Do exports of renewable resources lead to resource depletion? Evidence from fisheries*

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In the case of fisheries, exports are an important cause of resource depletion. This paper uses novel and detailed country-species-level fisheries data to estimate the causal effect of a fishery's exports on the collapse of the fishery. Identification is based on an export demand shock originating from Japan. The results reveal that an increase in logged exports by one standard deviation raises the likelihood of a fishery's collapse in the following period by 23 percentage points. Only fisheries without fishing quotas collapse as a result of exports.

JEL codes: Q27, Q22, F18

Keywords: Trade in renewable resources, resource depletion, trade in fishery products, overfishing, fisheries collapse

*I thank Christopher Costello, Nils Framstad, Bård Harstad, Benjamin Olken, Frederik Noak, Linda Nøstbakken, Rick van der Ploeg, Maarten Punt, Martin Quaas, Chiara Ravetti, Anouk Rigterink, Daniel Spiro, Gerhard Toews, Tony Venables, three anonymous referees and the Sustainable Fisheries Group at the UC, Santa Barbara for very helpful comments on this paper. This paper has benefited from suggestions by participants at the BIOECON and EAERE conferences 2017, the SURED conference 2018, the INRA conference on Public Choices in the Context of Global Chaanges and at the Energy and Resource Economics Workshop at the Christian-Albrechts-University Kiel. Moreover, I thank seminar participants at the University of Oxford, UC, Berkeley, Columbia University, UC, Santa Barbara, the Rosenstiel School for Marine and Atmospheric Science, Georgia State University, Virginia Tech, the University of Exeter, the University of Groningen, the University of Heidelberg, TU Dresden and the University of Oslo for constructive comments. Finally, I am grateful to Rashid Sumaila and the Institute for the Oceans and Fisheries at the University of British Columbia well as Christopher Costello and Tyler Clavelle for access to part of the data used in this paper.

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1 Introduction

The depletion of renewable resources is becoming ever more prevalent. Forest cover loss, fisheries collapse and the endangered status of rhinos and thousands of other animal and plant species are prominent examples (FAO, 2016*a*; Pinsky et al., 2011; Costello et al., 2012; IUCN, 2018). Even though renewable resources are important export products in the developing world, we still have a poor understanding of the extent to which trade contributes to resource depletion. Empirical studies on trade in renewable resources are limited by at least one of the following three factors: lack of causal inference, lack of species level information on trade flows and resource stocks and lack of external validity due to a focus on selected species. Existing research focuses on the effect of trade in forest products (Ferreira, 2004; Tsurumi and Managi, 2014; Faria and Almeida, 2016), ivory (Barbier et al., 1990) and buffalos hides (Taylor, 2011). Causal insights on the effect of fisheries exports on fish stocks are missing.

This paper uses novel and detailed fisheries data to estimate the causal effect of fisheries exports on the collapse of fisheries. I employ a novel identification strategy, using an export demand shock originating from Japan as an instrument for exports in the rest of the world. The use of country-species-year level data on trade in fishery products yields detailed insights about the way exports affect the collapse of numerous different fish species. Moreover, the paper highlights the importance of institutions. The results suggest that an increase in exports leads to a large increase in the likelihood of a collapse, especially in fisheries that are not regulated via quotas or other rights-based fisheries management tools.

Fisheries are a particularly interesting resource to study since they are both highly traded and threatened by resource collapse. 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*b*). At the same time, the world's fisheries are overfished and between 17% and 25% of the world's fisheries have collapsed (Pinsky et al., 2011; Costello et al., 2012). This begs the question whether exports cause the collapse of fisheries.

Insights on the effect of fisheries exports on fisheries collapse are especially important for developing countries, which produce more than half of global fisheries exports (FAO, 2016*b*). In the developing world, fisheries generate up to 50% of export revenue (Bellmann, Tipping and Sumaila, 2016) as well as employment for more than 37 million people (FAO, 2016*b*). Moreover, fish is an important source of animal protein for consumers around the world. Yet, all of these benefits are short-lived if fisheries collapse as a result of exports.

From a theoretical point of view, open access renewable resources do not necessarily collapse in exporting countries. Brander and Taylor (1997*a*,*b*, 1998); Chichilnisky (1994) and Hannesson (2000) show that the resource stock declines when a country exports an open access renewable resource. However, only Copeland and Taylor (2006) and Gars and Spiro (2018) discuss the possibility of a resource collapse in countries which export renewable resources.

To guide the empirical estimation, I illustrate that exports can cause the collapse of an open access renewable resource that is viable in autarky. The illustration is based on a Ricardian model similar to Brander and Taylor (1997*a*) and Copeland and Taylor (2006) and I focus on a situation in which a trade liberalization is associated with an exogenous increase in the resource price. This increase in the price makes harvesting more lucrative and, as a result, the country harvests more and exports the renewable resource. Since harvest exceeds resource growth, the resource stock shrinks over time. At high world market prices, exporting can lead to the collapse of an open access renewable resource if harvesting capacity is high relative to the resource growth rate.

The empirical analysis provides the first estimate of the causal effect of fisheries exports on the collapse of fisheries. I use a standard definition of fisheries collapse (see e.g. Worm et al., 2006; Costello, Gaines and Lynham, 2008) and define a species in a particular country as collapsed if catch is below 10 percent of the maximum catch recorded since 1950. This approach is necessary since scientific stock assessments are only available for a very small number of fish stocks globally. Moreover, export data at the species level are not always available for the fisheries with stock assessments.

The collapse of Japanese fisheries is used as an instrument for exports of fishery products in order to make causal inference. Since Japan is one of the largest markets for seafood products, the collapse of a Japanese fishery raises the world market price of the affected species and spurs exports from other countries. Therefore, the collapse of a Japanese fishery is positively correlated with exports in other countries. The instrumental variable estimation in necessary since both exports and the likelihood of a collapse in the following year depend on the size of the fish stock, which is unobserved. Therefore, the results from a simple OLS regression would be biased downwards.

The empirical strategy takes two steps to ensure that trade is the only channel via which a collapse in Japan can affect a collapse in the exporting country. Firstly, the sample does not include fisheries that are shared between Japan and the exporter. When stocks are shared, a collapse of a species in Japan could directly affect the collapse in the exporting country. Secondly, I control for other economic, biological and climatic factors which could lead to the collapse of a fish species in both countries.

I construct a comprehensive country-species level panel dataset which allows me to get both detailed and broadly applicable insights on the effect of exports on resource depletion. Insights are detailed since I link trade flows to data on fisheries collapse for every species in every country in the dataset. Every country-species combination represents one fishery in the context of this paper. The panel dataset covers around 100 countries and more than 100 fish species from 1976 to 2006. Due to the large number of species in the dataset, the results provide more external validity than most other studies in the literature on trade in renewable resources.

The paper shows that exports significantly contribute to the collapse of fisheries. The results suggest that an increase in exports by one percent raises the likelihood of a fishery's collapse in the following year by around 0.1 percentage points. This is a large effect, particularly considering the surge in exports of fishery products in the last few decades. Exports in the median fishery grew by 144 percent between 1976 and 2006. According to the estimates, this export boom raised the likelihood of a collapse by around 12.5 percentage points. This predicted increase in fisheries collapse is equivalent to more than two thirds of the observed increase in the percentage of collapsed fisheries by 18 percentage points.

I find that exports only lead to a collapse of fisheries that are not regulated through quotas or other rights-based fisheries management tools.[1] Therefore, the result of this paper is not to call for trade restrictions for fishery products, but rather for the implementation of sustainable fisheries management. Developing countries which rely heavily on income and export revenue from fisheries would likely benefit most from the adoption of sustainable regulations to guarantee long-term gains from fisheries exports.

[1] This is in line with the literature's finding that trade openness leads to the overharvesting of renewable resources, particularly if they are unregulated (see e.g. Barbier et al., 1990; Taylor, 2011; Ferreira, 2004). Please see Bulte and Barbier (2005), Fischer (2010) and Copeland (2011) for more comprehensive reviews of the literature on trade in renewable resources.

This paper contributes to the existing empirical literature on trade in renewable resources in three main ways. First, it estimates the causal effect of exports on the depletion of a renewable resource. Thus far, only Taylor (2011) provides convincing causal estimates of the effect of exports of bison hides on the near extinction of the North American bison.

Second, this paper provides better estimates of the effect of resource exports on resource depletion since it uses species level data on export quantities as well as data on trade barriers for fishery products in major seafood markets. Existing papers (see e.g Ferreira, 2004; Faria and Almeida, 2016; Erhardt, 2018) use country level exports plus imports relative to GDP as a proxy for trade openness. These proxies provide limited information on trade in renewable resources.

Finally, this paper analyses the effect of fisheries exports on the depletion of fisheries, whereas most of the existing literature focuses on other resources. To the best of my knowledge, Erhardt and Weder (2015) and Erhardt (2018) provide the only empirical analyses of the relationship between trade openness and overfishing. However, neither of those papers can quantify the effect of fisheries exports on the depletion of fisheries due to a lack of fisheries trade data.[2] The use of both detailed and comprehensive fisheries trade data and a novel instrumental variable allow me to remedy short-comings of Erhardt and Weder (2015) and Erhardt (2018)'s papers and, for the first time, estimate the causal effect of exports from a particular fishery on the collapse of that fishery.

This paper is structured as follows. Section 2 illustrates the theoretical background for the analysis. The empirical strategy is presented in Section 3, which discusses the potential bias in the OLS regression and explains the choice of the instrument as well as the estimating equation. Section 4 describes the construction on the novel dataset and Section 5 describes the relevant patterns in the data. The results from a benchmark OLS regression and an instrumental variable regression are presented in Section 6. Section 7 shows that the effect of exports depends on fisheries management and presents further heterogenous effects which are in line with the paper's theoretical hypotheses. Dynamics are discussed in Section 8. This

[2] Erhardt (2018) investigates the effect of trade openness on the percentage of collapsed species at the country level. He uses country-level exports plus imports relative to GDP and a country-level index for globalization as very crude proxies for trade in fishery products. Erhardt and Weder (2015) find a positive correlation between a shark species' IUCN red list status and a dummy variable, which indicates whether a shark species is traded internationally, but do not provide causal insights.

is followed by a sensitivity analysis in Section 9. Section 10 concludes.

2 Theoretical illustration: Exporting can lead to the collapse of fisheries

This section uses a simple Ricardian trade model like Brander and Taylor (1997*a*) and Copeland and Taylor (2006) to derive the hypotheses for the empirical analysis and illustrate under which circumstances exporting can lead to the collapse of a fishery that is viable in autarky. The discussion focuses on a situation in which opening up to trade is associated with an exogenous increase in the price of fish. As a result of this increase in the price, fishing becomes more lucrative and the country instantly produces and exports more fish. Due to this additional fishing pressure, the catch of fish exceeds resource growth and the stock declines over time. At high world market prices, a fishery can collapse if fishing capacity is high relative to the resource growth rate.

This section provides an intuitive explanation of the way trade affects the fishery. Technical details are deferred to Section 11 in the Appendix.

2.1 Model setup

The economy consists of two industries: Fishing and manufacturing. The total labour supply is L_T. L_H workers are employed in the fishing industry and the manufacturing industry employs L_M workers.

Manufacturing production technology is given by $M = L_M$. The price of the manufacturing product is normalized to 1. Therefore, the wage rate in manufacturing equals $w = 1$. Labour is assumed to be mobile across industries and hence the wage rate in fishing must also equal 1 in a diversified economy.

