries in a similar way in which we think about public goods.[17] As the price of fish increases, the marginal payoff from fishing increases and the monetary incentives to cooperate decline. If results from public good experiments can be translated to fisheries, an increase in the price of fish fosters overfishing and the collapse of harvesting restrictions based on social norms.

The empirical evidence from this paper is consistent with the mechanism suggested by Sethi and Somanathan (1996) and the findings from public goods experiments. We find that government are more likely to introduce catch share programs for lower priced species. There is one caveat: Sethi and Somanathan (1996)'s model does not directly apply to our analysis, since we study catch limits which are imposed by governments and not necessarily based on social norms. Customary use rights programs, such as the programs in the Philippines, Solomon Island, Vanuatu and Bangladesh are not in the sample and are thus not considered in this analysis. Yet, social norms and the willingness to cooperate could still facilitate the introduction of catch share programs due to reduction in monitoring and enforcement costs.

7.2 Rent-seeking

Rent-seeking is another mechanism that could explain the negative relationship between price and the introduction of catch shares.

Open access to fisheries is usually associated with rent dissipation. However, it is possible that governments have used other forms of regulation prior to the introduction of catch share programs. These could include input-based regulations like restriction on the days vessels can spend at sea, seasonal closures of fisheries or restrictions on the mesh size. Moreover, governments can limit participation in the fishing industry through limited fishing licences. Any of those measures could generate positive rents which could induce fishermen to lobby against the introduction of catch shares.

Anecdotal evidence evidence suggests that lobbying (see e.g. Nandakumar and Nayak,

[16] To be more precise, the experimental economics research looks at the marginal per capita return, which is equivalent to the marginal rate of substitution of the public good for the private good. The experiments show that an increase in the marginal per capita return improves cooperation (see e.g. Ledyard, 1995).

[17] Technically, a fishery is a common pool resource (CPR). CPRs differ from public goods since they are rival. However, Ledyard (1995) shows that both CPR games and public goods games can be analysed within a prisoner's dilemma framework. Ledyard (1995) argues that CPR experiments have the same structure as public goods experiments. Moreover, according to Apesteguia and Maier-Rigaud (2006) and Kingsley and Liu (2014), the findings in common pool experiments and in CPR games are qualitatively the same.

2010) and rent-seeking are not unusual in fisheries. Grafton (2005) argues that "[r]ent-seeking by groups of fishers is common in input-controlled fisheries and is promoted by arbitrary and insecure property rights" (Grafton, 2005, p. 760). Hence, it is worth investigating whether rent seeking can explain our findings.

As long as access to the fishery is limited and rents are not dissipated, fishermen may lobby against the introduction of catch share programs in order to avoid catch limits. Since lobbying is costly, lobbying against catch share programs is more likely to be worthwhile for higher-priced species, holding everything else constant. The theoretical model by Barbier et al. (2005) shows that an increase in the relative price of a non-renewable resource of increase in cumulative resource extraction, given that the government is sufficiently corrupt. A similar mechanism could explain the negative relationship between the price of fish and the introduction of catch share programs.

Moreover, lobbying or bribes for the government are more likely to prevent the adoption of catch share programs in corrupt countries. Hence, our finding of a negative relationship between corruption and the introduction of catch share programs lends further support to a rent-seeking story.

In a rent-seeking model, a higher price should hamper the introduction of catch share programs, particularly in corrupt countries. In order to test this hypothesis in our data, we interact the price with the corruption indicator. The results in Column 1 Table 10 suggests that an increase in the price facilitates resource management in corrupt countries. This finding is at odds with lobbying as underlying mechanism.

7.3 Rents and fishing cost

The theoretical literature on trade in renewable resources usually models trade openness as an exogenous increase in the price of the resource holding the fishermen's wage constant. Since labour is the only input into production, this implies that the factor costs remain constant. An increase in the price, thus, leads to higher rents.

Our analysis does not control for the cost of fishing due to a lack of data.[18] This lack of information on the cost side is not problematic, if rents are dissipated prior to the introduction of catch share programs. In that case, the marginal cost would be equal to the price. However, if rents are not dissipated, it is possible that lower-priced species generate higher rents than expensive species due to lower costs.