Prior to a description of the fishing industry, I explain the resource stock dynamics. In every period, the fish stock is given by $S(t)$. Changes in the fish stock dS/dt are a function of natural resource growth $G(S(t))$ and fishing $H(t)$, such that

$$dS/dt = G(S(t)) - H(t). \tag{1}$$

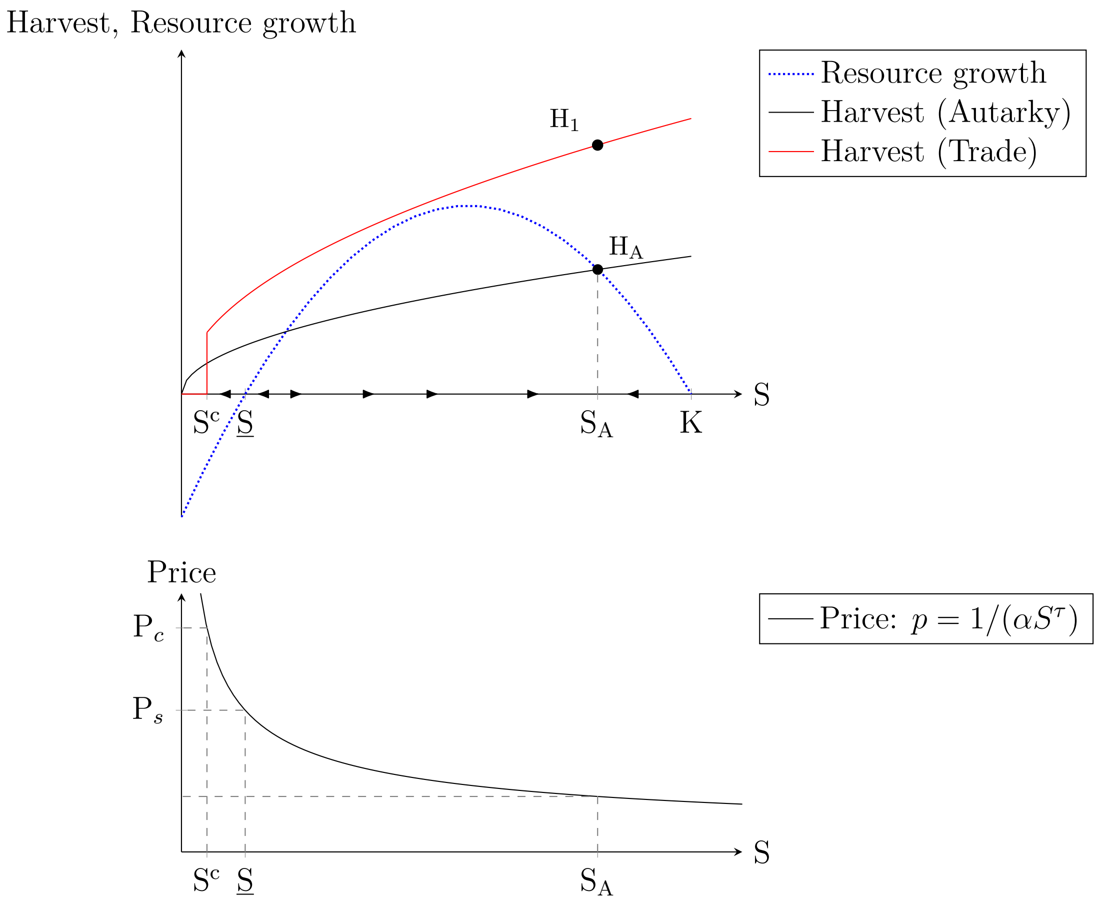
Natural resource growth is characterized by a commonly used logistic function with an intrinsic resource growth rate r and a carrying capacity K. Following

Copeland and Taylor (2006), the resource growth function used in Brander and Taylor (1997*a*) is extended by a minimum viable stock size $\underline{S}$ to obtain

$$G(S(t)) = r\,(S(t) - \underline{S})\left(1 - \frac{S(t)}{K}\right). \tag{2}$$

This resource growth function is depicted by the blue dashed line in Figure 1. The graph shows that resource growth is only positive if the stock exceeds the minimum viable stock size $\underline{S}$. If $S < \underline{S}$, the stock is depleted and does not replenish naturally. For any stock $S > \underline{S}$, the resource grows at a positive rate until it has reached its carrying capacity K, at which point the natural environment does not support any additions to the stock.

Figure 1: Resource dynamics and catch function



The bottom panel of Figure 1 shows all price-resource stock combinations that yield a diversified pattern of production. See Section 11.2 in the Appendix for details.

Fishing is characterized by the following function in which α describes the fishing technology and $\tau \geq 1$ is a schooling parameter[3]

$$H = \alpha S^{\tau} L_H. \tag{3}$$

The term αS^{τ} in this equation captures fishing productivity. Each worker in the fishing industry catches more if technology α is more advanced or if the stock is larger. The extent to which the catch depends on the stock size is measured by τ. Schooling fish species are relatively easy to catch when the stock is small. When a species forms schools, τ is low and fishing productivity is not very responsive to the stock size.

The fishery is assumed to be unregulated. Open access to the fishery results in zero profits such that the revenue from fishing equals the fishing cost. With the catch function described by Equation 3, open access to the fishery and Cobb-Douglas preferences, it is possible to derive the short-run supply of fish as a function of a given stock size (see Section 11.3 in the Appendix).

$$H = \alpha S^{\tau} \beta L_T. \tag{4}$$

This "short-run catch function" is depicted by the black line in Figure 1. Equation 4 shows that, in the short-run equilibrium, a fraction β of workers is employed in fishing.

In the autarky steady state equilibrium, catch equals the resource growth rate. Therefore, the autarky steady state is characterized by the intersection of the short-run catch function and the resource growth function with a stable steady state resource stock of S_A. The fishery can collapse even in the absence of trade if the parameters of the model change such that $G(S)$ and H do not intersect at any positive stock levels.

2.2 Trade

This section investigates the effect of trade openness on a small country, for which the world market price is exogenous. The pattern of trade depends on the world market price p^* relative to the country's autarky price p_A. Since this paper analyses

[3] This catch function is also used by Copeland and Taylor (2006). The schooling parameter is an extension of the model by Brander and Taylor (1997*a*).

the effect of exports on the domestic fishery, trade is modelled as an exogenous increase in the resource price $p^* > p_A$.

The exposition below focuses on the case in which the country is in the autarky steady state when it first opens up to trade. However, the same results follow through when a small economy is in a diversified trading equilibrium and experiences an exogenous increase in the price. This exogenous increase in the price could result from a further trade liberalization or from an export demand shock.

2.2.1 Short-term pattern of production and trade

When a country opens up to trade and the world market price for fish exceeds the domestic price, the country specializes in fishing. Catch and exports increase instantly and the stock declines over time.[4]

Catch increases instantly when the country opens up to trade, since the country's entire labour force moves into the fishing industry. The instantaneous increase in catch is captured by a move from H_A to H_1 in Figure 1. H_1 is on the "specialized catch function" H_S

$$H_s = \alpha L_T S, \tag{5}$$

which is represented by the upward-sloping segment of the red curve in Figure 1.

The country exports fish and imports manufacturing products when it opens up to trade. This is evident from the fact that the country only produces fish but workers consume both products. The stock declines over time, since catch exceeds the resource growth rate once the country has specialized in fishing (e.g. at H_1).

Brander and Taylor (1997*a*)'s findings on the effect of exports on resource stocks yield the first set of hypothesis for the empirical analysis.

Hypothesis 1. *In an open access fishery, an exogenous increase in the price leads to*

(a) an instantaneous increase in harvest and exports and

(b) a smaller resource stock in future periods.

[4] The country specializes in fishing since the marginal value product of labour in fishing exceeds the marginal value product of labour in manufacturing when the country opens up to trade. The marginal value product of labour in fishing is given by the worker's fishing productivity αS_A multiplied by the price of fish. When the price suddenly increases to p^* and the stock is fixed in the short term, the marginal value product of labour in fishing exceeds the marginal value product in manufacturing, which is fixed at 1.

In the long term, three outcomes are possible: A diversified steady state, a specialized steady state (both with a smaller resource stock than under autarky) or the collapse of the fishery. The collapse of the fishery is discussed in the following section. A discussion of the diversified and specialized steady states is deferred to Sections 11.4 and 11.5 in the Appendix.

2.2.2 Fisheries collapse in exporting countries

This section shows that a fishery that is sustainable in autarky can collapse when the country opens up to trade. However, not all fisheries collapse when the country exports fish. Therefore, this section derives the conditions under which a collapse is possible.

The dynamics leading to the collapse are illustrated by the red line in Figure 1. Given the world market price $p_c > p_A$, the small open economy remains specialized in fishing up to the point at which the stock has declined to $S_c = 1/(p_c\alpha)^{1/\tau}$ and the marginal value product of fishing equals the marginal value product of manufacturing. At this point, the economy could diversify and produce both products. However, even if diversification reduces catch and takes pressure off the resource, S_c cannot not be a steady state resource stock. Since resource growth is negative at S_c, the stock continues to decline to zero and the fishery collapses.

Yet, a collapse can only occur if two conditions are satisfied: First, a collapse can only happen if the world market price is high, i.e. $p_c \geq 1/(\alpha \underline{S}^{\tau})$.[5] Second, a collapse is only possible if harvest under specialization H_s exceeds resource growth $G(S)$ for any positive stock level.[6] This is the case if fishing capacity is high relative to the resource growth rate. Advanced fishing technology or a large labour force which can participate in fishing raise H_s and facilitate a collapse at high world market prices. A detailed analysis of the parameter values, for which a collapse is possible, is available in Section 11.6 in the Appendix.

[5]This implies that a collapse can only happen if the minimum viable stock size $\underline{S}$ is positive and fish population growth is negative for any stock $S < \underline{S}$. Negative population growth at small stock levels is also called a "strong Allee effect". Slow recovery of depleted fish populations (Hutchings, 2000) suggests that Allee effects exist for some species and Keith and Hutchings (2012) find evidence for Allee effects for several species. However, even species which do not exhibit Allee effects can collapse as a result of trade, as demonstrated by Gars and Spiro (2018) in an Armington trade model.

[6]If this is not the case, the stock shrinks to S_z, which is the stock at which catch under specialization equals resource growth. At this point, the stock cannot decline further since resource growth would exceed catch for any stock $S < S_z$ and the stock would recover. S_z is the specialized steady state discussed in Section 11.5 in the Appendix.

Hypothesis 2. *An open access fishery in an exporting country can collapse if the world market price is high and if fishing capacity is sufficiently high relative to the resource growth rate.*

The theoretical model shows that the collapse of a fishery in an exporting country can be inferred from catch data. Harvest is a function of the stock size and when the stock is depleted, harvest is low (see Equations 4 and 5). A very low catch compared to its historical maximum is indicative of the collapse of the fishery.

3 Empirical strategy

This section shows how I estimate the causal effect of fisheries exports on the likelihood of a fishery's collapse. The coefficient estimate for exports is biased downwards in a naive OLS regression of fisheries collapse on exports due to an omitted variable bias: Both the collapse of a fishery and exports depend on the size of a fish stock, which is not observed. To address this endogeneity, the collapse of Japanese fisheries is used as an instrument for fisheries exports in countries that do not share fish stocks with Japan. The collapse of a Japanese fishery is associated with a significant reduction in Japanese catch. Since Japan is a large market for fishery products, the Japanese collapse raises the world market price and export demand in other countries. Due to the increase in exports and the resulting higher fishing pressure, the fishery can collapse in the exporting country. The empirical strategy ensures that trade is the only channel through which a collapse in Japan can affect the collapse of a fishery in another country.

3.1 Estimating equation

This paper estimates the effect of exports on the likelihood of a fishery's collapse. Even though this paper's identification strategy is based on the idea that an increase in the price (and hence in catch) leads to an increase in exports, I do not use price or catch data as regressors for two reasons. First, the identification relies on a country being open to trade and exporting a particular species. This can only be guaranteed through the use of export data. Second, the majority of price data is estimated and hence of poorer quality than the export data.

The dependent variable Collapsed_{ikt} is a dummy variable, that takes the value of 1 if fish species i has collapsed in country k in year t. Since stock assessments are only available for a small number of species,[7] this paper uses a common approach (see e.g. Worm et al., 2006; Costello, Gaines and Lynham, 2008) and defines a fishery as collapsed if catch from marine capture fisheries is below 10 percent of the maximum catch recorded since 1950. Based on findings by Froese et al. (2012), the variable Collapsed_{ikt} is unlikely to systematically misrepresent the depletion of fisheries, as Froese et al. (2012) show that trends in catch data are consistent with trends in biomass data from stock assessments.

In the dataset used for the analysis, fisheries are observed up to the year in which they collapse.[8] Once the fishery has collapsed, the stock is very low. This implies that catch and exports are low as well. Hence, the causality is likely to run from the collapse to exports once the fishery has collapsed. Since observations from collapsed fisheries cannot be used to understand whether exports lead to a collapse, they are not used in the analysis.

Fisheries that have recovered reappear in the dataset. However, those fisheries may be more vulnerable to a future collapse. Therefore, the regression includes the dummy variable "Prev. Collapsed_{ikt}", which takes a value of 1 if the fishery has collapsed in the past. Fisheries that do not collapse are observed until the end of the sample period.

I model the likelihood of a fishery's collapse as a function of the natural logarithm of the export quantity of species i in country k in year $t-1$, of a vector of control variables "Controls_{ikt}", of region-year fixed effects γ_{rt}, country fixed effects γ_k, species fixed effects γ_i and an error term ϵ_{ikt}. The vector of control variables includes the dummy variable "Prev. Collapsed_{ikt}", which indicates whether the fishery has collapsed in the past, and the variable "Managed_{ikt}", which indicates whether the fishery was managed via a catch share program. The latter variable is discussed below. The analysis is, therefore, based on the following estimating

[7] The RAM Legacy stock assessment database covers a time series of 305 national stock assessments. Unfortunately, species level trade data only exist for a subset of these fisheries. The sample of observations for which I have both stock assessments and species-level export data is small.