A thorough analysis of differences in the rents across fisheries would require information on fishing costs, which is very sparse. The best proxy variable for the cost of fishing in our analysis is fisheries collapse. Cost are likely to be higher in collapsed fisheries since the stocks are smaller and the fish is more difficult to locate. Our empirical evidence suggests

[18]Fishing costs cannot be captured by species-fixed effects since the stock size and overcapacity vary over time and fishing costs vary with those two factors.

that fisheries which adopt catch share programs are both less likely to be collapsed and lower-priced than the unmanaged comparison group. If fisheries collapse reflects fishing costs, this would imply that the profits per kilo of fish are not necessarily lower in the fisheries which introduce catch share programs than in unmanaged fisheries.

7.4 Are the findings in line with Copeland and Taylor (2009)?

The results from our baseline model reveal that overcapacity in a fishery does not foster the adoption of fisheries management. Fisheries with a large number of fishermen or with access to small fishing grounds are less likely to be managed. Moreover, good governance seems crucial for the introduction of catch share programs. Corrupt countries are significantly less likely to introduce these rights-based management tools. Governments are also less likely to introduce catch share programs for fisheries which have collapsed. This corroborates the previous two points since fisheries collapse is a sign of both overcapacity in the fishery and poor governance.

If we take corruption as a proxy for enforcement power, these findings are in line with Copeland and Taylor (2009) who argue that overcapacity and low enforcement power are not conducive to the management of renewable resources. However, the result of a negative relationship between the price and fisheries management are at odds with Copeland and Taylor (2009)'s theory. According to Copeland and Taylor (2009), fisheries with low overcapacity and high enforcement power introduce resource management as the price increases.

In order to verify whether the data support Copeland and Taylor (2009)'s predictions concerning the relationship between the price and fisheries management, we interact the price with proxies for overcapacity and enforcement power. Our measure for overcapacity is based on all country characteristics that determine overcapacity in Copeland and Taylor (2009)'s model. In the model, overcapacity depends on the population that could potentially go harvesting, on harvesting technology and on the resource growth rate. The corresponding proxies in our analysis are the number of fishermen, agricultural value added as well as the fish population growth rate. We define a fishery as having overcapacity if it satisfies all of the following three criteria: Firstly, the number of fishermen is higher than the median number of fishermen. Secondly, agricultural value added is higher than the median agricultural value added. Thirdly, the resource growth rate is lower than the median resource growth rate. In other words, a fishery is considered to have overcapacity if its characteristics are above the median along all dimensions which determine overcapacity. This measure for overcapacity is quite strict. Only 6204 out of the 56816 observations have overcapacity according to this definition. 23 fisheries which are defined to have overcapacity adopt management during the sample period.

According to the model, a fishery should be able to introduce resource management as

Table 10: Corrutpion, overcapacity, weight, value

	(1) Corruption	(2) Overcap.	(3) Weight	(4) Value
Managed				
Ln (Lagged price)	0.594*	0.611*		
	(0.339)	(0.342)		
Growth	-0.183	-0.186	-0.144	-0.140
	(0.154)	(0.154)	(0.148)	(0.147)
Fishers	-0.004***	-0.004***	-0.004***	-0.004***
	(0.001)	(0.001)	(0.001)	(0.001)
GDP p.c.	-0.018	-0.018	-0.014	-0.016
	(0.011)	(0.011)	(0.012)	(0.012)
Agri VA	0.030***	0.030***	0.019*	0.020**
	(0.009)	(0.009)	(0.010)	(0.010)
Corruption	-0.812***	-0.810***	-0.779***	-0.781***
	(0.128)	(0.128)	(0.129)	(0.130)
Coastline	0.021	0.020	0.032**	0.033**
	(0.015)	(0.015)	(0.016)	(0.016)
Collapsed	-0.610***	-0.611***	-0.564**	-0.548**
	(0.224)	(0.224)	(0.230)	(0.230)
Resource rents	0.006	0.005	0.007	0.007
	(0.012)	(0.012)	(0.012)	(0.012)
P*Corruption	0.158**	0.157**		
	(0.065)	(0.066)		
Pr*Overcapacity		-0.203		
		(0.204)		
L. Landed weight			0.569***	
			(0.126)	
L.Value of catch				0.819***
				(0.147)
Observations	56816.000	56816.000	51217.000	51217.000
Managed	179.000	179.000	165.000	165.000
N_Overcapacity		6204.000		
Overcap, Man		23.000		

Standard errors in parentheses

* p<0.1, ** p<0.05, *** p<0.01

the price increases if overcapacity and corruption are low. We thus expect the coefficient estimates for both variables to be negative.

The results are shown in Column 2 of Table 10. The direct effect of the price on the introduction of catch share programs is positive. A higher price is even more likely to foster the introduction of catch share programs in corrupt countries, as shown by the positive coefficient estimate for the interaction term "P*Corruption". Since less corruption is used as a proxy for more enforcement power, this finding contradicts Copeland and Taylor (2009)'s model, which predicts that an increase in the price leads to the introduction of fishing limits when enforcement power is high. However, we cannot reject Copeland and Taylor (2009)'s model based on the positive coefficient estimate for the interaction term ""P*Corruption", since the country-level variable "Corruption" may not be able to capture variations in enforcement power at the species level.

The coefficient estimate for the interaction term between the price and overcapacity "P*Overcapacity" is not statistically significant, indicating that the relationship between the price and catch share programs does not depend on overcapacity.

8 Landed weight and value

In their survey of catch share programs in developing countries, Jardine and Sanchirico (2012) point out that several low-price species which introduce catch share programs are forage fish which are caught in large quantities. The total value of landings in these fisheries is, thus, likely to be high, despite the low price. This section analyses whether this pattern holds true in our data.

Information on the landed weight and the value of landings is from Swartz et al. (2012). The landed weight is measured in million tonnes and the value of the catch is measured in billions of constant US$. We use the lag of the respective variables as regressors in the baseline regression instead of the price variable.

The results in Column 1 of Table 10 show that the landed weight is significantly positively correlated with the introduction of catch share programs and Column 2 of Table 10 reveals that more valuable fisheries are more likely to be managed. An increase in the value of landings by 1 billion US$ is estimated to raise the hazard rate by 0.8 percent. The effect is small, especially considering the fact that the average value of landings is 20 million US$. An increase in the value of the catch by one standard deviation is associated with an increase in the hazard rate by merely 0.1.

The statistically significant and positive coefficient estimate for the total value of landings is in line with Jardine and Sanchirico (2012)'s hypothesis that "catch shares are motivated by the value of the resource. If costs are associated with the development and enforcement of catch shares, designing these systems around low-value resources may yield negative net benefits to program adoption" (Jardine and Sanchirico, 2012, p. 1251).

9 Other measures for trade openness

The theoretical literature on trade in renewable resources models trade openness though an exogenous increase in the relative price of the resource. Therefore, the price has been a key variable in the analysis. This section, however, explores the relationship between the introduction of catch share programs and a range of other indicators for trade openness. We draw on trade data at the species level which are available from the FAO's FishStat J. The matching is described in detail in Section 3.

Our measure for trade openness is defined at the country-species level. Trade openness of country i to trade in species j in year t is measured as

$$\text{Openness}_{ijt} = \frac{\text{Export value}_{ijt} + \text{Import value}_{ijt}}{\text{Catch (value)}_{ijt} + \text{Aquaculture (value)}_{ijt}} \tag{3}$$

Due to potential reverse causality, we follow the same approach as in the baseline model and analyse the effect of trade openness in period $t-1$ on the introduction of catch share programs in period t.

The regression results in Column 1 of Table 11 suggest that trade openness at the species level is not a significant determinant of the adoption of catch share programs. The coefficient estimate for the variable "Open (Lag)" is negative but statistically insignificant.[19]

In this regression, the introduction of catch share programs is only significantly correlated with corruption and GDP per capita. The coefficient estimates for all other variables are not significantly different from zero. This may be due the the small number of observations for which we can match trade data and data on the price and landings at the species level. There are only 3127 observations in the sample and only 53 adoptions of catch share programs.

The behaviour of exporters is of particular relevance. Exporting increases the pressure on the resource. Hence, it is worthwhile investigating whether exporting as such affects the introduction of catch share programs. We use a dummy variable which takes the value of one if a country i is a net exporter of fish species j in year $t-1$ and regress this variable on the introduction of catch share programs in year t. The coefficient estimate for the variable "Net exporter (Lag)" in Column 3 of Table 11 suggests that there is no statistically significant relationship between being a net exporter of species j and introducing a catch share program for species j.[20]

Moreover, we explore whether fisheries which export a larger fraction of their catch are

[19]Trade data at the species level are only available for a subset of our sample. In order to test the sensitivity of our results to sample selection issues, we aggregate the data to the level of the ISSCAAP groups. At this level of aggregation, it is possible to match all of the trade data with the rest of the dataset and use the full sample. The results confirm a statistically insignificant relationship between trade and the introduction of catch share programs.