[8] The dependent variable captures the conditional probability of collapse, since fisheries are only observed up to the point in time at which they collapse. It reflects the probability of a fishery's collapse in time period t, conditional on the fishery not being collapsed in time period $t-1$. To facilitate the language, this paper refers to this conditional probability as the likelihood of a fishery's collapse.

equation

$$\text{Collapsed}_{ikt} = \beta_0 + \beta_1 \ln(\text{Exports})_{ikt-1} + \boldsymbol{\beta}\text{Controls}_{ikt} + \gamma_{rt} + \gamma_i + \gamma_k + \epsilon_{ikt}. \quad (6)$$

An increase in exports will only manifest itself as a reduction in the fish stock or a collapse in future periods. Therefore, it is necessary to use lags of exports as predictors of fisheries collapse. The baseline specification uses exports in year $t-1$ as the regressor. This captures the short-term effect of exports on the likelihood of a collapse in the following period. Long-term effects and dynamics are discussed and estimated in Sections 8.1 to 8.2.

In order to net out price effects, I use the export quantity rather than the export value as regressor.[9] Since the dispersion of the export quantity is very skewed, this paper uses the natural logarithm of exports as a regressor. The sample, thus, only includes observations with strictly positive trade flows which, in turn, implies that the analysis focuses on the intensive margin of trade. In other words, this paper investigates whether an increase in the volume of fisheries exports raises the likelihood of a fishery's collapse. The question whether countries start exporting as a result of the Japanese collapse and how this affects their fish stocks is not analysed in this paper since data on zero trade flows are incomplete.

Exports are certainly not the only cause of fisheries collapse. Domestic fisheries management is likely to be a key determinant of a fishery's sustainability. Specifically catch share programs have been shown to significantly reduce the likelihood of fisheries collapse (Costello, Gaines and Lynham, 2008). Catch share programs are fisheries management tools that allocate secure fishing privileges to individual entities. Most of the catch share programs are individual transferrable quotas (ITQs) or similar quota-based programs. But a small percentage of catch share programs are area-based and allocate the privilege to fish in specific areas to groups or individuals. These programs are called Territorial Use Rights for Fishing programs (TURFs). Since catch share programs such as quotas could also affect exports via a reduction in supply, the empirical model includes the control variable "Catch share$_{ikt-1}$" which takes the value of 1 if a fishery is regulated using a catch share program.

Region-specific variation in climatic and environmental factors is captured by

[9] I cannot distinguish between exports from marine capture fisheries and exports from aquaculture fisheries. However, only 334 observations in my sample represent fisheries that use both production methods.

region-year fixed effects. Those fixed effects control for all factors that raise the likelihood of a collapse equally for all species in one region in a particular year and capture time trends in the rate at which fisheries collapse. A region is defined as either the Atlantic Ocean including the Mediterranean Sea or the Pacific Ocean and Indian Ocean.

A set of species fixed effects captures all time-invariant species characteristics that could affect the likelihood of a collapse. Those characteristics include the species' fecundity and growth rate. Moreover, I control for time-invariant country characteristics, such as the preference for fish using country fixed effects. There is no need to use country-species fixed[10] effects since there are no time-invariant country-species-specific factors that could be correlated with the instrument and violate the exclusion restrictions. Standard errors are clustered at the species level.

Since the dependent variable is binary, I estimate a linear probability model as advocated by Angrist and Pischke (2009). There are several reasons to choose a linear probability model over a nonlinear binary dependent variable model such as logit or probit. First, Angrist and Pischke (2009) point out that 2SLS models estimate average local treatment effects even if the dependent variable is binary. Second, linear probability models require fewer functional form and distributional assumptions and they offer a straightforward interpretation of the coefficient estimates as marginal effects. Finally, the estimated marginal effects from IV probit regressions with fewer fixed effects (either $\gamma_{rt} + \gamma_i$ or $\gamma_{rt} + \gamma_k$) were are almost identical to the marginal effects in a linear probability model. Considering the difficulties in implementing a non-linear model with a large number of fixed effects and instrumental variables, this paper only displays results from a linear probability model.

3.2 OLS estimates are biased downwards

An OLS regression would underestimate the effect of exports on fisheries collapse. This holds true even if we only observe fisheries up to the point in which they collapse. The downward bias results from the fact that both exports in period $t-1$ and the dependent variable are correlated with the stock size S_{t-1}, which is not observed. When a fish stock is overfished and S_{t-1} is low, the stock is more likely to collapse in period t. This may be due to the fact that the catch exceeds resource

[10]The baseline results follow through with country-species fixed effects.

growth in period $t-1$ or due to a small stock's reduced resilience to environmental factors that could cause a collapse. At the same time, a small stock S_{t-1} implies a small catch and low export volumes in period $t-1$.

3.3 Collapse of Japanese fisheries as an instrument

To address this endogeneity, the collapse of Japanese fisheries is used as an instrument for fisheries exports in countries that do not share stocks with Japan. The instrument "Collapse Japan$_{it}$" varies at the species-year level. I argue that the collapse of species i in Japan has a strong influence on exports of species i in other countries, since Japan is both a large supplier and consumer of seafood. When Japanese catch declines as a result of the collapse, Japan sources more seafood products on foreign markets. The resulting increase in Japanese import demand raises the world market price for species i spurring exports of species i in the rest of the world. Therefore, a collapse in Japan generates an export demand shock in other countries. The data confirm that this mechanism is at work.

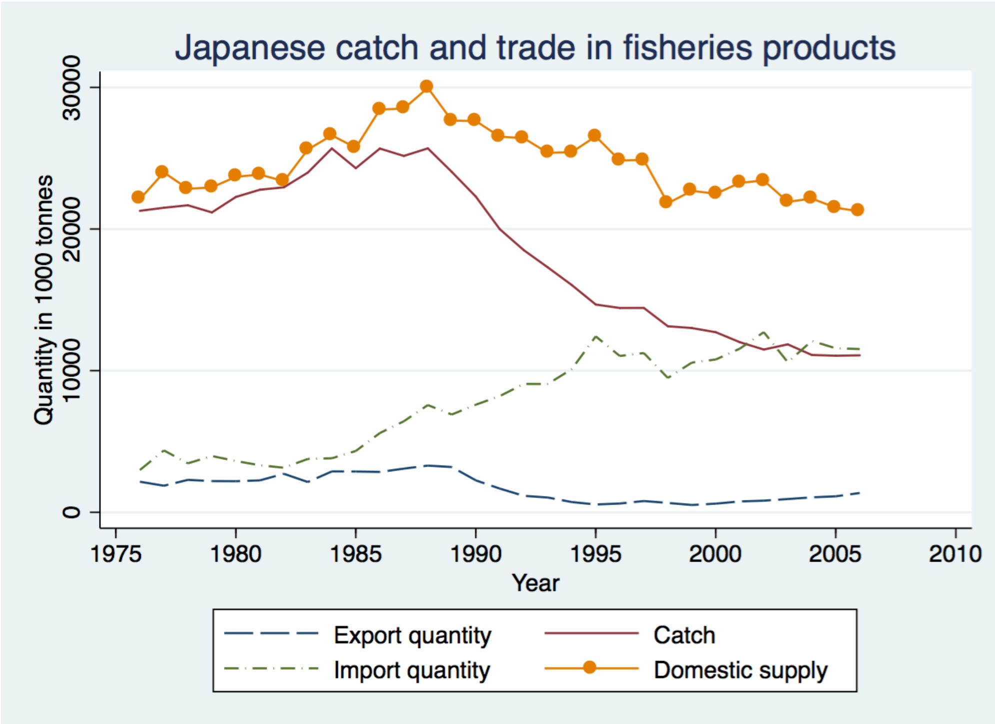
Japan was the largest producer of fishery products until the late 1980s and caught around 18% of the world's marine catch at the beginning of the sample period in 1976. Japan's total production of fishery products declined over the course of the sample period as Japanese fisheries collapsed. The percentage of collapsed fisheries in Japan increased from 14 percent in 1976 to 32 percent in 2006 and Figure 2 shows that total catch declined starkly during that time.

An increase in imports guaranteed a stable supply of fishery products in Japan as domestic fisheries where depleted. The green dashed line in Figure 2 shows the rapid growth in fisheries imports, which made Japan the second largest importer of seafood products from 1987 onwards. Due to this increase in imports, the domestic supply (defined as production-exports+imports+stock changes) of fishery products remained relatively stable as demonstrated by the yellow line in Figure 2. Japan remains the second largest market for seafood products after China.[11]

Detailed price data corroborate the idea that the collapse of a Japanese fishery raises the price of the respective species in the rest of the world and thus lead to an export demand shock. Table 1 shows that a collapse of species i in Japan is

[11] This paper does not use the collapse of Chinese fisheries as an instrument for exports, even though China has become the largest market for seafood products in the late 1980s, since Chinese landings statistics are likely to be overreported (see e.g. Pang and Pauly, 2001; Watson and Pauly, 2001; Pauly and Froese, 2012)

Figure 2: Japanese landings and trade in fishery products



Total exports, imports, landings and domestic supply of marine fish and other fishery products, excluding freshwater fish. Domestic supply is defined as production-exports+imports+stock changes. The underlying data are from the FAO food balance sheets.

associated with an increase in the price of species i in exporting countries by 7 percent.[12] This increase in the world market price raises exports in the rest of the world and the first stage regression, which is discussed in Section 6.2, captures this effect. Since about two thirds of the price data are estimated, the remainder of the analysis focuses on export data to capture the effect of an exogenous increase in price on the collapse of fisheries.

3.4 Exclusion restrictions are satisfied

The instrument is only valid if trade is the only channel through which a Japanese collapse affects a collapse in the exporting country. In order to guarantee that the exclusion restrictions are satisfied, this paper only studies fisheries that are

[12] Country-species-year level price data are from Swartz, Sumaila and Watson (2012), who collect a comprehensive dataset of ex-vessel prices and estimate missing price data. In the sample used for this paper, about two thirds of the price data are estimated. Therefore, the price data are not used for the remainder of the analysis.

Table 1: A collapse in Japan raises the ex-vessel price in exporting countries

	(1) Ln (Price)$_{ikt}$
Collapse in Japan	0.075**
	(0.035)
Country FE, Species FE, Region-Year FE, Management Control	Yes
No. of clusters	113
Observations	8980

Standard errors (clustered at the species level) in parentheses. I control for the existence of a catch share program, country, species and region-year fixed effects. The sample covers the same observations as the baseline regression.
* p<0.1, ** p<0.05, *** p<0.01

not shared between Japan and the exporting county. If fish stocks are shared, the collapse of a Japanese fishery would be directly related to a fisheries collapse in the exporting country. The empirical strategy ensures that the collapse in Japan and the exporting country are not driven by common shocks.

Since neighbouring countries are likely to share fish stocks, all countries with Exclusive Economic Zones (EEZ)[13] adjacent to Japan are excluded from the sample. The sample does not include Russia, North and South Korea, China, Taiwan, the Philippines and the Northern Mariana Islands.

Some species migrate large distances and might, thus, be fished by Japan and more remote countries which are not excluded from the sample. Therefore, the sample does not include fish species which migrate large distances (e.g. tunas) and species which have extensive distributions in the high seas. To be precise, I exclude highly migratory fish species listed in Annex 1 of the UN Convention of the Law of the Sea (UN General Asssembly, 1982) as well as fish species with ranges in the high seas and all straddling fish stocks[14] in the area surrounding Japan (FAO fishing area 61). A list of the latter two groups is based on Maguire et al. (2006).

Moreover, I use a collapse in Japan in year $t-1$ as an instrument. Using the lag of the Japanese collapse should further reduce the risk that unobserved shocks, such as short-term fluctuations in climatic conditions like El Nino, simultaneously affect fisheries in Japan and in the exporting country.

Major climatic events which affect fisheries beyond the countries which are

[13]EEZs were formally established with the UN Convention on the Law of the Sea, which grants coastal states exclusive rights to explore marine resources within an area of up to 200 nautical miles (370 km) from a country's coast.

[14]Straddling fish stocks are stocks which occur both within a country's EEZ and beyond it.

excluded from the sample are picked up by region-year fixed effects. Hence, they do not violate the exclusion restrictions. Species fixed effects capture all species-specific biological factors, such as growth rates or age-at-maturity which determine a species' innate proneness to collapse.

3.5 Why did Japanese fisheries collapse?

Anecdotal evidence suggests that the collapse in Japan is not driven by shocks that could also affect exporting fisheries in the sample. Makino (2011) shows that the collapse of most Japanese fisheries is the result of an extremely high demand for fishery products, overcapacity in the Japanese fishing industry and inadequate fisheries management. It is mostly driven by domestic factors and often precedes the collapse in other countries.

Seafood has traditionally been an important component of the Japanese diet and per capita seafood consumption in Japan was about 7 times the world average in 1976. At the beginning of the sample period, this high demand for fisheries products was mostly catered for by the Japanese fleet. Japan was the largest producer of seafood and one of the first countries to develop large fishing fleets. Hence, Japan had the capacity to overfish before other countries did.

High demand, a well-developed fishing fleet and the lack of appropriate fisheries management lead to overfishing and early collapse of Japanese fish stocks. The Japanese Ministry of Fishing, Forestry and Agriculture classified 37 out of 82 fish stocks as low in 2009 (Japanese Ministry of Agriculture Forestry and Fisheries, 2009). Where available, anecdotal evidence suggests that overfishing was responsible for the collapse of these fisheries.[15]

4 Data

This section explains the construction of the novel country-species level dataset on trade in fishery products and fisheries collapse.

[15] See Makino (2011) for evidence on the collapse of sandeels, chub mackerels, sand fish, snow crab, Makino (2010) for evidence on Walleye pollock, Matsukawa et al. (2008) for manila clam, Nagai et al. (1996) for growth-overfishing of Spanish mackerel. Moreover, Uchino et al. (2004) documents that the decline in abalone abundance was at least partly due to overfishing. In all the anecdotal evidence I reviewed, only the collapse of the Japanese sardine was due overfishing or due to a change in the oceanic conditions around Japan Makino (2011).

A fishery's collapse is inferred based on catch data, which map species level catch to each country's Exclusive Economic Zones. The catch data are from the Sea Around Us catch database, which is described in detail in Watson and Kitchingman (2004).[16] The original dataset contains species-level information on catch for almost all countries in the world from 1950 to 2006.

Disaggregate fisheries trade data for the years 1976 to 2006 are from the FAO Fisheries Commodities Production and Trade Statistics. The trade data are matched with the catch data at the country-species-year level. The correspondence table that links catch and trade data at the country-species-level was constructed as part of this research project.

Two characteristics of the trade data are worth highlighting. First, the dataset distinguishes between different ways in which the fish is processed. For example, exports of cod are broken down into three categories: exports of fresh and chilled cod, exports of frozen cod and exports of cod meat. To obtain exports at the country-species level, the data are aggregated over all of these different categories for each species in each country. Second, exports are recorded at the species level for some species of fish like Atlantic cod and European plaice. For other species, the trade statistics are reported in more aggregate categories, like "mussels". The category "mussels" includes a whole range of species and the catch data would generally provide more disaggregate information. Since it is not possible to know which of the species in the catch data are exported, export data for aggregate categories like "mussels" are not used for the analysis in this paper.

This paper uses data on catch share programs from the Environmental Defense Fund (EDF). I use information from government websites, scientific articles and I contacted the respective fisheries management authorities to complete missing information on the year in which a catch share program was adopted.

5 Summary statistics

The summary statistics reveal that an increase in fisheries exports coincides with an increasing prevalence of fisheries collapse in exporting countries. Moreover, maps show that the biggest exporters are the countries with the highest percentage

[16] This paper uses the same data as Swartz, Sumaila and Watson (2012). Those data were made available to me by the Institute for the Oceans and Fisheries at UBC and I thankfully acknowledge their cooperation.

Table 2: Summary statistics

	(1) Mean	(2) Overall Sd.	(3) Between Sd.	(4) Within Sd.
Collapsed	0.047	0.211	0.154	0.190
Export quantity (lag)	10.152	38.864	24.211	22.668
Export quantity (lag, ln)	6.578	2.679	2.667	1.105
Catch share (lag)	0.103	0.304	0.207	0.190
Collapsed Japan (lag)	0.127	0.333	0.252	0.236
Tariff Japan (lag)	6.140	2.227	2.204	0.712
Observations	8980	8980	8980	8980

Between Sd: Standard deviation between country-species combinations
Within Sd: Standard deviation within country-species combinations

of collapsed fisheries at the end of the sample period.

Exports of fishery products grew by 265 percent over the sample period. The total export quantity of fishery products in the sample used for this study increased from 1.2 million tonnes in 1976 to 4.4 million tonnes in 2006 (see Figure 3).[17] The summary statistics in Table 2 show that, on average, a country exports 10,000 tonnes of any given fish species per year. However, the export quantity varies considerably (see Column 2 for the overall standard deviation). Due to outliers with very high export quantities, the baseline specification uses the natural logarithm of the export quantity.

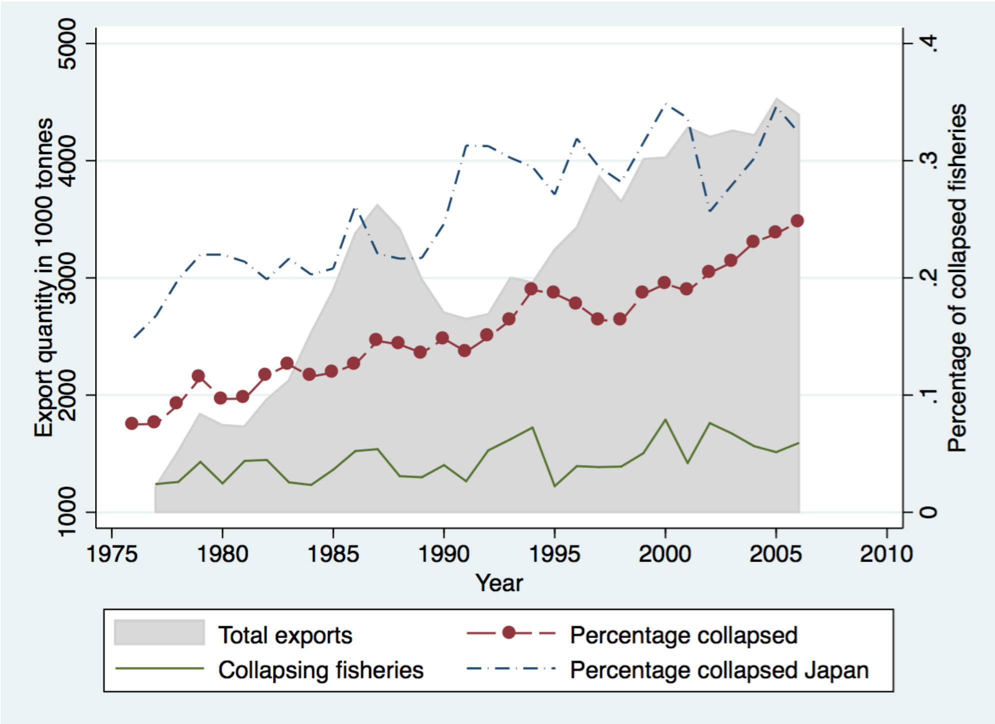
This export growth coincides with an increasing prevalence of fisheries collapse in exporting countries. The red line in Figure 3 shows that the percentage of collapsed fisheries increased from 7 percent in 1976 to 25 percent in 2006. Fisheries collapse throughout the sample period. The green line in Figure 3 indicates that between 2 and 8 percent of the fisheries collapse every year. The summary statistics in Table 2 show that 4.6 percent of the observations represent collapsing fisheries, i.e. fisheries in the year of the collapse.

Most of the collapsed fisheries are cod, hake and haddock fisheries, as demonstrated by Table 11 in the Appendix. This holds true for both the exporting countries and fisheries in Japan.

Fisheries collapse is more prevalent in Japan than in the rest of the world. The green dashed line in Figure 3 reveals that the percentage of collapsed fisheries

[17] Total exports of all fishery products, including exports of species which are not in the sample grew by almost 400 percent over the same time period.

Figure 3: Fisheries collapse and export quantities in the sample



Note: Collapsing fisheries are fisheries the year in which they collapse.

in Japan surges from 14 percent in 1976 to 32 percent in 2006. Japanese stock assessments confirm the poor state of Japanese stocks. 43 out of the 90 assessed stocks within Japan's EEZ were categorized as being at low levels in 2007 (Makino, 2010).

Maps show that the countries with high exports are also the ones with the highest percentage of collapsed fisheries in 2006. The map presented in Figure 4 shows the percentage of collapsed fisheries at the end of the sample period for every country and Figure 5 shows average country-level exports. Average exports are defined as $(\sum_{t=1976}^{T=2006} \sum_{i \in I} \text{Exports})/31$, where I is the set of all fisheries within a country that are in the sample. Countries with high average exports tend to have a large proportion of collapsed fisheries at the end of the sample period.

Figure 4: Percentage of collapsed fisheries at the end of the sample period

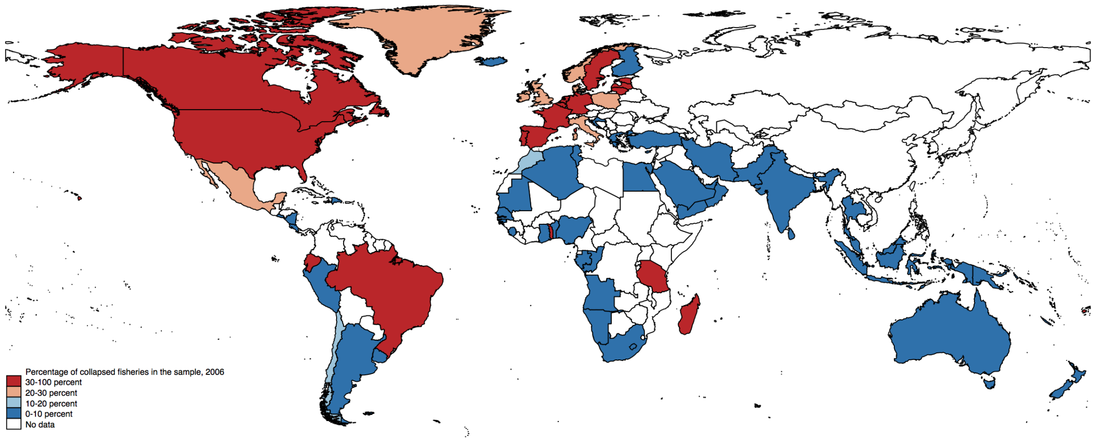
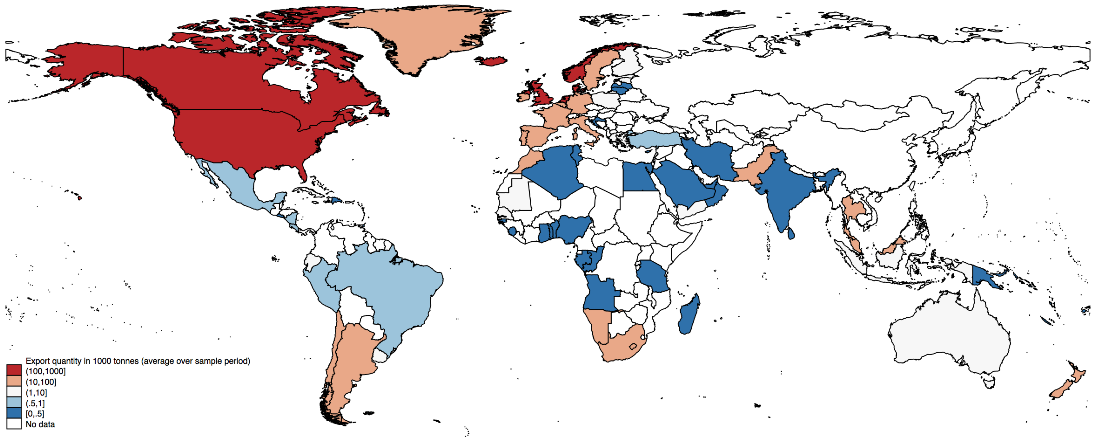


Figure 5: Countrys' annual total export quantity, averaged over a 30 year sample period



6 Results: Exporting leads to the collapse of fisheries

The results in this section show that exporting significantly raises the likelihood of fisheries collapse. The instrumental variable estimation addresses a downward bias in the OLS regression.

Table 3: OLS and baseline results

	(1)	(2)	(3)
Dependent variable:	Collapse	Exports	Collapse
Export quantity (lag, ln)	-0.004**		0.087**
	(0.002)		(0.037)
L.Col. Japan		0.258***	
		(0.083)	
L.Catch share	-0.012	0.483**	-0.055*
	(0.011)	(0.202)	(0.031)
Prev. Col	0.061***	-0.760***	0.131***
	(0.009)	(0.164)	(0.033)
Region-Year FE	Yes	Yes	Yes
Species FE	Yes	Yes	Yes
Country FE	Yes	Yes	Yes
IV	-	-	L.Col. Japan
1st stage F-Stat			9.902
Anderson-R. p-value			0.006
No. of clusters	113	113	113
Observations	8980	8980	8980

Standard errors (clustered at the species level) in parentheses. The p-value of the Anderson and Rubin (1949) test (Anderson-R. p-value) provides weak instrument robust inference for the coefficient estimate for the export quantity.