[20]The results are similar if the dummy variable take a value of one if a country is an exporter rather than a net exporter.

Table 11: Trade

	(1)	(2)	(3)	(4)	(5)
Managed					
Open (Lag)	-0.0014				
	(0.0012)				
Net exporter (Lag)		0.5034			
		(0.6165)			
Export/Prod. (Lag)			-0.0021		
			(0.0023)		
Export value (Lag)				0.0015*	
				(0.0009)	
Net exports (Lag)					0.0018**
					(0.0009)
Growth	0.2841	-0.1256	0.1542	-0.0118	0.0925
	(0.4063)	(0.5423)	(0.4163)	(0.3959)	(0.3863)
Fishers	-0.0035	-0.0010	-0.0050*	-0.0049*	-0.0034
	(0.0031)	(0.0020)	(0.0029)	(0.0029)	(0.0031)
GDP p.c.	-0.0307	-0.0452**	-0.0212	-0.0274	-0.0393*
	(0.0203)	(0.0227)	(0.0179)	(0.0188)	(0.0211)
Agri VA	0.0131	0.0283	0.0137	0.0051	0.0145
	(0.0177)	(0.0185)	(0.0152)	(0.0163)	(0.0179)
Corruption	-0.8792***	-0.9199***	-0.7244***	-0.7627***	-0.8678***
	(0.2509)	(0.3067)	(0.2149)	(0.2247)	(0.2520)
Coastline	-0.0117	0.0022	0.0255	0.0379	-0.0109
	(0.0456)	(0.0488)	(0.0268)	(0.0277)	(0.0458)
Collapsed	-0.1737	-0.6221	-0.3771	-0.4640	-0.3402
	(0.3624)	(0.5563)	(0.3355)	(0.3346)	(0.3589)
Resource rents	0.0456	0.0440	0.0297	0.0302	0.0372
	(0.0327)	(0.0421)	(0.0287)	(0.0307)	(0.0357)
Observations	3127.0000	1635.0000	4699.0000	4339.0000	3127.0000
Managed	53.0000	37.0000	69.0000	67.0000	53.0000

Standard errors in parentheses

* $p<0.1$, ** $p<0.05$, *** $p<0.01$

more or less likely to introduce catch share programs. We use the lag of exports relative to domestic production as a regressor instead of the measure of openness. The results are displayed in Column 2 of Table 11. They show that the introduction of catch share programs is not significantly related to the percentage of domestic production which is exported. The variable "Export/Production" is not statistically significant. Hence, there is little evidence to suggest that exporting a larger fraction of domestic catch affects the decision to adopt a catch share program.

However, the data show that species which generate larger export earnings are more likely to be managed. We use the lag of the export value, measured in millions of constant 2005 US$ as a regressor. The results in Column 4 of Table 11 show that an increase in the export value by 1 million US$ in period $t-1$ raises the likelihood that a government introduces a catch share program in period t by 0.001 percent, given survival up to period $t-1$. With a standard deviation of 75, an increase in the net export value by one standard deviation is associated with an increase in the hazard rate by 0.11 percent.

The results are similar if we use the *net* export value rather than the export value. The net export value is defined as the export value minus the import value. An increase in the lagged net export value by one million US$ is estimated to raise the likelihood of introducing a catch share program by 0.002 percent. This is obvious from the coefficient estimate for the variable "Net exports (Lag)" in Column 5 of Table 11. Since the standard deviation of the net export value is 99.3, the hazard rate is predicted to increase by 0.18 percent as the net export value increases by one standard deviation.

The positive relationship between the export value and the adoption of catch share programs is opposed to our expectations based on anecdotal evidence. Satia and Jallow (2010, p. 259), e.g., argue that fisheries exports are an important source of revenue needed to service local debt for a lot of West African countries. Similarly, India used fisheries exports as a source of foreign exchange revenue in the 1970s (Nandakumar and Nayak, 2010, p. 280). Both in West Africa and in India, increasing fisheries exports were not accompanied by sustainable fisheries management. However, these examples seem to be the exception rather than the norm. Most countries can earn foreign exchange from exports of other products.