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

6.1 Benchmark OLS regression

The results from the OLS regression presented in this section reveal a downward bias in the coefficient estimate. The coefficient estimate for the export quantity in Column 1 of Table 3 suggests that an increase in exports by one percent reduces the likelihood of a fishery's collapse in the following period by 0.004 percentage points. The negative relationship between exports and the fishery's collapse is counterintuitive but, as discussed in Section 3.3, it may be due to a downward bias of the coefficient estimate. The result from the instrumental variable regressions in the next sections confirm this.

6.2 Are the instruments strong?

Prior to the discussion of the 2SLS results, it is necessary to assess the quality of the instrument. This section highlights that the collapse of fisheries in Japan is a sufficiently strong instrument for exports from countries that do not share stocks with Japan. This is important, since it is well known that the 2SLS estimates are biased in the direction of the OLS estimates if instruments are weak.

The first stage regression reveals a strong positive relationship between the collapse of a Japanese fishery and other country's exports of the same species. Column 2 of Table 3 shows that the collapse of a Japanese fishery is associated with an increase in exports from other countries by 25.8 percent. The coefficient estimate for the export quantity is statistically significant at the 0.1 percent level, suggesting a strong positive conditional correlation between the two variables.

A more formal test by Stock and Yogo (2005) confirms that the instrument is sufficiently strong.[18] Moreover, the Kleibergen-Paap first stage F-statistic[19] of 9.9 in the baseline model is just at Staiger and Stock (1997)'s threshold for sufficiently strong instruments of 10.

In addition to standard hypothesis tests, this paper reports weak instrument robust hypothesis tests for all regressions. The penultimate column of all results tables in this paper is labelled "Anderson-R. p-value" and shows the p-value for Anderson and Rubin (1949)'s test of structural parameters which is fully robust to weak instruments. When this p-value is below 0.1, the coefficient estimate for the export quantity is significant even when the instruments are weak. This is relevant for regressions in which the first-stage F-Statistic is below 10. In those regressions hypothesis tests and confidence intervals can be wrong when instruments are weak (see e.g. Stock, Wright and Yogo, 2002).

It is worth highlighting that weak instruments would not invalidate the results presented in this paper. With weak instruments, the coefficient estimate for the export quantity would be biased downward in the direction of the OLS coefficient estimate. Any reader worrying about weak instruments should think of the coefficient estimates as the lower bound of the effect of exports on the collapse of fisheries.

[18]Based on this test, I can reject the null-hypothesis that the asymptotic bias of the 2SLS bias exceeds 15% of the OLS bias.

[19]Since standard errors are clustered, this paper reports the Kleibergen-Paap F-statistic as the relevant first stage F-statistic in all results tables.

6.3 IV results: Exporting leads to the collapse of fisheries

The baseline instrumental variable results reveal that exports significantly contribute to overfishing. Column 3 of Table 3 shows that an increase in exports by one percent raises the likelihood of a fishery's collapse in the following year by 0.087 percentage points. The effect is large: An increase in logged exports by one standard deviation raises the likelihood of a collapse by 23 percentage points.

Are the estimates realistic in light of the observed trend in fisheries collapse over the sample period? An answer to this question requires more insights into the development of exports during the sample period. Exports in the median fishery grew by 144 percent between 1976 and 2006. According to the estimates, this export boost raised the likelihood of a collapse by around 12.5 percentage points. Since the percentage of collapsed fisheries increased by 18 percentage points over the course of the sample period, the predicted increase in the likelihood of a collapse is equivalent to about two thirds of the observed cases of fisheries collapse. However, these numbers have to be interpreted with caution since they extrapolate an estimated short-term effect over a time period of 30 years.

The findings also provide tentative evidence for serial fisheries depletion due to trade. Based on the results from the reduced form regression, the collapse of a Japanese fishery raises the likelihood of a collapse in a non-neighbouring country by 2 percentage points. This paper only captures one link in a potential chain of resource collapse. If trade leads to serial fisheries depletion beyond this first link, it could be more damaging for the oceans than the estimates in this paper suggest.

Section 2 and Hypothesis 1 highlighted that exports lead to a collapse of fisheries in exporting countries due to an increase in catch. To show this empirically, I can use the same empirical approach and the same sample as in the baseline regression but use the log of catch as a regressor instead of the log of exports. The results reveal that an increase in catch by one percent raises the probability of a collapse in the following period by 0.4 percentage points (see Table 12 in the Appendix). This coefficient estimate is statistically significant based on weak instrument robust inference.

7 Heterogeneous effects

This section presents heterogeneous effects based on theoretical insights. I find that exporting only leads to the collapse of fisheries that are not regulated via catch share programs. Moreover, the results reveal that countries seem to have sufficient fishing capacity to deplete fisheries.

7.1 Only fisheries without quotas are affected

The theoretical prediction that exporting can lead to a collapse applies to open access fisheries. However, some of the observations in the dataset are managed via quotas and other rights-based fisheries management tools. In the presence of catch limits, harvest and exports are likely to respond less to a demand shock from Japan. Moreover, Brander and Taylor (1997*b*) show that well-managed fisheries are not depleted as a result of exporting.

This section reveals that exports only raise the likelihood of a collapse in fisheries that are not regulated via quotas or similar rights-based management tools. Regulated fisheries do not seem to be negatively affected by exports.

Table 4: Only unmanaged fisheries collapse as a result of exports

	(1) Quota	(2) No quota	(3) Never under quota	(4) All
Export quantity (lag, ln)	-0.093	0.110**	0.097***	0.089**
	(0.066)	(0.047)	(0.035)	(0.037)
L. ln(Exports) $\times$ L. Managed				0.005
				(0.029)
Controls	Yes	Yes	Yes	Yes
FEs γ_{rt}, γ_i, γk	Yes	Yes	Yes	Yes
1st stage F-Stat	1.910	8.920	10.129	8.940
Anderson-R. p-value	0.083	0.006	0.004	0.012
No. of clusters	47	113	99	113
Observations	992	7985	6552	8980

Standard errors (clustered at the species level) in parentheses. The p-value of the Anderson and Rubin (1949) test (Anderson-R. p-value) provides weak instrument robust inference for the coefficient estimate for the export quantity.

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

To show this, I split the sample into fisheries that are regulated using quotas or other catch share programs and fisheries that are not regulated via catch share programs. The first stage regression reveals that a collapse in Japan does not lead to a significant increase in exports from catch share fisheries. Moreover, the results from the second-stage regression in Column 1 of Table 4 show that exports do not spur a collapse of fisheries that are regulated via catch share programs. However, the weak correlation between the instrument and exports in the sample of managed fisheries implies that the second-stage regression results may be biased downwards and have to be interpreted with caution.

The results indicate that only fisheries that are not managed via catch share programs collapse as a result of exports. Column 2 of Table 4 reveals that an increase in exports by one percent raises the likelihood of a collapse in the following period by 0.11 percentage points in fisheries without catch share programs. This sample includes fisheries that are not managed via catch share programs in that year but adopt those programs later on. In a sample of fisheries that are never managed via catch share programs, an increase in exports by one percent raises the likelihood of a collapse by 0.097 percentage points (see Column 3). [20]

Since catch share fisheries may differ from fisheries without catch share programs, I also present results for the full sample and include an interaction term between exports and the catch share dummy variable as a regressor. The interaction term is endogenous since exports are endogenous, but the collapse of the respective species in Japan interacted with the catch share dummy variable can be used as an instrumental variable. The second instrumental variable is valid if the adoption of a catch share program for species i in country k is exogenous and not affected by a collapse in country k. Table 5 shows that this is the case.

I find that an increase in exports does not significantly raise the probability of a collapse in catch share fisheries (see Column 4 of Table 4). However, the results

[20] The results presented in Columns 2 and 3 of Table 4 have to be considered a lower bound of the effect of exports on unregulated fisheries, since catch limits may apply to some of these fisheries. An example is a fishery that is closed for the rest of the fishing seasons once catch has reach the total allowable catch (TAC). This fishery would not be classified as a catch share fishery, but could still be subject to a well-enforced TAC. Based on the theory (and the empirical results for the catch share fisheries), I would not expect the demand shock originating from the collapse in Japan to raise exports and the likelihood of the collapse in TAC fisheries by the same amount as in unregulated fisheries. The results in Column 2 of Table 4 present the average treatment effect on fisheries that are truly unregulated and TAC fisheries. Since the effect of exports on TAC fisheries is likely to be lower than for unregulated fisheries, the coefficient estimates presented in Columns 2 and 3 have to be considered a lower bound of the effect on unregulated fisheries.

Table 5: Catch share adoption is exogenous

	(1)
	Catch share program$_{ikt}$
Collapsed$_{ikt-1}$	-0.0010
	(0.0058)
Country-species FE, Year FE	Yes
Observations	8050

Standard errors (clustered at the country-species level) in parentheses. The table shows the results of a regression with the catch share dummy variable, Catch share$_{ikt}$, as a dependent variable and the Collapse$_{ikt-1}$ as well as country-species fixed effects and year fixed effects as regressors. The approach is akin to a survival analysis since I only follow fisheries up to the year in which they introduce the catch share program. The findings indicate that the collapse of a fishery does not have a significant effect on the adoption of catch share programs.

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

confirm that exports significantly raise the probability of a collapse in unmanaged fisheries by 0.089 percentage points. The coefficient estimate is only slightly higher than in the baseline regression and indicates that the findings in the baseline regression are mostly driven by fisheries without catch share programs.

The results presented in this section imply that sustainable fisheries management is necessary to guarantee long-term benefits from fisheries in exporting countries. When fisheries are regulated through catch share programs, exporting does not seem to harm fisheries.

7.2 Countries seem to have the capacity to overfish

Hypothesis 2 suggests that exporting only leads to the collapse of the fishery if fishing capacity is large relative to the fish population growth rate. This section tests empirically whether the effect of exports on the collapse of fish stocks depends on fishing capacity. Fishing capacity is proxied by the number of fishermen relative to the length of the coastline. I split the sample along the median into fisheries with either a small or a large number of fishermen relative to the length of the coastline.

The results reveal that exporting leads to a collapse of fisheries even if fishing capacity is low. The first two columns of Table 6 suggest that an increase in exports raises the likelihood of a collapse by 0.1 percentage points in a sample with a large number of fishermen and by 0.07 percentage points in a sample with a small number of fishermen. The coefficient estimates for the export quantity are

Table 6: Heterogeneous effects: Fishing capacity and aquaculture

	(1) Many fishers	(2) Few fishers	(3) Aquaculture	(4) No Aqua.
Export quantity (lag, ln)	0.097	0.067	-0.080	0.087**
	(0.063)	(0.060)	(0.212)	(0.035)
Fixed effects	Yes	Yes	Yes	Yes
Controls	Yes	Yes	Yes	Yes
1st stage F-Stat	5.189	4.780	1.627	9.875
Anderson-R. p-value	0.080	0.111	0.661	0.007
No. of clusters	93	88	13	112
Observations	4452	4454	334	8644

Standard errors (clustered at the species level) in parentheses. The p-value of the Anderson and Rubin (1949) test (Anderson-R. p-value) provides weak instrument robust inference for the coefficient estimate for the export quantity.

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

statistically significant at the 10 percent level based on weak instrument robust inference. The results indicate that most countries have the fishing capacity to overfish up to the point at which the fishery collapses.

7.3 Aquaculture

The possibility to harvest a species using aquaculture production seems to take pressure off capture fisheries and dampen the effect of exports on the collapse of fisheries. Indeed, there is tentative evidence that species that are suitable for aquaculture production are not depleted due to exports (see Column 3 of Table 6). Column 4 of Table 6 reveals that the results from the baseline regression follow through if fisheries which report positive aquaculture production are excluded from the sample.

8 Dynamics

While the baseline regression analyses the short-term effect of exports on the collapse of fisheries, this section shows that exporting significantly raises the probability of a collapse in the medium and long term. The medium and long term effects are important to investigate since the stocks may be eroded gradually due to exports.

8.1 Maximum historical exports, longer lags and persistent collapse in Japan

The theoretical model in Section 2 predicts a temporary spike in catch and exports as a result of the exogenous increase in the price. Even if the price stays high, exports decline over time as the stock declines. The effect of this temporary spike in exports can be captured empirically regressing the collapse of fishery ik in year t on fishery ik's maximum historical exports recorded up to year t. The variable is defined such that fishery ik's maximum historical exports increase over time as the fishery's exports increase. Once the fishery's exports have reached a peak, the variable stays constant. This approach is agnostic about the time lag between the increase in exports and a fishery's collapse. It is well suited to translate the medium-term to long-term effect of exports on a collapse from the theory to the data, since the speed at which a fishery transitions to the collapse depends on the fishery's characteristics.

The results confirm that exporting leads to fisheries depletion in the medium to long-term. Column 1 of Table 7 shows that an increase in maximum historical exports by 1 percent raises the likelihood of a fishery's collapse by 0.11 percentage points. The coefficient estimate is statistically significant based on weak instrument robust inference.

Longer lags of exports can shed further light on the dynamic relationship between exports and the collapse of fisheries. Column 2 of Table 7 shows that an increase in exports in period $t-2$ is estimated to raise the likelihood of a fishery's collapse in period t by 0.11 percentage points. This estimate is slightly higher than the short-term effect estimated in the baseline regression.[21]

Unfortunately, it is not possible to estimate a distributed lag model, since I would need an IV for every lag of exports. Using several lags of the collapse in Japan as instruments yields weak IVs due to the high correlation between the different lags of the collapse in Japan. However, the dynamics can be captured by the dynamic panel data model presented in the following section, which uses the best available stock data and shows that exports are associated with smaller fish stocks.

[21] I do not find a significant effect of exports in period $t-3$ on a fishery's collapse in period t (see Column 3 of Table 7). Exports in period $t-4$ are estimated to raise the likelihood of a collapse in period t by 0.09 percentage points. In all of those regressions, the collapse of a Japanese fishery in period $t-l$ is used an instrument for exports in period $t-l$.

Table 7: Different lags of exports

	(1)	(2)	(3)	(4)
Ln(Max. Exp. up to t)	0.113			
	(0.072)			
L2.ln(Exports)		0.105**		
		(0.048)		
L3.ln(Exports)			0.053	
			(0.077)	
L4.ln(Exports)				0.088
				(0.080)
IV	L.Col. Japan	L2.Col. Jap.	L3.Col. Jap.	L4.Col. Jap.
1st stage F-Stat	3.750	6.488	2.673	2.325
Anderson-R. p-value	0.017	0.004	0.382	0.098
No. of clusters	118	110	107	104
Observations	11379	8423	7907	7430

Standard errors (clustered at the species level) in parentheses
* p<0.1, ** p<0.05, *** p<0.01

8.2 Exporting reduces stock biomass

This section uses biomass data to capture both the short-run and long-run effects of exports on fish stocks. The theoretical model in Section 2 shows that the stock in any period is a function of the stock in the previous period, of resource growth and catch. The use of biomass data allows me to model these dynamics empirically. However, this requires a different empirical strategy. I use a dynamic panel data model to explain stock biomass as a function of past stock biomass and exports. The estimation is based on biomass data from scientific stock assessments, where available. Due to the sparsity of stock assessments, these data have to be supplemented with estimates of stock biomass. The results show that exporting is associated with a reduction in stock biomass and confirm that exports can have a detrimental effect on fish stocks.

8.2.1 Alternative empirical strategy to capture dynamics

The use of biomass data allows me to model the stock dynamics which result from an increase in exports in more detail. I use a dynamic panel data model in which the dependent variable is the natural logarithm of stock biomass of fish species i in country k in year t, $ln(S_{ikt})$. Based on a simplified version of the resource dynamics explained in Section 2, current stocks are a linear function of the natural logarithm of stocks in period $t-1$, $ln(S_{ik,t-1})$ and of the natural logarithm of the export quantity in period $t-1$, $ln(\text{Exports})_{ik,t-1}$.

This yields the estimating Equation 7, in which the error term consists of a country-species specific time-invariant component η_{ik} and the time-varying component ϵ_{ikt}. The empirical model includes year fixed effects γ_t and controls for fisheries management via catch share programs, as represented by the dummy variable "Catch share$_{ikt-1}$".

$$ln(S_{ikt}) = \alpha_1 ln(S_{ikt-1}) + \alpha_2 ln(\text{Exports})_{ikt-1} + \alpha_3 \text{Catch share}_{ikt-1} + \gamma_t + \eta_{ik} + \epsilon_{ikt} \tag{7}$$

The short-term effect of exports on biomass is captured by the coefficient α_2 in Equation 7. Based on the theoretical model presented in Section 2 and hypothesis 1, an increase in exports in period $t-1$ is associated with a reduction in stock biomass in period t.

The long-term effect of exports on biomass can be calculated as $\alpha_2/(1-\alpha_1)$. This long-term effect captures the effect of an increase in exports in period $t-1$ on biomass in all future periods through a change in biomass in period t.

Equation 7 is estimated using an Arellano-Bond estimator. The Arellano-Bond model uses the first difference of Equation 7 to eliminate the time-invariant components of the error term, η_{ik}. A consistent estimator can then be obtained using lags of $ln(S_{ikt-l})$, $ln(\text{Exports})_{ikt-l}$, and Catch share$_{ikt-l}$ for all $l > 2$ as instruments for the first difference equation. Due to the availability of alternative instruments, it is not necessary to use the collapse of Japanese fisheries as an instrument in this section. Details on the construction of the instrument matrix and the data are available in the Appendix in Section 13.5.

8.2.2 Results: Exporting reduces stock biomass

The results reveal that exporting significantly reduces stock biomass, both in the short term and in the long term.[22] The short-term effect is captured by the

[22]The usual specification tests suggest that the model is correctly specified. The Arellano-Bond test shows that the null-hypothesis of second-order serial autocorrelation in the first-differenced

Table 8: Dynamic model for the effect of exports on fisheries collapse

	(1)
L.Ln(Biomass)	0.573***
	(0.142)
L.Ln(Exports)	-0.035**
	(0.015)
L.Catch share	-0.199
	(0.407)
Long-run effect	-0.082***
Instrument #	45
AR(1) p-value	0.001
AR(2) p-value	0.786
Hansen p-value	0.208
Observations	9362

Standard errors (clustered at the country-species level) in parentheses. Standard errors for the long term effect are calculated using the delta method.
* p<0.1, ** p<0.05, *** p<0.01

coefficient estimate for the export quantity in Table 8. The results suggest that an increase in exports by one percent reduces stock biomass by 0.04 percent in the following period. In the long-term, an increase in exports by one percent is estimated to reduce stock biomass by 0.08 percent (see lower half of Table 8). This corroborates the finding that exporting has a negative effect on fish stocks.

9 Sensitivity analysis

This section shows that the baseline results withstand a series of robustness tests. First, Section 9.1 argues that the results are not driven by potential violations of the exclusion restrictions. Second, Section 9.2 shows that the results are not biased due to measurement error in the dependent variable, and that they follow through with different definitions of fisheries collapse.

Further robustness tests are available in the Appendix. Section 13.1 and Section 13.2 investigate the robustness of the results to changes in the instrumental variable.

error term can be rejected. The p-value of the test is shown in the third but last row of the results table. Moreover, the p-value for the Hansen test, displayed in the penultimate row of Table 8, shows that the null-hypothesis of valid moment conditions cannot be rejected.

First, import tariffs for seafood products are used as a second instrument. Second, the fisheries collapse in Japan is interacted with the exporting country's distance from Japan to reflect the empirical regularity that trade flows are higher between close neighbours. Section 13.3 dispels concerns about a potential downward bias in the coefficient estimate resulting from substitution effects. Section 13.4 shows that the findings follow through if net exports are used as an alternative measure for trade openness.

9.1 No violation of instrument exogeneity

This section discusses three potential violations of the exclusion restrictions. It investigates whether the collapse of a Japanese fishery and the fishery in the exporting country are potentially related to each other via (a) landings of the Japanese fishing fleet (b) Japanese exports which lead to a collapse in the Japanese fishery or (c) unobserved environmental factors. There is no evidence that any of these channels are at work and therefore they do not influence the results.

9.1.1 The Japanese foreign fishing fleet's catch does not increase due to a collapse in Japan

The empirical strategy assumes that the collapse of Japanese fisheries only affects a collapse in other countries due to exports. In principle, it is also possible that the Japanese foreign fishing fleet increases its catch in other countries' Exclusive Economic Zones as a result of the Japanese collapse. This would violate the exclusion restrictions since the Japanese foreign fishing fleet's activity could raise the likelihood of a collapse in the exporting countries in the sample.

In practise, there are several reasons why this is not a concern. First, Swartz et al. (2010) argue that higher operating cost as well as increasing cost of accessing foreign country's fishing grounds[23] lead to the decline of the Japanese long distance fleet. Currently, the Japanese fleet's activity outside of Japan's waters focuses on tuna or takes place in the EEZs of China, South Korea and Russia, where reciprocal fishing agreements are in place. Since neither tuna nor Japan's neighbours are included in the sample, the Japanese fleet's activities do not invalidate the instrument.

[23] Japan would need to sign a fishing agreement with the exporting country in order to fish within the country's exclusive economics zone.

Furthermore, there is no evidence that fishing in distant waters increases as a result of a collapse in Japan. Table 13 in the Appendix shows that a collapse of species i in Japan's Exclusive Economic Zone is not associated with an increase in the Japanese fleet's landings of species i outside of the FAO fishing area that surrounds Japan.

To corroborate the validity of the instrument, I show that the results follow through if I control for landings by the Japanese foreign fishing fleet. To that end, I construct the variable "Foreign fleet landings$_{ikt}$", which represents Japanese catch (measured in tonnes) of species i in year t in FAO fishing areas adjacent to country k's borders.[24]

Controlling for the Japanese long distance fleet's landings does not change the results, as shown in Table 9. An increase in exports by 1 percent is estimated to raise the likelihood of a fishery's collapse in the following year by 0.083 percentage points. This is almost identical to the coefficient estimate in the baseline regression.

9.1.2 A collapse in Japan is not driven by Japanese exports

The exclusion restrictions would also be violated if a species' collapse in Japan was the result of the same species' collapse in the exporting country. Theoretically, this would be possible if a collapse in another major market raised the price of exports and Japan responded with an increase in exports to the extent that Japan's own fishery collapsed. This is unlikely to drive the results for several reasons. The main reason is that I only observe fisheries up to the year in which they collapse. Therefore, the estimates are not affected by events that happen as a result of a collapse in the exporting country unless the fishery recovers and reappears in the dataset.

Moreover, it is reasonable to think of Japan as the first (or at least an early link) in a potential chain of serial resource collapse. In the entire sample of catch data (not all of which are used in the analysis due to a lack of export data), 113 fish species collapsed in Japan prior to 2006. For 30 percent of those species, Japan was the first country worldwide to report a collapse of the respective species. In more than 50 percent of the cases, it was amongst the first three countries in which the species collapsed.

[24] The FAO divides the world's oceans into 19 marine fishing areas. A map of the marine fishing areas is available on http://www.fao.org/fishery/area/search/en. Data on Japanese landings in each FAO fishing area are from the FAO's global capture production database.

Table 9: No violation of instrument exogeneity

	(1)	(2)	(3)	(4)
	Jap col	-	Northeast	West. C
Export quantity (lag, ln)	0.083**	0.088**	0.092***	0.087**
	(0.033)	(0.044)	(0.031)	(0.036)
L.Jap landings	-0.001***			
	(0)			
L.Catch share	-0.051*	-0.042	-0.036	-0.059*
	(0.029)	(0.033)	(0.030)	(0.033)
Prev. Col	0.129***	0.131***	0.139***	0.130***
	(0.031)	(0.038)	(0.033)	(0.032)
Region-Year FE	Yes	Yes	Yes	Yes
Species FE	Yes	Yes	Yes	Yes
Country FE	Yes	Yes	Yes	Yes
IV 1	L.Col. Japan	L.Col. Japan	L.Col. Japan	L.Col. Japan
1st stage F-Stat	10.182	12.997	14.091	10.697
Anderson-R. p-value	0.005	0.022	0.003	0.007
No. of clusters	113	110	98	110
Observations	8980	8488	8234	8439

Standard errors (clustered at the species level) in parentheses

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

Even if a fishery in another country collapsed first, this is unlikely to affect Japanese exports. Japan was the largest market for fishery products at the beginning of the sample period. Therefore, a collapse in Japan is likely to have a stronger effect on the world market price and exports than a collapse elsewhere. Furthermore, Figure 2 shows that Japan exports a small fraction of its landings and was a net importer throughout the sample period. Hence, it is unlikely that exports caused the collapse of Japanese fisheries.