According to the results which were presented in this section, trade affects fisheries management only in one way. It creates an export market on which the landings can be sold. This increases the value of the fishery. The fact that the introduction of catch share programs is higher for species with a larger export value is in line with the finding in Section 8, which suggested that more valuable fisheries are more likely to be managed. Part of this value seems to be created via exports.

10 Conclusion

This paper studies the factors which motivate governments to introduce catch share programs. Our focus is on the role of international trade in fisheries management. The theoretical literature on trade and renewable resources models international trade through an exogenous change in the price of the resource. Hence, the effect of the price on the introduction of catch share programs is at the core of this paper. However, we also explore the conditional correlation between the price and other measures for trade openness.

Our results reveal a robust negative relationship between the price and a government's decision to manage a fishery via catch limits. Three mechanisms can potentially explain this finding. Firstly, an increase in the price could lead to a collapse of social norms and thus hamper fisheries management. Secondly, a higher price could foster lobbying efforts against catch limits and thus halt their introduction, particularly in corrupt countries. Thirdly, the result could be explained by different fishing costs across species. Low fishing cost per kilo of catch could also explain why the average landed weight is considerably higher in the fisheries which introduce catch share programs. This paper cannot provide a definite answer which of these channels prevails, mostly due to a lack of relevant data on lobbying efforts and fishing costs. Further research is necessary to understand the factors which drive the negative relationship between the price and the introduction of catch share programs.

Fisheries which introduce catch share program are more valuable than their unmanaged counterparts due to higher volumes of landings, despite the low price per kilo. The overall value of a fishery is significantly positively correlated with rights-based management approaches. Part of this value is generated on export markets and the results suggest that fisheries with higher export values are more likely to introduce catch share programs. According to Jardine and Sanchirico (2012), the total value of a fishery is an important consideration for governments due to the high cost involved in setting up and enforcing those programs.

This study does not find a statistically significant effect of openness to international trade, measured as the sum of exports and imports relative to domestic production of the respective fish species, on the introduction of catch share programs. Moreover, the likelihood that a government introduced catch share programs does not differ significantly between fisheries which export their products and those which do not.

The empirical results presented in this paper do not allow us to conclude that trade is either good or bad for fisheries management. Our analysis uses several measures to capture openness to international trade. The different measures point in different directions. Future research should try to find more conclusive results and explain the precise channels via which trade affects the management of renewable resources.

References

Apesteguia, J. and Maier-Rigaud, F. P. (2006). The Role of Rivalry: Public Goods Versus Common-Pool Resources. *Journal of Conflict Resolution*, 50(5):646–663.

Barbier, E. B., Damania, R., and Léonard, D. (2005). Corruption, trade and resource conversion. *Journal of Environmental Economics and Management*, 50(2):276–299.

Cheung, W. W. L. and Sumaila, U. R. (2015). Economic incentives and overfishing: a bioeconomic vulnerability index. *Marine Ecology Progress Series*, 530:223–232.

Connor, R. and Shallard, B. (2010). Evolving governance in New Zealand fisheries. In Grafton, R. Q., Hilborn, R., Squires, D., Tait, M., and Williams, M. J., editors, *Handbook of Marine Fisheries Conservation and Management*, chapter 26, pages 347–359. Oxford University Press, New York.

Copeland, B. and Taylor, M. (2009). Trade, Tragedy, and the Commons. *American Economic Review*, 99(3):725–749.

Copeland, B. and Taylor, M. S. (2003). *Trade and the environment: Theory and evidence.* Princeton University Press, Princeton, N.J.

Copes, P. (1986). A Critical Review of the Individual Quota as a Device in Fisheries Management.

Costello, C., Gaines, S. D., and Lynham, J. (2008). Can catch shares prevent fisheries collapse? *Science (New York, N.Y.)*, 321(5896):1678–81.

Costello, C., Ovando, D., Hilborn, R., Gaines, S. D., Deschenes, O., and Lester, S. E. (2012). Status and solutions for the world's unassessed fisheries. *Science*, 338(6106):517–520.

Demsetz, H. (1967). Toward a theory of property rights. *American Economic Review*, 52(2):347–359.

FAO (1999). Numbers of fishers 1970-1997. C929Rev.2. *FAO Fisheries Circular*, C929Rev.2.

FAO (2014). *FAO yearbook. Fishery and Aquaculture Statistics. 2012.* FAO, Rome.