To make sure that the results are not biased by an effect of a fisheries collapse in the exporting country on fisheries collapse in Japan, I exclude all country-species-combinations from the sample in which the first reported collapse of fishery i in the exporting country k precedes the first reported collapse of fish species i in Japan.

The results for a regression using this slightly smaller sample are presented in Column 2 of Table 9. The coefficient estimate for the export quantity suggests that an increase in exports by one percent raises the likelihood of a fishery's collapse in the following period by 0.088 percentage points, which is almost identical to the result in the baseline regression.

9.1.3 Environmental factors do not violate instrument exogeneity

This section shows that the exclusion restrictions are not violated due to shared environmental shocks. There is a concern that ocean currents like the Kuroshio Current and its extensions, the Oyashio Current and the North Pacific Current[25] might allow the transmission of shocks from Japan to the Northeast Pacific, e.g. through long distance migration of specific fish species. In that case, fisheries in the United States and Canada would be affected by the same shocks as fisheries in Japan.

In the baseline model, region-year-fixed effects capture all biological and climatic shocks which affect all species in the same way in one region. Moreover, Japan's direct neighbours, which would be affected by similar environmental factors, are excluded from the sample. As a further robustness check, I exclude the US and Canada from the sample.

Column 3 of Table 9 show that the findings in this paper are not driven by common shocks between Japan and the US or Canada. The coefficient estimate of 0.09 is very similar to the result in the baseline regression.

[25] I am grateful to an anonymous referee for highlighting this.

Moreover, there is no evidence of biased coefficient estimates due to common shocks affecting Japan and countries in the Western Pacific. Column 4 of Table 9 shows that the results follow through in a sample that excludes countries in the Western Pacific (FAO fishing area 71).[26]

9.2 No bias resulting from measurement error in fisheries collapse

Even though the collapse of fisheries is inferred based on catch statistics, measurement error in the dependent variable does not seem to affect the results. This section discusses two reasons why the collapse of fish stocks may be mis-measured: a reduction in the price of fish, or the introduction of fisheries management, could lead to a drastic reduction in catch that does not represent a collapse of the fish stock. However, it is shown that neither of these factors bias the results. Moreover, the results are qualitatively similar if the threshold for a collapse is changed, as demonstrated in the last part of this section.

Let us denote the measurement error in fisheries collapse by $e_{ikt} = collapsed_{ikt} - collapsed^*_{ikt}$ where *collapsed** is the true collapse of a fishery and *collapsed* is the measure for a fishery's collapse which is inferred based on catch statistics and which is used in the analysis. With measurement error e_{ikt} in the dependent variable, the estimating equation is

$$\text{Collapsed}_{ikt} = \beta_0 + \beta_1 \ln(\text{Exports})_{ikt-1} + \boldsymbol{\beta}\text{Controls}_{ikt} + \gamma_{rt} + \gamma_i + \gamma_k + \epsilon_{ikt} + e_{ikt}. \quad (8)$$

The first concern is that measurement error leads to a violation of the exclusion restrictions if e_{ikt} is correlated with the instrument. This could be the case if a stark reduction in global demand for a particular species lead to a drop in the world market price and, as a result, fishermen in Japan and the exporting country would cease to catch the species. While this is a theoretical possibility, the author is not aware of any example of a global reduction in demand. Moreover, the empirical results in Table 1 show that the collapse in Japan is associated with an *increase* in the world market price. This finding is not consistent with a reduction in demand for the affected fish species.

Furthermore, there is no evidence that the results are biased due to a potential

[26] A map of FAO fishing areas is available on http://www.fao.org/fishery/area/search/en.

Table 10: Measurement error

	(1) Collapsed (10%)	(2) Collapsed (5%)	(3) Collapsed (15%)
Export quantity (lag, ln)	0.092**	0.053	0.089*
	(0.036)	(0.042)	(0.045)
Region-Year FE	Yes	Yes	Yes
Species FE	Yes	Yes	Yes
Country FE	Yes	Yes	Yes
Controls	Yes	Yes	Yes
1st stage F-Stat	9.757	8.778	12.773
Anderson-R. p-value	0.002	0.114	0.047
No. of clusters	113	113	112
Observations	8941	9663	8461

Standard errors (clustered at the species level) in parentheses. The p-value of the Anderson and Rubin (1949) test (Anderson-R. p-value) provides weak instrument robust inference for the coefficient estimate for the export quantity. Column 1: Fisheries for which the introduction of management coincides with the collapse are excluded from the sample. Columns 2 and 3: Sample only includes fisheries which have not collapsed according to the respecitve definitions of fisheries collapse.

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

measurement error resulting from the introduction of fisheries management. It is possible that a fishery is falsely measured as collapsed when a government introduces particularly strict catch limits. However, this does not appear to be relevant in practise. There are only three fisheries in the sample for which the introduction of catch share programs coincides with the collapse of the fishery. Stock data, which are available for one of those fisheries, suggest that the stock had actually declined drastically. If the above-mentioned three fisheries are excluded from the sample, the results are very similar to those from the baseline regression, as demonstrated in Column 1 of Table 10.

The results are also (partly) robust to changing the definition of fisheries collapse. This is shown for both stricter and more lenient definitions of fisheries collapse in Table 10. In Columns 2 (or 3) of the Table a fishery is defined as collapsed if catch is below 5% (or 15%) of the maximum catch recorded since 1950. Both columns suggest that exports raise the likelihood of a collapse, but the coefficient estimate is only statistically significant for the more lenient definition of fisheries collapse in Column 3.[27]

[27] Even though the definition of fisheries collapse depends on an arbitrary cut-off, the use of catch relative to maximum historical catch would not be a better dependent variable. The

10 Conclusion

This paper investigates the causal effect of fisheries exports on the collapse of fisheries using a global panel dataset with variation at the country-species-year level. Due to the endogeneity of exports, the collapse of Japanese fisheries is used as an instrument for exports of fishery products in countries that do not share fish stocks with Japan.

The results show that exports have a large negative impact on fisheries. An increase in logged exports by one standard deviation raises the likelihood of a collapse in the following year by 23 percentage points. The estimated effect is large but not unrealistic. The predicted increase in the likelihood of a collapse for the median fishery is equivalent to roughly two thirds of the observed increase in the percentage of collapsed fisheries over the sample period.

The results highlight the importance of fisheries management. The estimates show that exporting only causes a collapse of fisheries which are not regulated via quotas or other rights-based fisheries management tools. Hence, trade liberalization should be accompanied by the implementation of sustainable catch limits in exporting countries.

The introduction of sustainable catch limits is particularly important for developing countries, which export half of the global export value (FAO, 2016*b*). In those countries, exports of fishery products are an important source of foreign exchange earnings, income and employment. However, the use of quotas or similar rights-based fisheries management tools is not very wide-spread in the developing world (Jardine and Sanchirico, 2012). In order to guarantee long-term benefits from fisheries exports, developing countries should consider the introduction of sustainable fisheries management.

This paper focuses on the collapse of fisheries in exporting countries. An assessment of the overall effect of trade on fisheries is beyond the scope of this paper for two reasons. First, this paper cannot identify the effect of fisheries

theoretical model in Section 2 shows why this is the case. The variable "Collapse" is a proxy for a very small or depleted fish stock and Hypothesis 1 clearly predicts that an exogenous increase in the price in period $t-1$ is associated with a smaller stock period t. Therefore, the collapse in Japan raises the likelihood of a collapse in the exporting country. However, it is not generally the case that an exogenous increase in the price in period $t-1$ leads to a smaller catch in period t. A country which is in a diversified steady state in period $t-2$ and specializes in fisheries in period $t-1$ does not necessarily catch less in period t than in period $t-2$ if it remains specialized in period t.

imports on a stock's potential recovery in importing countries, since the collapse of Japanese fisheries is a weak instrument for imports.[28] Second, a stock's recovery in importing countries may be temporary. Copeland and Taylor (2006) show that, in the long run, trade could lead to the serial depletion of all fisheries. Future research of trade's overall effect on fisheries should take patterns of serial depletion into consideration.

[28] Imports seem to be very price-inelastic and the collapse of fisheries in Japan is not associated with a significant reduction in imports in the rest of the world.

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11 Theoretical Appendix

11.1 Demand for fish

A representative consumer has Cobb-Douglas preferences for individual consumption of a manufactured product m and fish h. The taste parameter β ($0 < \beta < 1$) reflects the consumer's taste for fish and the utility function is given by

$$u = h^{\beta} m^{(1-\beta)}. \tag{9}$$

In every time period, the representative consumer maximizes consumption subject to a budget constraint

$$ph + m = w \tag{10}$$

where w is the worker's wage income. The price of the manufactured product is normalized to 1 and p is the price of fish. Maximizing utility (9) subject to the budget constraint (10) yields the individual demand for fish $h = \beta w/p$ and manufactured goods $m = (1-\beta)w$. Multiplying individual demand by the number of workers in the economy L_T yields the aggregate demand for fishery products

$$H^C = hL_T = \frac{\beta w L_T}{p}. \tag{11}$$

11.2 Price of fish

The fishery is assumed to be unregulated. Open access to the fishery results in zero profits such that the revenue from fishing equals the fishing cost $pH = wL_H$. Solving for H and substituting this into the catch function in Equation 3 yields

$$\frac{w}{p} L_H = \alpha L_H S^{\tau}. \tag{12}$$

This equation can be solved for the open access resource price

$$p = \frac{w}{\alpha S^{\tau}}. \tag{13}$$

In a diversified economy, $w = 1$. This yields the resource price depicted in the bottom panel of Figure 1.

11.3 Short run equilibrium harvest

Substituting the short run price from Equation 13 into the aggregate demand for fish from Equation 11 allows us to pin down the short run supply of fish as a function of the stock size

$$H = \beta L_T \alpha S^{\tau}. \tag{14}$$

11.4 Diversified steady state with a smaller stock

One potential outcome of international trade is a diversified steady state with a smaller resource stock. A diversified steady state occurs if the stock declines to a point at which the marginal value product of workers in both industries equalizes. This is the case if a reduction in the stock reduces fishing productivity such that $p^* \alpha S_T^{\tau} = 1$. Solving this Equation for S_T allows us to show that exporting leads to an unambiguous reduction in the resource stock compared to the autarky stock

$$\frac{S_T}{S_A} = \left(\frac{\frac{1}{p^* \alpha}}{\frac{1}{p_A \alpha}} \right)^{\frac{1}{\tau}} = \left(\frac{p_A}{p^*} \right)^{\frac{1}{\tau}} < 1. \tag{15}$$

The steady state stock under trade is smaller than the autarky stock ($S_T < S_A$) if $p^*/p_A > 1$. Equation 15 also shows that exporting is more detrimental to schooling fish species for which τ is small.

11.5 Specialized steady state

A specialized steady state is possible at high world market prices, when the specialized catch function and the resource growth function intersect. Let us define S_z as the stable steady state stock at which the specialized catch function equals resource growth and $p_z = 1/(\alpha S_z^{\tau})$. If the economy opens up to trade and the world market price is given by $p^* > p_z > p_A$, the economy instantly specializes in fishing and catch surges. The stock shrinks gradually due to the intense fishing pressure. Once the stock has diminished to S_z, it cannot decline further. If the stock were to decline slightly more, resource growth would exceed catch and the stock would recover. Therefore, S_z is a stable steady state and the fishery cannot collapse even at high resource prices. The economy remains specialized at S_z, since the marginal value product of labour in fishing exceeds the marginal value product of manufacturing at $p^* > p_z$.

11.6 Conditions for a collapse to be possible

A fishery collapses if (1) $p_c \geq 1/(\alpha \underline{\mathrm{S}}^{\tau})$ and if (2) catch under specialization exceeds resource growth for any stock $S > 0$. Condition (1) is more likely to be satisfied if fishing technology is advanced (α is high), if the size of the minimum viable stock, $\underline{\mathrm{S}}$, is high and if fish species form schools implying that τ is low.

Condition (2) requires that

$$L_T \alpha S^{\tau} > r \left[S - \underline{S}\right] \left[1 - \frac{S}{K}\right]. \tag{16}$$

Manipulating terms yields

$$S^2 + (L_T \alpha K/r) S^{\tau} - KS + \underline{S}(K - S) > 0 \tag{17}$$

Condition (1) is more likely to be satisfied if fishing technology is advanced (α is high), if the minimum viable stock size $\underline{\mathrm{S}}$ is high and if fish species form schools implying that τ is low.

Condition (2) is more likely to hold if fishing pressure is high relative to resource growth, i.e. $L_T \alpha / r$ is high. Since the stock cannot exceed carrying capacity, $K - S$ must be larger than zero. Therefore, this condition is also more likely to be satisfied when the minimum viable stock size $\underline{\mathrm{S}}$ increases. An increase in the carrying capacity K makes it more likely that this condition holds as long as $(L_T \alpha / r) S^{\tau} - S + \underline{S} > 0$. For any stock $S > 1$ this condition is also more likely to be satisfied if τ is large.