FAO (2016). *The State of World Fisheries and Aquaculture 2016: Contributing to Food Security and Nutrition for all.* FAO, Rome.

Fenske, J. (2014). Imachi Nkwu: Trade and the Commons. *The Journal of Economic History*, 74(1):39–68.

Grafton, R. Q. (2005). Social capital and fisheries governance. *Ocean and Coastal Management*, 48(9-10):753–766.

Grossman, G. and Helpman, E. (1993). Environmental Impacts of the North American Free Trade Agreement. In Garber, P., editor, *The U.S. Mexico Free Trade Agreement*. MIT Press, Cambridge, MA.

Hotte, L., Long, N. V., and Tian, H. (2000). International trade with endogenous enforcement of property rights. *Journal of Development Economics*, 62(1):25–54.

Isaac, R. M., Walker, J. M., and Thomas, S. H. (1984). Divergent evidence on free riding: An experimental examination of possible explanations. *Public Choice*, 43(2):113–149.

Jardine, S. L. and Sanchirico, J. N. (2012). Catch share programs in developing countries: A survey of the literature. *Marine Policy*, 36(6):1242–1254.

Jenkins, S. (2005). *Survival Analysis*. Available at https://www.iser.essex.ac.uk/files/teaching/stephenj/ec968/pdfs/ec968lnotesv6.pdf, accessed on 01/12/2014.

Kingsley, D. C. and Liu, B. (2014). Cooperation across payoff equivalent public good and common pool resource experiments. *Journal of Behavioral and Experimental Economics*, 51:79–84.

Ledyard, J. O. (1995). Public goods: A survey of experimental research. In Kagel, J. H. and Roth, A. E., editors, *Handbook of Experimental Economics*, pages 111–194. Princeton University Press, Princeton.

Matthiasson, T. and Agnarson, S. (2010). Property Rights in Icelandic Fisheries. In Grafton, R. Q., Hilborn, R., Squires, D., Tait, M., and Williams, M. J., editors, *Handbook of Marine Fisheries Conservation and Management*, chapter 22, pages 299–309. Oxford University Press, New York.

Nandakumar, D. and Nayak, N. (2010). Coastal Fisheries in India: Current Scenario, Contradictions, and Community Responses. In Grafton, R. Q., Hilborn, R., Squires, D., Tait, M., and Williams, M. J., editors, *Handbook of Marine Fisheries Conservation and Management*, pages 274–286. Oxford University Press, New York.

Parsons, L. S. (2010). Canadian marine fisheries management: A case study. In Grafton, R. Q., Hilborn, R., Squires, D., Tait, M., and Williams, M. J., editors, *Handbook of Marine Fisheries Conservation and Management*, chapter 30, pages 393–414. Oxford University Press, New York.

Pascoe, S. and Tingley, D. (2010). Fisheries Mangement in the United Kingdom. In Grafton, R. Q., Hilborn, R., Squires, D., Tait, M., and Williams, M. J., editors, *Handbook of Marine Fisheries Conservation and Management*, chapter 27, pages 370–371. Oxford University Press, New York.

Pinsky, M. L., Jensen, O. P., Ricard, D., and Palumbi, S. R. (2011). Unexpected patterns of fisheries collapse in the world's oceans. *Proceedings of the National Academy of Sciences*, 108(20):8317–8322.

San Martín, G., Parma, A. M., and Orensaz, J. L. (2010). The Chilean experience with territorial use rights in fisheries. In Grafton, R. Q., Hilborn, R., Squires, D., Tait, M., and Williams, M. J., editors, *Handbook of Marine Fisheries Conservation and Management*, chapter 23, pages 324–337. Oxford University Press, New York.

Satia, B. P. and Jallow, A. M. (2010). West African Coastal Capture Fisheries. In Grafton, R. Q., Hilborn, R., Squires, D., Tait, M., and Williams, M. J., editors, *Handbook of Marine Fisheries Conservation and Management*, chapter 19, pages 258–273. Oxford University Press, New York.

Sethi, R. and Somanathan, E. (1996). The evolution of social norms in common property resource use. *The American Economic Review*, 86(4):766–788.

Steinshamn, S. I. (2010). Norwegian Fisheries Management. In Grafton, R. Q., Hilborn, R., Squires, D., Tait, M., and Williams, M. J., editors, *Handbook of Marine Fisheries Conservation and Management*, chapter 27, pages 360–369. Oxford University Press, New York.