12 Empirical Appendix

Table 11: Which fish species collapse?

	Exporting countries	Japan
Abalones, winkles, conchs	3	2
Cods, hakes, haddocks	111	32
Crabs, sea-spiders	1	3
Flounders, halibuts, soles	52	23
Herrings, sardines, anchovies	59	5
King crabs, squat-lobsters	11	0
Lobsters, spiny-rock lobsters	20	0
Miscellaneous coastal fishes	4	18
Miscellaneous demersal fishes	38	30
Miscellaneous diadromous fishes	4	0
Miscellaneous pelagic fishes	21	18
Oysters	6	0
Salmons, trouts, smelts	35	5
Scallops, pectens	8	0
Sea-urchins and other echinoderms	4	0
Sharks, rays, chimaeras	1	10
Shrimps, prawns	13	0
Squids, cuttlefishes, octopuses	28	15

This table shows the total number of collapsing fisheries by species category for exporting countries (Column 1) and Japan (Column 2).

Table 12: Catch as regressor

	(1) Collapse
Catch (lag, ln)	0.404
	(0.759)
FEs γ_{rt}, γ_i, γk	Yes
Controls	Yes
1st stage F-Stat	0.294
Anderson-R. p-value	0.006
Observations	8970

Standard errors (clustered at the species level) in parentheses. The p-value of the Anderson and Rubin (1949) test (Anderson-R. p-value) provides weak instrument robust inference for the coefficient estimate for the export quantity.

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

Table 13: Long distance fleet landings do not increase

	(1) Long distance fleet total catch
Col. Japan	-781.931
	(1075.277)
Species FE	Yes
Year FE	Yes
Observations	1318

Standard errors (clustered at the species level) in parentheses. I regress the long distance fleet's total landings on the collapse of species i in Japan in year t, on year fixed effects and species fixed effects. The long distance fleet's landings, Long distance total catch$_{it}$, are measured in tonnes and represent Japanese landings in all FAO fishing areas except the fishing area surrounding Japan. The sample does not include highly migratory and high sea fish stocks.

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

13 Online Appendix

13.1 Seafood tariffs as second instruments

Import tariffs for seafood products in Japan (or other markets) could be used as a second instrument. A reduction in Japanese tariffs should raise Japanese imports and hence spur other countries' exports. The instrument is arguably exogenous since Japanese import tariffs can only affect the collapse of fisheries in exporting countries via trade.

Table 14: Alternative instruments

	(1) IV tariff	(2) IV distance	(3) Spillovers
Export quantity (lag, ln)	0.030	0.076**	0.080**
	(0.041)	(0.035)	(0.034)
FEs	Yes	Yes	Yes
Controls	Yes	Yes	Yes
IV 1	L.Col. Japan	Col. Japan*distance	L.Col. Japan
IV 2	Tariff Japan	-	L.Col. J. Family
1st stage F-Stat.	4.299	7.571	5.036
Anderson-R. p-value	0.069	0.019	0.022
No. of clusters	108	113	113
Observations	6145	8976	8980

Standard errors (clustered at the species level) in parentheses
* p<0.1, ** p<0.05, *** p<0.01

However, the Japanese preferential import tariff[29] at the species level is a weak instrument for exports. Due to little variation in the tariff through time, the Japanese imports tariff is not significantly related to exports in the first stage regression.

The coefficient estimate of 0.03 in the second stage regression is smaller than the coefficient estimate in the baseline regression. This difference could either be due to a downward bias in light of weak instruments or due to the shorter sample period from 1988-2006.[30]

13.2 Exporter's distance from Japan

The results from the baseline regression follow through if the collapse of a Japanese fishery is interacted with the country's distance from Japan.

Exports are likely to react less a to the collapse of a Japanese fishery if a country is far away from Japan.[31] Therefore, the instrumental variable "Collapse Japan"

[29] The analysis is based on preferential tariff data at the HS6 digit level from the WITS database. The data are available for the years 1988 to 2006. The preferential tariff at the species level is calculated as the simple average over all HS6 digit tariff lines which apply to the species. The preferential tariff for Atlantic cod, for example, is calculated as the unweighted average over the tariff rate for the categories "fresh or chilled cod", "frozen cod" and "frozen cod meat".

[30] I also tried to use species-level preferential import tariffs in the US, EU or China as instruments. However, none of these variables is significantly related to exports in other countries using regressions with country fixed effects, species fixed effects and region-year fixed effects.

[31] It is a well-established empirical fact that trade flows are negatively correlated with distance

is interacted with a measure for the distance between Japan and the exporting country. Distance is measured as the great circle distance (in 1000km) between the most important cities in terms of population in each country using data are from the CEPII GeoDist database (Mayer and Zignago, 2011).

With this instrument, an increase in exports by one percent is estimated to raise the likelihood of a collapse by 0.08 percentage points. This coefficient estimate, which is displayed in Column 2 of Table 14, is only slightly smaller than the coefficient estimate in the baseline regression.

13.3 No evidence of substitution effects

Substitution effects may occur since the collapse of a Japanese fishery is associated with an increase in the price of the collapsed species. In response to this increase in the price, consumers may shift their expenditure to a close substitute. This, in turn, could raise the price of, and export demand for, the substitute, and induce fishermen to harvest more of the substitute. The resulting increase in the likelihood of a collapse of the substitute would contaminate the control group and bias the coefficient estimates downward. In case of substitution effects, the coefficient estimate for the export quantity in the baseline regressions would have to be interpreted as a lower bound. This section uses evidence from the demand side and the supply side to argue that there is no evidence of a downward bias resulting from substitution effects.

13.3.1 No evidence of substitution on the demand side

This section highlights that a collapse of a species in Japan does not raise export demand for a substitute. Species from the same family are likely to be close substitutes since they share a lot of characteristics. Therefore, the variable "Col. J. Family$_{it}$" can be used as a second instrument to assess spillover effects. The variable takes a value of 1 if a species which is in the same family as species i has collapsed in Japan in year t. A positive and statistically significant coefficient estimate for the variable "Col. J. Family$_{it}$" in the first stage regression would indicate that export demand for species in the same family increases when the species collapses in Japan.

(see e.g. Head and Mayer, 2014).

There is no evidence of substitution effects on the demand side. In the first stage regression, the coefficient estimate for "Col. J. Family$_{it}$" is not significant. This indicates that exports of fish species which are in the same family as the fish species which has collapsed in Japan do not increase as a result of the collapse. Moreover, the results in the second stage regression are not affected by the introduction of this second instrument. Column 3 of Table 14 shows that an increase in exports by one percent is estimated to raise the likelihood of a fishery's collapse by 0.08 percentage points. This is very similar to the finding in the baseline regression. It is reassuring that the test for overidentifying restrictions suggests that the instruments are valid.

13.3.2 Substitution on the supply side does not drive results

Moroever, there is little concern of a downward bias in the coefficient estimates resulting from substitution on the supply side. If there is substitution on the supply side, fishermen will catch more of species j in the years following a collapse of species i.

This kind of substitution on the supply side is likely to be limited by the fact the different fish species in the sample are caught in different parts of the sea using a broad range of fishing gear and different fishing technology. Therefore, fishermen potentially have to invest in alternative fishing gear in order to target a different species. The immediate increase in fishing pressure for species j as a result of a collapse of species i is therefore likely to be low.

Moreover, the results follow through if I control for different trends in the likelihood of a collapse resulting from substitution on the supply side. If fishermen target species j in response to a collapse of another species, fishing pressure for species j and the likelihood of a collapse of fishery jkt should increase in the percentage of collapsed fisheries within in country k at time t. Controlling for the percentage of collapsed fisheries captures different trends and removes any bias resulting from substitution on the supply side. Column 1 of Table 15 shows an increase in exports raises the likelihood of a collapse by 0.098 percentage point. The effect is only slightly higher than the coefficient estimate in the baseline regression.

13.4 Different measures for exports

It is possible that a country both exports and imports the same species. This could be due to processing trade. China, for example has developed into a processing

Table 15: Substitution and net exports

	(1) Substitution	(2) Net exports	(3) Prev. net exp.
Export quantity (lag, ln)	0.098**		
	(0.039)		
Percentage collapsed	0.454***		
	(0.101)		
L.Ln(Net Exports)		0.157	
		(0.128)	
Ln(Max. Net Exp. up to t)			0.071*
			(0.042)
Region-Year FE	Yes	Yes	Yes
Species FE	Yes	Yes	Yes
Country FE	Yes	Yes	Yes
Controls	Yes	Yes	Yes
1st stage F-Stat	9.210	2.288	7.644
Anderson-R. p-value	0.002	0.014	0.039
No. of clusters	113	108	113
Observations	8980	5880	9185

Standard errors (clustered at the species level) in parentheses. The p-value of the Anderson and Rubin (1949) test (Anderson-R. p-value) provides weak instrument robust inference for the coefficient estimate for the export quantity.

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

market for U.S. and Norwegian seafood (Roheim, 2005; Asche and Smith, 2009). This section investigates whether we come to similar conclusions using net exports, defined as exports-imports at the country-species-year level, as a regressor. Both the short-term effect of an increase in net exports on the likelihood of collapse in the following period, and the long-term effect of net exports, are discussed here.

The estimated effect of net exports on fisheries collapse is stronger than the effect of exports. The results in Column 2 of Table 15 suggest that an increase in net exports by one percent raises the likelihood of collapse in the following period by 0.16 percentage points. This is almost twice the effect size found in the baseline regression. Moreover, this coefficient estimate maybe downward biased and underestimate the true effect due to weak instruments (see Kleibergen-Paap first stage F-statistic of 2.88). The p-value of the Anderson-Rubin (1949) test of

0.01 indicates that the coefficient estimate is statistically significant based on weak instrument robust inference.

The long-term effect of net exports on the collapse of a fishery can be captured by the maximum of a fishery's previous net exports. This regressor is motivated by the idea that an exogenous increase in the price leads to an instantaneous increase in catch and exports. As the stock declines over time, catch and exports decline as well up to the point at which the fishery collapses. The effect of this peak in exports on the likelihood of a fishery's collapse can be captured by the maximum of the fishery's previous net exports.

Column 3 of Table 15 shows that an increase in maximum historical net exports by one percent raises the likelihood of a fishery's collapse by 0.07 percentage points. These findings indicate that net exports have a significant and large negative impact on the sustainability of fisheries both in the short term and in the long term.

13.5 Dynamic panel data model of stock biomass

Instrument matrix

When constructing the instrument matrix, the lag of stock biomass, exports and the catch share program are considered to be predetermined, implying that they may be correlated with past error terms ϵ_{ikt-l} for all $l > 0$ but not with the contemporaneous error term ϵ_{ikt}. Stock biomass is predetermined by definition, since it is a function of the stock in previous years. In the theoretical model, catch (and thus exports) are functions of the current stock size. Therefore, exports in any time period must also be correlated with past errors. Moreover, the introduction of catch share programs is treated as a predetermined variable and allowed to be a function of past biomass.

In Arellano-Bond models, the number of instruments is quadratic in the number of years in the sample. While more instruments improve efficiency, a very large number of instruments are associated with biased coefficient estimates and misleadingly small standard errors. There are two approaches to reducing instrument count in dynamic panel data models. The first one limits the lags of the regressors which are used as instruments. The second approach combines instruments to a smaller set by collapsing the instrument matrix (see Roodman, 2009).

Since the panel spans almost 30 years, a combination of both approaches is used to reduce the instrument count. I only use lags up to 10 years as instruments for the stock biomass and lags up to 3 years for exports and catch share programs. Moreover, the instrument matrix is collapsed.

I use a two-step estimator of the covariance matrix with a Windmeijer (2005) finite sample correction. The latter addresses the potential downward bias in two-step estimates of the covariance matrix. The standard errors presented in this paper are robust to any form of heteroskedasticity and autocorrelation within panels. The standard errors for the long-term effects of exports on biomass are calculated using the delta method.

Data on stock biomass and exports

This model is estimated using data on total stock biomass from the RAM legacy stock assessment database (Ricard et al., 2012). Since the RAM legacy database only covers around 500 fish stocks, these data are supplemented with estimates of biomass from Costello et al. (2016),[32] who estimate stock biomass based on catch statistics.

If one country hosts several stocks of one species along different parts of their coastline, the RAM legacy database may provide several stock assessments for one country. In that case, the data are aggregated to the country-species level and matched with country-species-level export data.

[32] I am very grateful to Chris Costello and Tyler Clavelle for access to these data.