Swartz, W., Sumaila, R., and Watson, R. (2012). Global ex-vessel fish price database revisited: A new approach for estimating 'missing' prices. *Environmental and Resource Economics*, 56(4):467–480.

Tajibaeva, L. S. (2012). Property Rights, Renewable Resources and Economic Development. *Environmental and Resource Economics*, 51(1):23–41.

Taylor, M. S. (2011). Buffalo hunt: International trade and the virtual extinction of the North American bison. *American Economic Review*, 101(December 2011):3162–3195.

Vetemaa, M., Eschbaum, R., and Saat, T. (2006). The transition from the Soviet system to a market economy as a cause of instability in the Estonian coastal fisheries sector. *Marine Policy*, 30:635–640.

Watson, R. and Kitchingman, A. (2004). Mapping global fisheries: sharpening our focus. *Fish and Fisheries*, 5:168–177.

Williams, M. J. and Staples, D. (2010). Southeast Asian Fisheries. In Grafton, Q. R., Hilborn, R., Squires, D., Tait, M., and Williams, M. J., editors, *Handbook of Marine Fisheries Conservation and Management*, chapter 18, pages 243–257. Oxford University Press, New York.

Worm, B., Barbier, E. B., Beaumont, N., Duffy, J. E., Folke, C., Halpern, B. S., Jackson, J. B. C., Lotze, H. K., Micheli, F., Palumbi, S. R., Sala, E., Selkoe, K. A., Stachowicz, J. J., and Watson, R. (2006). Impacts of biodiversity loss on ocean ecosystem services. *Science (New York, N.Y.)*, 314(5800):787–90.

11 Appendix

Table 12: Location of fisheries management with missing start year

	(1) freq	pct	cumpct
Belgium	2	2.15	2.15
Canada	13	13.98	16.13
Finland	9	9.68	25.81
Germany	9	9.68	35.48
Grenada	2	2.15	37.63
Latvia	3	3.23	40.86
Lithuania	8	8.60	49.46
Malta	1	1.08	50.54
Norway	10	10.75	61.29
Papua New Guinea	13	13.98	75.27
Poland	3	3.23	78.49
Portugal	3	3.23	81.72
South Africa	6	6.45	88.17
Sweden	11	11.83	100.00
Total	93	100.00	

Table 13: Adoption of management programs by year

	(1) freq	pct	cumpct
1984	11	6.15	6.15
1985	7	3.91	10.06
1986	1	0.56	10.61
1988	6	3.35	13.97
1989	3	1.68	15.64
1990	9	5.03	20.67
1991	21	11.73	32.40
1992	27	15.08	47.49
1993	1	0.56	48.04
1994	5	2.79	50.84
1995	4	2.23	53.07
1996	2	1.12	54.19
1997	12	6.70	60.89
1998	4	2.23	63.13
1999	36	20.11	83.24
2001	12	6.70	89.94
2002	8	4.47	94.41
2003	10	5.59	100.00
Total	179	100.00	

Table 14: Correlation table

	(1)										
	Managed	Ln (Lagged price)	Growth	Fishers	GDP p.c.	Agri VA	Corruption	Coastline	Collapsed	Resource rents	Open (Lag)
Managed	1.00										
Ln (Lagged price)	-0.00	1.00									
Growth	-0.01*	-0.07***	1.00								
Fishers	-0.01***	-0.16***	0.07***	1.00							
GDP p.c.	0.05***	0.23***	-0.10***	-0.20***	1.00						
Agri VA	0.06***	0.20***	-0.09***	-0.19***	0.88***	1.00					
Corruption	-0.06***	-0.21***	0.09***	0.22***	-0.68***	-0.57***	1.00				
Coastline	0.05***	-0.06***	-0.00	0.09***	0.22***	0.31***	-0.21***	1.00			
Collapsed	-0.01	-0.01	-0.04***	-0.08***	0.07***	0.06***	-0.06***	0.01*	1.00		
Resource rents	-0.02***	-0.10***	0.04***	0.00	-0.31***	-0.29***	0.37***	-0.03***	-0.03***	1.00	
Open (Lag)	-0.01	-0.08***	0.01	-0.01	0.03	0.01	-0.05***	-0.02	0.03*	-0.02	1.00

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$